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Article

Synthesis, Characterization, and Biological Evaluation of New Schiff Bases and their Derivatives

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Abstract

The synthesis and characterization of a few Schiff base derivatives with exceptional biological activity are the main objectives of this study. Schiff bases, formed due to the reaction between carbonyl compounds and primary amines, are very versatile compounds in medicinal chemistry, biotechnology, and other related fields. Schiff bases are ideal candidates for drug design since they have been shown to exhibit a wide range of biological activities, including antiviral, antioxidant, antifungal, anticancer, and antibacterial properties. Derivatives of Schiff bases were synthesized by a set of systematic steps involving condensation reactions of oxime [A] with various other aldehydes, followed by sulfonylation steps. Thin-layer chromatography (TLC), elemental microanalysis, nuclear magnetic resonance (^{1}HNMR and ^{13}CNMR), Fourier transform infrared spectroscopy (FT-IR), and melting point were used to describe the generated compounds. During the study, extremely pure reagents and advanced equipment were employed to ensure precision in results. The result stated that Schiff base derivatives, [A1], [A2], and [A3], prepared by the above procedure were well characterized, thereby confirming the presence of crucial functional groups such as azomethine (-C=N-), sulfonyl (-SO□-), and N,N-dimethylamino groups. While the absence of specific indications in the spectra supported the assumed chemical changes, the spectrum data verified the compounds' structural integrity. It was discovered that the compounds have significant potential against a variety of biological activities, including antiviral,

antioxidant, and antibacterial activity. In conclusion, the synthesis and full characterization of these novel Schiff base derivatives unlock their huge potential in medicinal chemistry and drug design.

Keywords: Schiff bases, Oximes, Sulfonylation, Tetrazole derivatives, and Thiazolidinone derivatives.

1. Introduction

Schiff bases, formed by the condensation of primary amines with aldehydes or ketones, are versatile compounds with significant pharmaceutical potential (Mushtaq et al., 2024). These compounds exhibit a wide range of biological activities, including antibacterial, antifungal, antiviral, anti-inflammatory, and antioxidant properties (Dubey & Chourisia, 2024). The synthesis of Schiff bases typically involves heat or acid/base catalysis, resulting in crystalline solids or insoluble salts (Dubey & Chourisia, 2024). Various characterization techniques, such as FT-IR, NMR, and mass spectrometry, are employed to confirm the structural integrity of these compounds (Thakor et al., 2024). Recent studies have explored the potential of Schiff bases in drug discovery, particularly for Alzheimer's disease and stress-related disorders (Thakor et al., 2024). Additionally, Schiff bases have shown promising anticancer properties against human lung cancer cells (Thakor et al., 2024). The diverse applications and ease of synthesis make Schiff bases attractive candidates for further research in medicinal chemistry and drug design (Mushtaq et al., 2024).

Schiff bases are complex molecules of significant interest to organic chemistry. They are formed when carbonyl compounds and primary amines react with each other (Meenachi & Chitra, 2015; Alshamrani, 2022). They exhibit diversified biological activities like antiviral, antioxidant, antifungal, anticancer, and antibacterial activities, and contain the imine or azomethine (–C=N–) functional group (Kajal et al., 2013; Al-Mosawy, 2023).

Schiff bases and derivatives are widely utilized in medicinal chemistry as bioactive scaffolds for the design of drugs (Kajal et al., 2013). They are responsible for numerous applications, such as anticorrosion inhibition, polymer stabilizing, and catalysis (Alshamrani, 2022). They are typically easy to synthesize and inexpensive, thus commercially accessible to most labs (Alshamrani, 2022). The preparation of bioactive Schiff base derivatives has been made straightforward by recent research, particularly in the exploration of their potential in chemosensing, more specifically metal ion sensing (Alshamrani, 2022; Al-Mosawy, 2023).

Research on ionic liquids and natural products has received a lot of interest because of their diverse biological activity and potential in numerous fields. Ionic liquids are potential lead compounds for drug discovery and drug delivery systems because of their established cytotoxicity and antibacterial potential (Egorava et al., 2017). Natural compounds of varying biological activities that have evolved to be chosen by nature are used in food, cosmetic, and pharmaceutical industries (Seca et al., 2020).

Although the abstract provides no detail, it was discovered that extracts of mango peels have potential for various applications in biotechnology (Kučuk, et al., 2022). From 2005 to 2019, 115 compounds have been accrued through a broad volume of study on acetogenins of family Annonaceae because of their biological activity as well as mode of action (Neske et al., 2020). Synthetic and natural compounds must be evaluated for biological activity and potential applications in biotechnology, medicine, and other disciplines, it is crucial, the research finds.

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2. Materials and Methods

2.1. Chemicals Used

The chemicals used in this investigation were acquired from reputable vendors to ensure maximum purity and repeatability of findings. These include acetone (99%) from Alfa Aesar, benzene (99.5%) and benzenesulfonyl chloride from BDH, ethanol absolute (99.8%) from Merck, methanol (99.99% HPLC grade) from Fluka, and 4-Methylbenzenesulfonyl chloride and sodium azide from Aldrich.

The chemicals were chosen depending on the specific function in the synthesis and characterization processes.

2.1.Instruments

2.1.1. Spectroscopy

1) Fourier transform infrared spectrophotometer (FTIR)

KBr discs were used to record FT-IR spectra on a SHIMADZU FT-IR spectrometer located at Babylon University in Iraq. At the Central Laboratory of the College of Pure Science, University of Babylon, further spectra were measured.

2) Nuclear magnetic resonace (^{1}HNMR & ^{13}CNMR)

The Bruker Ultra Shield 300 MHz spectrometer at Sharif University of Technology in Tehran, Iran, was used to acquire the ^{1}H and ^{13}C NMR spectra. TMS serves as an internal reference, and DMSO is used as the solvent. The chemical shifts are expressed in δ (ppm).

3) Elemental microanalysis

The Central Service Laboratory at the College of Education for Pure Science, University of Babylon, used a EuroEA Elemental Analyzer (Euro Vector, Italy) to perform elemental micro-analysis (C, H, N, and S) on a few chosen chemicals.

2.1.2. Melting point measurements

Open capillaries were used to measure the melting points to apply the Stuart melting point (SMP30, England).

2.1.3. Thin layer chromatography (TLC).

Aluminum plates covered with silica gel, provided by MACHEREY-NAGEL, were used for thin-layer chromatography (TLC). The plate was burned to visualize the spots. A solvent mixture of benzene and methanol in a 9:1 ratio was used to evaluate the reaction's progress and the purity of the newly produced chemicals.

2.1.4. Evaluate biological activity.

Assessments of biological activity were conducted at the University of Babylon's Market Research and Consumer Protection Center.

2.2. Synthesis of compounds

2.2.1. Preparation of compound [A]

The 4-aminoacetophenone (5.5 g, 40 mmol) was dissolved in 20 mL of ethanol in a round-bottom flask. A solution of sodium acetate (3.28 g, 40 mmol) and hydroxylamine hydrochloride (2.77 g, 40 mmol) was made in the meantime by dissolving the ingredients in ethanol with a tiny bit of water until the mixture turned transparent. After adding this produced solution to the flask gradually, the reaction mixture was refluxed for six hours. After finishing, the mixture was put into ice water after cooling to room temperature. Using ethanol, the resultant crystals were filtered, dried, and recrystallized. Table 1 lists the product's R_f value and physical characteristics in detail (Rafiq, M. et al. 2008).

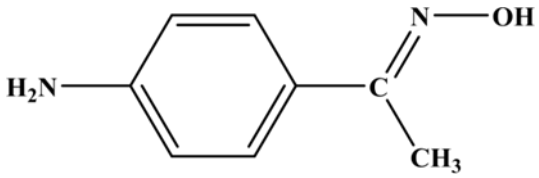


Fig. 1. Compound [A].

2.2.2. Synthesis of compound [A1] [4]

Glacial acetic acid (G.A.A.) was added in small amounts to a solution of 4-(Dimethylamino) benzaldehyde (10 g, 67 mmol) in 30 mL of ethanol. The resultant oxime (10.06 g, 67 mmol) was then added after stirring for five minutes. The mixture was then heated for three hours at 78°C under reflux. To refine the yellow precipitate, it was recrystallized in ethanol once the reaction was finished, and the solution was filtered. The product's physical attributes and R_f value are listed in Table 1.

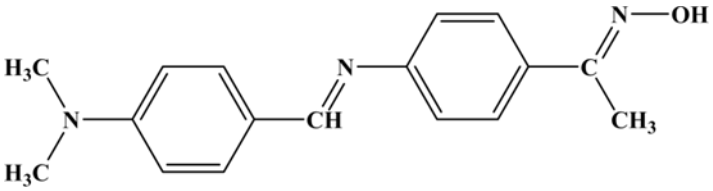


Fig. 2. Compound [A1].

2.3.3 Synthesis of compounds [A2, A3] [6,7]

Ten milligrams of schiff base [A1] were dissolved in twenty milliliters of pyridine and allowed to cool to zero degrees Celsius in an ice bath. Following the addition of 10 mmol of either 4-methylbenzenesulfonyl chloride or benzoenesulfonyl chloride, the reaction mixture was stirred for eight hours. The resultant maronite precipitate was filtered, recrystallized from ethanol, and cleaned with a cold, diluted hydrochloric acid solution. Table 1 lists the R_f values and the product's physical characteristics.

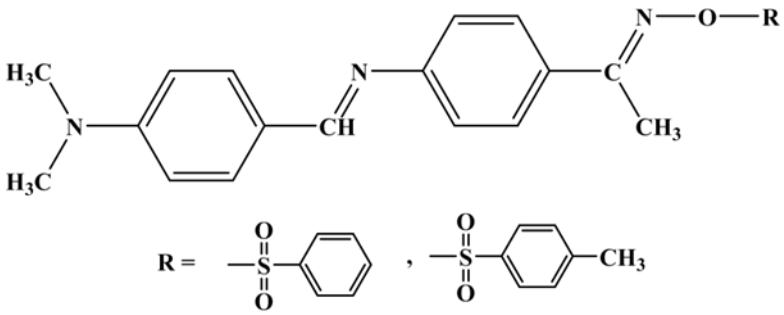


Fig. 3. Compounds [A2, A3].

2.3.4. Synthesis of compounds [A4–A6]

In a round-bottom flask, a solution of Schiff bases [A1, A2, A3] (1 mmol) in 10 mL of DMF was made, and then sodium azide (1 mmol) was added. Using a methanol:benzene (1:9) solvent system, TLC tracked the reaction progress as the combination refluxed for 20 hours. Following completion, the product underwent

recrystallization in ethanol for purification, drying, and filtering. Table 1 provides a summary of the compounds' R_f values and physical characteristics.

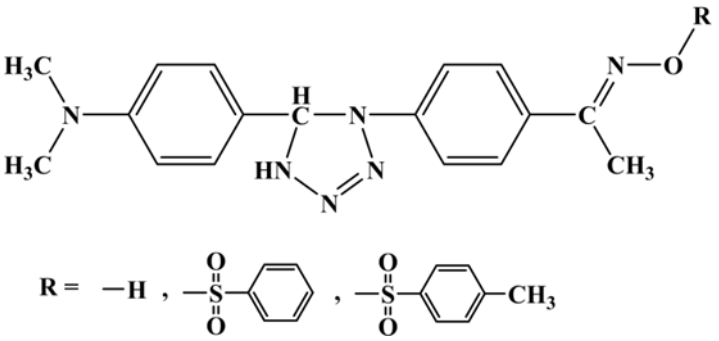


Fig. 4. Compounds [A4–A6]

2.3.5. Synthesis of compounds [A7-A9]

In 20 milliliters of acetone, schiff bases [A1, A2, A3] (1 mmol) were dissolved, and then 1 milligram of thioglycolic acid was added. As the reaction mixture refluxed for 12 hours, TLC and a methanol:benzene (1:9) solvent solution were used to monitor its development. The final step was evaporating the solvent and washing the resultant solid with water. After then, the product was recrystallized in ethanol to guarantee its purity. Table 1 provides an overview of the compounds' R_f values and physical attributes.

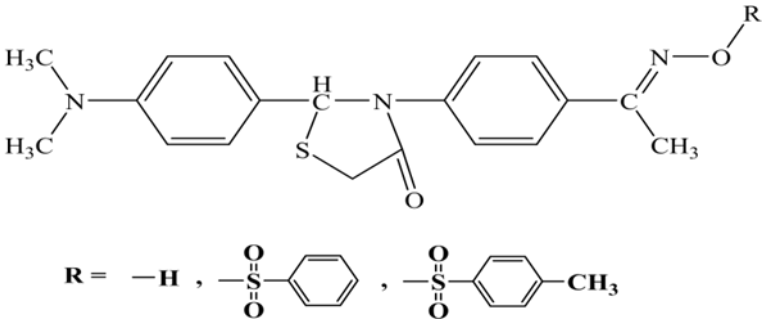


Fig. 5. Synthesis of compounds [A7-A9]

2.3.6. Synthesis of compounds [B1]

After dissolving 50 mmol of 4-hydroxyacetophenone and 3 mL of glacial acetic acid (G.A.A.) in 30 mL of dry benzene, the mixture was heated in a water bath to 80°C. Following the addition of 50 mmol of 4-aminobenzenesulfonamide, the reaction was refluxed for 48 hours. Recrystallization in dry benzene was used to filter and purify the resultant yellow product. Table (1) lists the product's Rf values and physical characteristics.

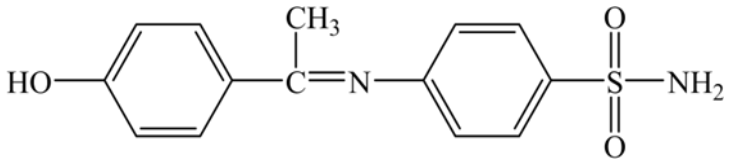


Fig. 6. Compound [B1].

2.3.7. Synthesis of compound [B2]

After diluting a Schiff base (1 mmol) in 15 mL of acetone, thioglycolic acid (1 mmol) was added. After that, the mixture was refluxed for ten hours while TLC tracked the reaction's development using a solvent solution that included a 1:9 methanol to benzene ratio. The solvent was removed when the process was finished, and the solid that resulted was cleaned with water and refined by recrystallization in ethanol. In Table 1, the compound's physicochemical characteristics and R_f value are compiled.

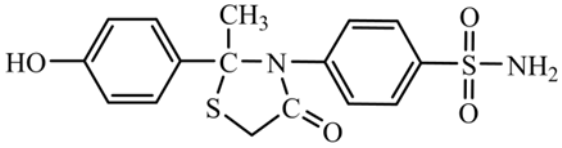
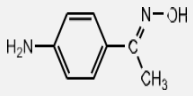
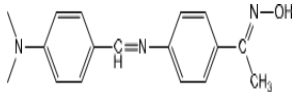
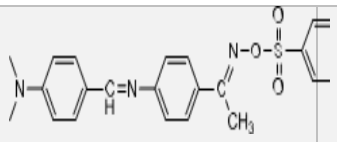
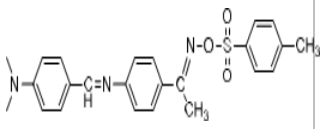
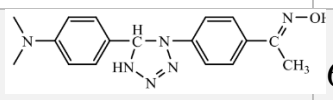
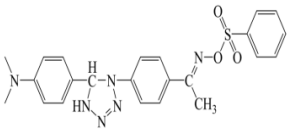
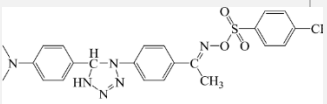
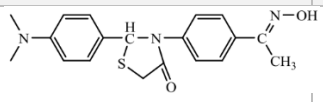
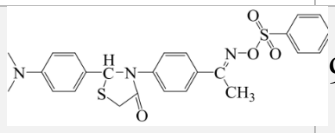
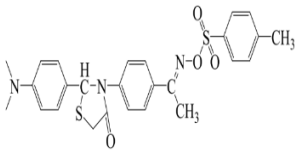
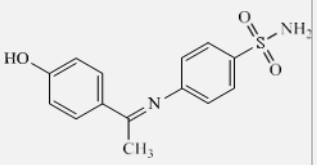
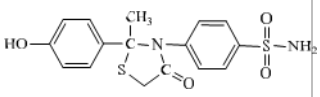


Fig. 7. Compound [B2].

Table 1. Structures and physical properties.

Com. No.	Nomenclature	Structural formula	M. wt. g/mol	M.p .°C	Yield%	Color	R_f
A	(E)-1-(4 aminophenyl) ethan- 1-one oxime		150	128 -130	70	Golden brown	0.56
A1	(E)-1-(4-((4-1 (dimethylamino) benzylidene)amino) phenyl)ethan-1-one oxime		281	244 - 246	86	Shiny-yellow	0.52
A2	(E)-1-(4-((4-1(dimethylamino) benzylidene)		421	525 -520	51	Brown	0.35

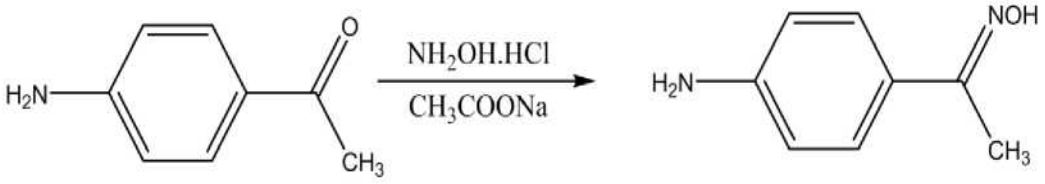
	amino) phenyl) ethan-1-one O-phenylsulfonyl oxime						
A 3	(E)-1-(4-((4-1 (dimethylamino)benzylidene) amino)phenyl)ethan-1-one O-tosyl oxime		435	265 -263	25	Reddish black	0.63
A 4	(E)-1-(4-(5-(4- (dimethylamino)phenyl)-4,5-dihydro-1H-tetrazol-1-yl)phenyl)ethan-1-one oxime		464	586 -588	85	Brown	0.66
A 5	(E)-1-(4-(5-(4- (dimethylamino)phenyl)-4,5-dihydro-1H-tetrazol-1-yl)phenyl)ethan-1-one O-phenylsulfonyl oxime		464	586 -588	85	Brown	0.66
A 6	(E)-1-(4-(5-(4- (dimethylamino)phenyl)-4,5-dihydro-1H-tetrazol-1-yl)phenyl)eth		478	522 -528	83	Reddish black	0.25

	an-1-one O-tosyl oxime						
A 7	(E)-2-(4-(dimethylamino)phenyl)-3-(4-(1-(hydroxyimino)ethyl)phenyl)thiazolidin-4-one		355	136-138	54	Red-black	0.56
A 8	(E)-2-(4-(dimethylamino)phenyl)-3-(4-(1-(((phenylsulfonyl)oxy)imino)ethyl)phenyl)thiazolidin-4-one		495	513-518	53	Grayish	495
A 9	(E)-2-(4-(dimethylamino)phenyl)-3-(4-(1-((tosyloxy)imino)ethyl)phenyl)thiazolidin-4-one		509	582-588	55	Grayish-green	0.51
B 1	-8(-1((-8hydroxyphenyl)ethylidene) amino)benzenesulfonamide		290	230-232	77	Yellow	o.41
B 2	hydroxyphenyl)-2--8(-5(-8 methyl-4-oxothiazolidin-3-yl)benzenesulfonamide		364	256-258	59	Pale-yellow	0.77

3. Result and Discussion

3.1. Preparation and characterization of compound [A]

Oxime [A] was synthesized by refluxing equimolar amounts of 4-aminoacetophenone with hydroxylamine hydrochloride ($H_2NOH{\cdot}HCl$) and sodium acetate (CH_3COONa) in ethanol, yielding a product with a melting point of 128-130°C.

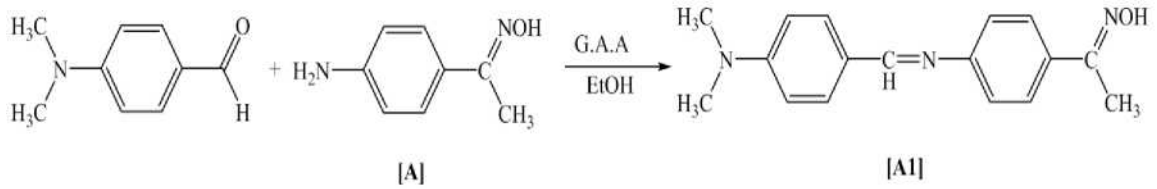


Equation .1. Preparation and characterization of compound [A].

As seen in Equation . 1, the structure was examined using its FT-IR spectrum and melting point. There were no absorption bands linked to the starting material's -C=O group in the FT-IR spectrum. Rather, the -C=N- group was identified by a significant absorption at 1627 cm^{-1}, the -C-N group by a vibration at 1303 cm^{-1}, and the -O-H group by a stretching band at 3182 cm−1. These spectra alterations verify that the target structure was successfully synthesized.

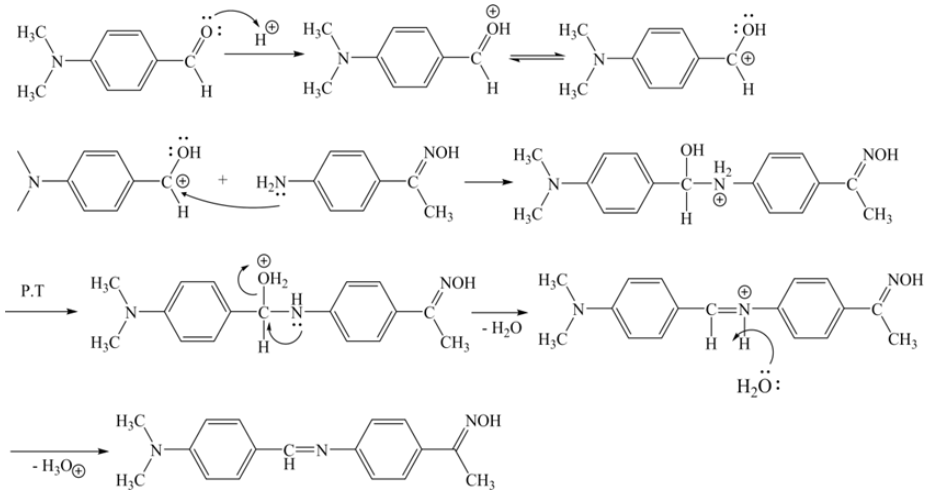
3.1.1. Synthesis and characterization of compound [A1]

Oxime [A] was refluxed with 4-(N,N-dimethylamino)benzaldehyde in absolute ethanol, with a few drops of glacial acetic acid acting as a catalyst, to create Schiff base [A1].



Equation . 2. Synthesis and characterization of compound [A1].

The mechanism of this reaction outlined as follows in the Scheme (1) according to Al-Rawi, M.S. et al. 2013):



Scheme.1. The mechanism of synthesis compound [A1]

The melting point and spectroscopic techniques, such as FT-IR, ^{1}H NMR, and C NMR, were used to describe compound [A1]. A new band at 1608 cm^{-1} suggested the creation of the azomethine group, while the FT-IR spectrum verified the elimination of absorption bands corresponding to the -NH_2 and C=O groups from the starting material. The FT-IR spectrum displayed in Scheme.(1) confirmed the structural alterations. When compound [A1] was recorded in DMSO, its ^{1}H NMR spectrum showed a singlet at δ 11.12 ppm, which corresponded to the N=OH proton (Equation .2).

It was determined that the Schiff base's CH=N proton had a singlet at δ 8.44 ppm. Between δ 6.80 and 7.76 ppm, doublet-doublet signals were identified as coming from eight aromatic protons. Furthermore, 6 protons of the dimethylamino group [$(CH_3)_2N$] and 3 protons of the CH_3-C=N group were represented by singlets at δ 3.02 ppm and δ 2.17 ppm, respectively.

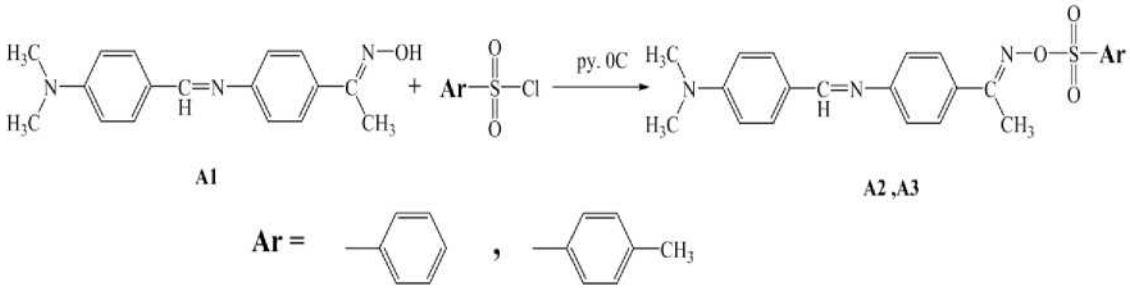
The carbon in the Schiff base group (C=N) was represented by a peak at δ 159.43 ppm in the chemical [A1]'s C NMR spectrum, which was recorded in DMSO (Scheme.1). The carbon in the -C=NOH oxime group was identified as having a signal at δ 152.02 ppm. Aromatic carbons were assigned peaks between δ 133.03 and 110.91 ppm, whereas N,N-dimethylamino groups were identified by a signal at δ 39.49 ppm. Furthermore, the CH_3-C=NOH group was associated with a signal at δ 10.19 ppm.

Williams and Fleming (2020) say the findings are in line with those already reported for similar compounds. In conclusion, spectroscopic data confirms the effective synthesis of the chemical [A1] and validity of its structure. There are new

peaks typical of the Schiff base and oxime functions, and the fact that signals typical of the starting material cannot be observed confirms the proposed structure. The results refer to the accuracy of FT-IR, ^{1}HNMR, and CNMR in fully characterizing organic compounds.

3.1.2 Synthesis and characterization of compounds [A2, A3]

In pyridine at 0°C, Schiff base [A1] was reacted with benzenesulfonyl chloride and 4-methylbenzenesulfonyl chloride to produce Schiff base derivatives [A2, A3].



Equation .3. Synthesis compounds [A2-A3].

Compounds [A2 and A3] were characterized through their melting points, FT-IR, ^{1}H NMR, and C NMR spectroscopy. The S=O groups were represented by new asymmetric bands at 1373 and 1369 cm^{-1} and symmetric bands at 1161 and 1165 cm^{-1}, while the FT-IR spectrum verified the elimination of the -OH absorption band, as seen in Equation .3. Furthermore, a band that showed the presence of the C-S group was found in the 844–837 cm^{-1} range. Table (2) provides an overview of the FT-IR absorption data.

Table 2. Characteristic FTIR absorption bands of Schiff bases[A1-A3].

Comp. No.	FTIR Spectra (cm $^{-1}$)							
	μC-H Arom.	μC-H Aliph.	μC=N Schiff b.	μC=N Oxime	μC=C Arom.	μS=C	μC-S	Others
A1	3078	2900	1608	1627	1585	-	-	μO-H 3221
A2	3062	2908	1651	1670	1600	1373 asy. 1161 sy.	844	-
A3	3062	2897	1608	Overlap	1589	1369 asy. 1165 sy.	833	-

The ^{1}H NMR spectrum of compound [A2] recorded in DMSO showed a singlet at δ 9.68 ppm, which matched the CH=N proton of the Schiff base (Equation .3). The multiplet and doublet-doublet signals between δ 8.59 and 6.77 ppm were used to identify 13 aromatic protons. Six protons of the $[CH_3)_2N]$ group were assigned to a singlet at δ 3.03 ppm, whereas a singlet at δ 2.17 ppm was determined to be a member of the CH_3-C=N group. Since there was no evidence for the OH proton, it was removed.

A singlet at δ 8.90 ppm, which represents the CH=N proton, was seen in the molecule [A3]'s ^{1}H NMR spectrum recorded in DMSO (Equation .3). It was discovered that twelve aromatic protons were the cause of the doublet-doublet signals between δ 8.06 and 6.79 ppm. Six protons from the methyl groups attached to the nitrogen atom were discovered by a singlet at δ 3.05 ppm, whereas three protons from the CH_3-C=N group were identified by a singlet at δ 2.19 ppm. A singlet was seen in the CH_3-tosyl group at δ 2.33 ppm.

Compound [A2]'s ^{2}C NMR spectrum, which was recorded in DMSO (Equation .3), showed different signals that corresponded to different carbon atoms. It was determined that the carbon in the Schiff base group (-C=N) had a peak at δ 159.03 ppm, and the carbon in the oxime's -C=NOH group had a peak at δ 152.07 ppm. Signals corresponding to aromatic carbons ranged from δ 137.49 to 118.89 ppm. Furthermore, the CH_3-C=NOH group was linked to a signal at δ 10.72 ppm, whereas the N,N-dimethylamino group was associated with a peak at δ 39.13 ppm.The C NMR spectrum of compound [A3], shown in Equation .3, exhibited distinct signals. A peak at δ 151.61 ppm was attributed to the carbon in the Schiff base group (C=N), while another at δ 142.75 ppm corresponded to the carbon in the -C=NOH oxime group.

Aromatic carbons were identified using the signals at δ 137.63–118.37 ppm. The CH_3-tosyl and CH_3-C=NOH groups were associated with signals at δ 20.37 ppm and δ 10.72 ppm, respectively, whereas the N,N-dimethylamino groups were associated with a peak at δ 39.31 ppm. The elemental analysis of compound [A3] yielded experimental values of N = 10.06, C = 66.46, H = 6.23, and S = 7.09, which were in good agreement with the estimate values of N = 9.65, C = 66.19, H = 5.79, and S = 7.36.

Schiff base [A1] produced Schiff base derivatives [A2, A3] by reacting with benzenesulfonyl chloride and 4-methylbenzenesulfonyl chloride in pyridine at 0°C. New asymmetric bands at 1373 and 1369 cm^{-1} and symmetric bands at 1161 and 1165 cm^{-1} that correspond to the S=O groups also appeared in the FT-IR spectra, which verified the removal of the -OH group. Furthermore, a band that showed the presence of the C–S group was found in the 844–837 cm^{-1} range.

These results are consistent with typical FT-IR absorption bands of Schiff bases as reported by Silverstein et al. (2014). [A2] ^{1}H NMR showed resonances from δ 8.59 to 6.77 ppm for thirteen aryl protons and a singlet at δ 9.68 ppm for the CH=N proton. Likewise, compound [A3] also had doublet-doublet signals for twelve aryl protons in the range of δ 8.06-6.79 ppm and singlet for the CH=N proton at δ 8.90 ppm. Absence in the syntheses was illustrated by failure to show signal due to OH proton for two compounds (Pavia et al., 2015). Other supporting evidence regarding structures of [A2] and [A3] was further provided by C NMR spectra.

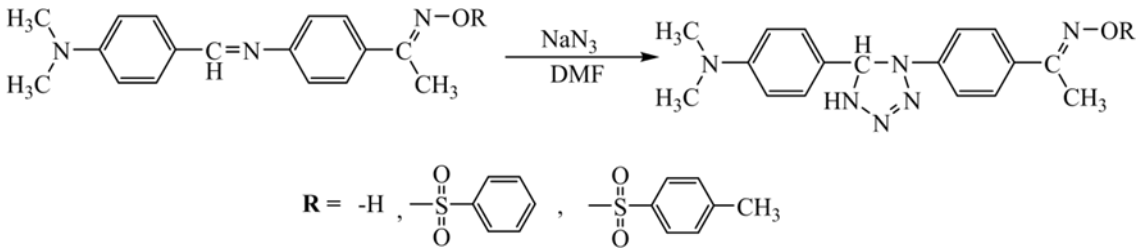
Carbon of the Schiff base functional group (-C=N) of compound [A2] was attributed as the source of a peak at δ 159.03 ppm, and the carbon of the -C=NOH functional group was attributed as the source of another peak at δ 152.07 ppm. The carbon position within the Schiff base structure was established as the source of a peak in compound [A3] at δ 151.61 ppm, and the carbon position within the -C=NOH oxime is established as the source of a second peak at δ 142.75 ppm. The results are consistent with literature data reported previously for similar chemicals (Williams & Fleming, 2020).

Finally, the spectroscopic analysis confirms that compounds [A2] and [A3] were successfully synthesized and their structures intact. The proposed structures are confirmed by the appearance of new peaks for oxime and Schiff base functions and disappearance of peaks of the starting materials. The outcomes confirm evidence on the usefulness of FT-IR, ^{1}HNMR, and ^{2}CNMR in the detailed study of organic molecules.

Complementary to this, the spectroscopic findings validate the successful synthesis of [A2] and [A3] and the plausibility of their structures. The suggested structures can be revealed by the appearance of new peaks related to Schiff base and oxime functional groups and disappearance of characteristic signals related to starting material. The findings establish the indispensability of FT-IR, ^{1}HNMR, and ^{2}CNMR methods in thoroughly characterizing organic compounds.

3.1.3. Synthesis and characterization of compounds [A4–A6]

Schiff bases [A1–A3] reacted with sodium azide in DMF as a solvent to produce tetrazole derivatives.



Equation.4. Synthesis and characterization of compounds [A4–A6]

Both FT-IR and ¹H NMR spectroscopy were used to examine the compounds. The removal of the υ(-C=N) imine band seen in [A1–A3] was verified by the FT-IR spectra, which are shown in Equation.4. Instead, additional bands were found at 3394–3251 cm□¹, which were attributed to NH stretching, and at 1550–1552 cm□¹, which corresponded to N=N stretching. Table 4 summarizes the absorption information for various substances.

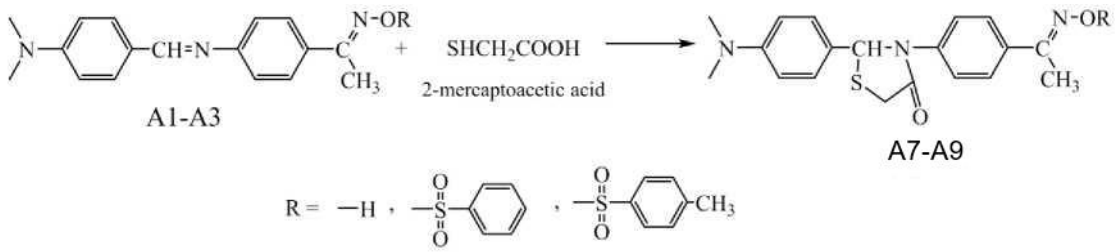
Table 3. Characteristic FTIR absorption bands of [A4–A6].

No.	FTIR Spectra (cm $^{-1}$)								
	μNH	μC-H arom.	μCH Aliph.	μN=N	μC=N oxime	μC=C	μC-N	μS=O	Others
A4	overlap	3005	2947	overlap	1627	1577	overlap	-	μO-H 3176
A5	3394	3055	2902	1552	1652	1596	1334	1373asy. 1164 sy.	μC-S 837
A6	3251	3032	2904	1550	1654	1593	1334	1385asy. 1161 sy.	μC-S 837

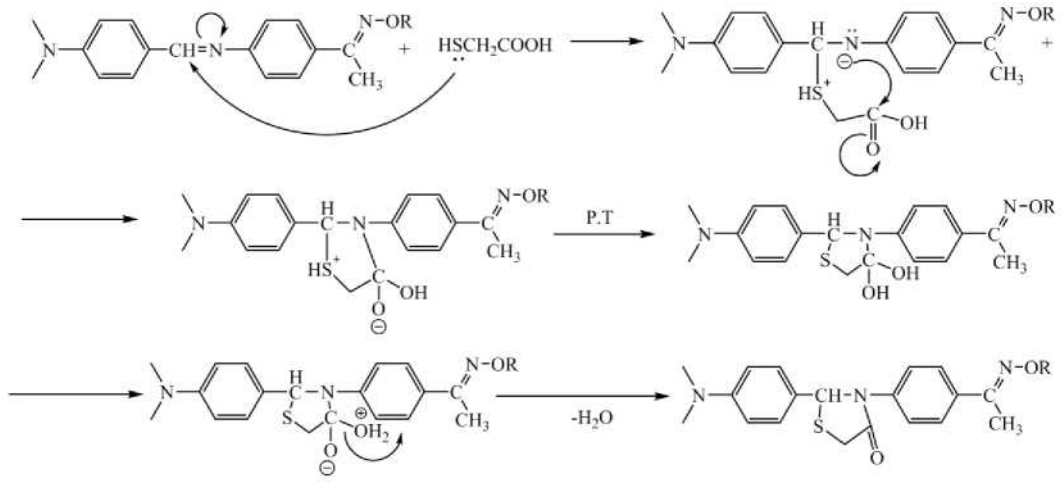
Equation.4. Shows the chemical [A5]'s ¹H NMR spectra recorded in DMSO. It showed a singlet at δ 10.80 ppm, which is the proton of the C-NH-N group in the tetrazole ring. It was determined that the N-CH-N group's solitary proton has another singlet at δ 5.45 ppm. The $(CH_3)_2N$ and CH_3-C=N groups were identified by singlets at δ 3.02 ppm and δ 2.16 ppm, respectively, while signals between δ 8.51 and 6.50 ppm were ascribed to twelve aromatic protons.

3.1.4. Synthesis and characterization of compounds [A7-A9]

The Schiff bases [A1-A3] were dissolved in acetone then Thioglycolic acid was added, and refluxed to 12 hrs.



Equation.5. The mechanism suggested for this reaction as shown in the (Scheme.1).



Equation.6. The mechanism of synthesis compounds [A7-A9].

The compounds were examined using FT-IR and ¹HNMR spectroscopy. As illustrated in Figure (9), the spectra showed the disappearance of the imine group stretching band in [A1–A3]. New absorption bands that corresponded to (N-C=O) stretching appeared in 1714–1726 cm□¹, and those that corresponded to C–S stretching appeared in 837–850 cm□¹. Table (4) summarizes the absorption statistics for various substances.

Table 4. Characteristic FTIR absorption bands of [A7-A9]

Comp. No.	FTIR Spectra (cm $^{-1}$)							
	μC-H Arom.	μC-H Aliph.	μC=O	μC=N Oxime	μ(C=C)	μC-N	μC-S	Others
A7	3047	2897	Overlap	1670	1597	1323	837	μO-H 3271
A8	3064	2866	1726	1662	1602	1336	850	-
A9	3049	2867	1714	1670	1596	1338	846	-

The chemical [A7]'s ^{1}H NMR spectrum, shown in Figure (9), showed a singlet at δ 11.07 ppm for the proton of the -N=OH group. It was determined that the S-CH-N group was responsible for a singlet at δ 6.68 ppm, while eight aromatic protons were responsible for signals between δ 7.96 and 7.19 ppm. The thiazolidinone ring's CH_2 group showed a peak at δ 3.74 ppm.

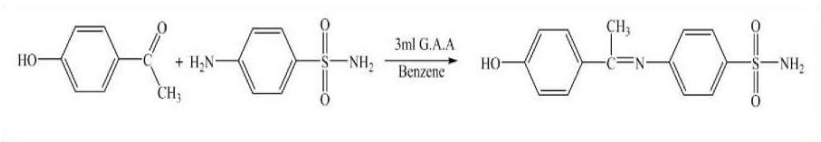
Furthermore, two singlets were connected to six and three protons, respectively, from the compound's methyl groups at δ 3.04 ppm and δ 2.13 ppm. The carbonyl carbon in the thiazolidin-4-one ring was represented by a peak at δ 195.87 ppm in the chemical [A9]'s ^{2}C NMR spectrum, which is seen in Figure (9). The carbon in the C=N oxime group was identified as the source of a signal at δ 143.12 ppm.

Peaks between δ 129.21 and 111.40 ppm were assigned to aromatic carbons. Additionally, a signal at δ 51.97 ppm was linked to the S-CH-N group, while another at δ 40.56 ppm corresponded to the CH_2 group. Further signals at δ 39.37, 25.76, and 20.36 ppm were associated with the N,N-dimethylamino group, CH_3-tosyl group, and CH_3-C=N group, respectively.

3.2. Synthesis and characterization of compound [B]

3.2.1. Synthesis and characterization of compound [B1]

Using G.A.A. as a catalyst, 4-hydroxyacetophenone and 4-aminobenzenesulfonamide were reacted in dry benzene to create this chemical.



Equation.7. The mechanism of synthesis compounds [B1].

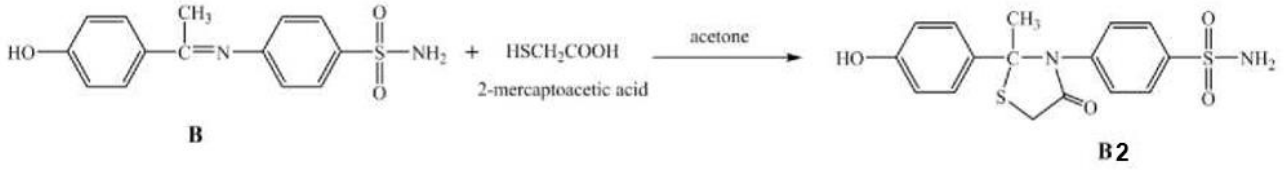
Compound [B1] was examined using spectroscopic methods such as FT-IR, ^{1}HNMR, and CNMR, as well as its melting point. The FT-IR spectrum verified that the stretching bands for the C=O and -NH_2 groups vanished, signifying their conversion. Figure (9) illustrates the discovery of a new band at 1645 cm^{-1} that corresponds to the azomethine group. When compound [B1] was recorded in DMSO, its ^{1}HNMR spectrum revealed a singlet for the -OH proton at δ 10.38 ppm.

It was determined that the two protons of the -NH_2 group were responsible for a singlet at δ 5.81 ppm. The three protons of the methyl group were represented by a singlet at δ 1.91 ppm, whereas eight aromatic protons were identified by doublet signals between δ 6.60 and 7.84 ppm. Figure (9) shows these aspects of the spectrum. The carbon of the Schiff base group (C=N) was identified as the peak at δ 161.48 ppm in the molecule [B1]'s ^{2}CNMR spectrum. A peak at δ 25.66 ppm was associated with the CH_3 group, whilst signals between δ 151.37 and 111.93 ppm

were attributed to aromatic ring carbons. An illustration of these spectral features can be found in (Fig. 9.).

3.2.2. Synthesis and characterization of compound [B2]

The chemical [B1] was refluxed with thioglycolic acid in acetone for 10 hours to create compound [B2].



Equation.8. Synthesis compounds [B1].

Compound [B2]'s FT-IR spectrum, displayed in Figure 9, verified that the azomethine absorption band seen in compound [B1] had vanished. Rather, a novel band was found at 1662 cm□¹, which is associated with the carbonyl group (N-C=O), and another band at 844 cm□¹ is associated with the (C-S) bond. The molecule [B2]'s ¹H NMR spectrum, which was recorded in DMSO (Fig. 9), showed a singlet for the -OH proton at δ 10.33 ppm.

Doublet readings were attributed to eight aromatic protons with δ 7.86 to 6.60 ppm. It was determined that the two protons of the $-NH_2$ group were responsible for a singlet at δ 5.85 ppm, while the $-S-CH_2-CO$ group was responsible for another singlet at δ 3.45 ppm. A singlet was also detected for the three protons of the $C-CH_3$ group at δ 2.05 ppm.

A singlet at δ 10.33 ppm, which corresponds to the -OH proton, was seen in the chemical [B2]'s ¹H NMR spectrum, which was recorded in DMSO (Fig. 9). It was determined that eight aromatic protons were responsible for doublet signals between δ 7.86 and 6.60 ppm. The two protons of the $-NH_2$ group were identified by a singlet at δ 5.85 ppm, and the $-S-CH_2-CO$ group was identified by a singlet at δ 3.45 ppm. Furthermore, a singlet for the three protons of the $C-CH_3$ group was detected at δ 2.05 ppm.

3.3. Biological activity assay

The antibacterial and antifungal properties of certain synthesized compounds were assessed at a concentration of 10^{-2} M. In addition to one fungus strain, Candida albicans, four bacterial strains were assessed, including Gram-positive

species like Staphylococcus aureus and Bacillus cereus, as well as Gram-negative species like E. coli and Pseudomonas aeruginosa.

Nutrient agar was employed as the medium for growth and DMSO as solvent for test compounds and control. The experiment indicated that test compounds exhibited variable biological activity against the microbes chosen. The antimicrobial potential of the synthesized compounds against Bacillus cereus had different activities. Compounds [A5, A9, B1, B2] yielded clear zones of inhibition, which was an indicator of strong activity, whereas others exhibited moderate or weak activity as shown in (Fig. 8).

Against Staphylococcus aureus, [A2, A5, A9, B1, B2] compounds were effective, and it suggests their potential application as antibacterial compounds against this bacterium. Against E. coli, [A1, A3, A5, B2] compounds produced large zones of inhibition, suggesting high antibacterial activity, whereas the rest of the compounds display medium and low activity. Against Pseudomonas aeruginosa, compounds [A5, B1] were found to be active, suggesting activity against this Gram-negative bacterium. Finally, in Candida albicans, compounds A3, A4, A9 and B1 showed activity, signifying that these are anti-fungal in nature as shown in (Fig. 8).

Against Staphylococcus aureus, the compounds [A2, A5, A9, B1, B2] were extremely effective, which suggested their potential for antibacterial activity against the bacterium. Against E. coli, compounds [A1, A3, A5, B2] exhibited intense zone inhibition, which suggested intense antibacterial activity, whereas the rest of the compounds exhibited medium to poor activity as shown in (Fig. 8). By being active against the Gram-negative bacterium Pseudomonas aeruginosa, the [A5, B1] compounds showed their effectiveness against it. Lastly, in the case of Candida albicans, [A3, A4, A9, B1] were demonstrated to be effective, indicating that they might possess antifungal properties.

Table 5. Inhibition Zones (mm) of Synthesized Compounds Against Gram-Positive, Gram-Negative Bacteria, and Fungi.

Compound No,	Inhibition zone (mm.)				
	Gram positive (+)		Gram negative (-)		
	Bacillus cereus	Staphylococcus aureus	E. coli	Pseudomonas aerug.	Candida albicans
A1	-	-	18	15	10
A2	16	20	17	13	14
A3	15	17	19	15	19

A4	-	13	16	14	18
A5	25	20	21	19	14
A6	-	-	-	-	-
A7	-	-	-	-	-
A8	-	-	-	-	-
A9	19	22	17	16	18
B1	21	25	16	22	19
B2	22	20	25	18	21

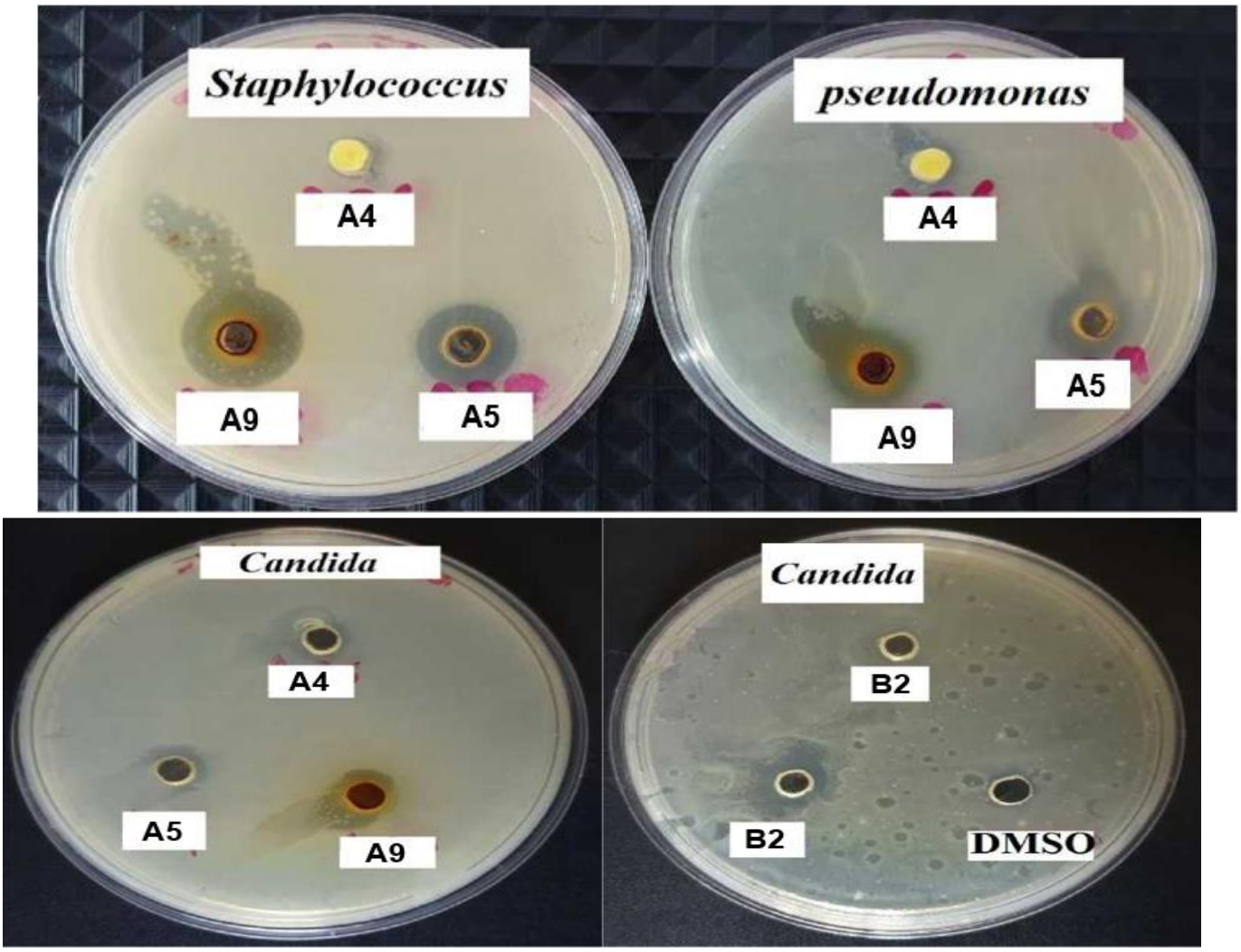
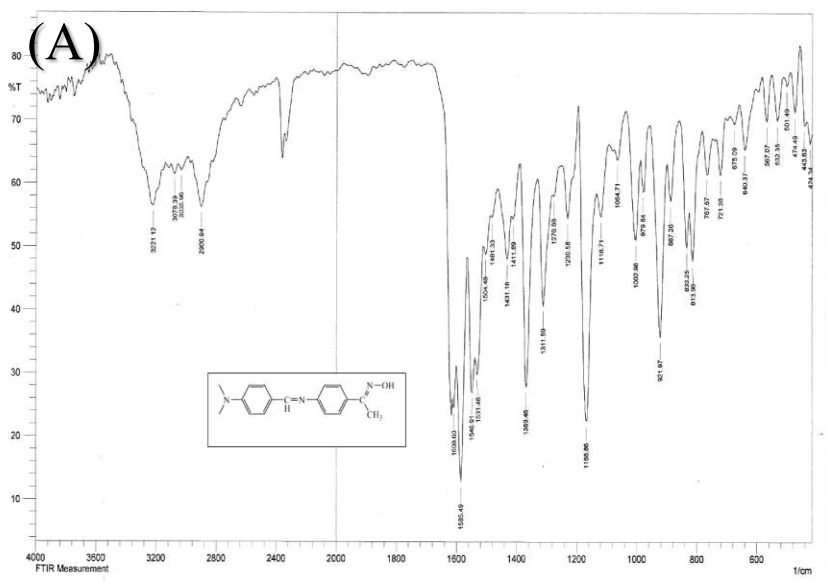
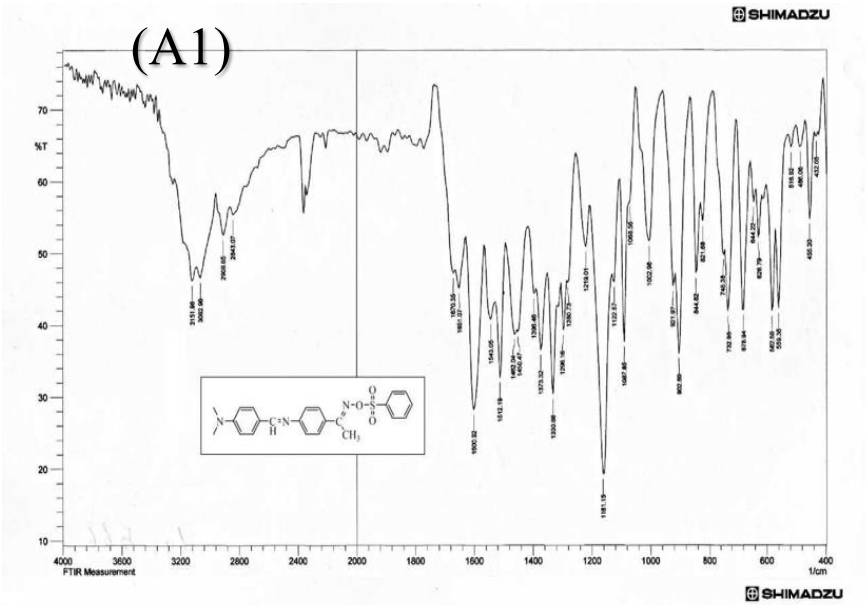
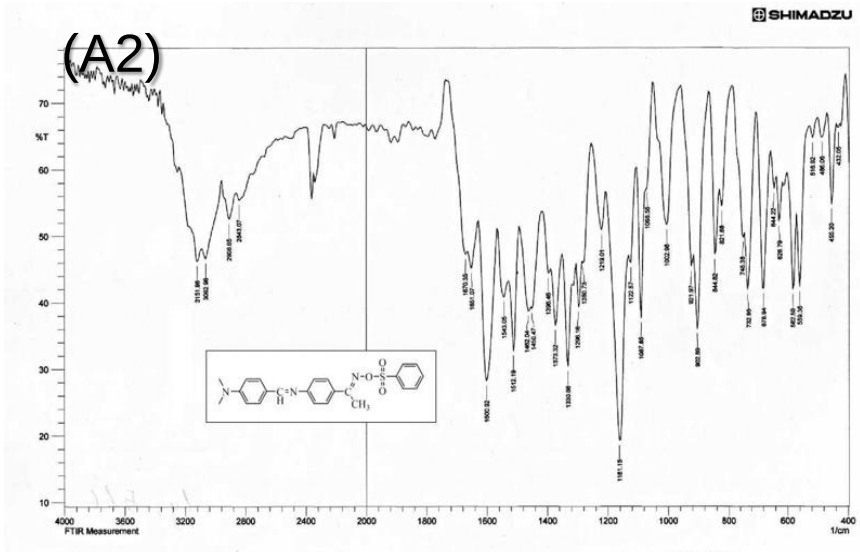
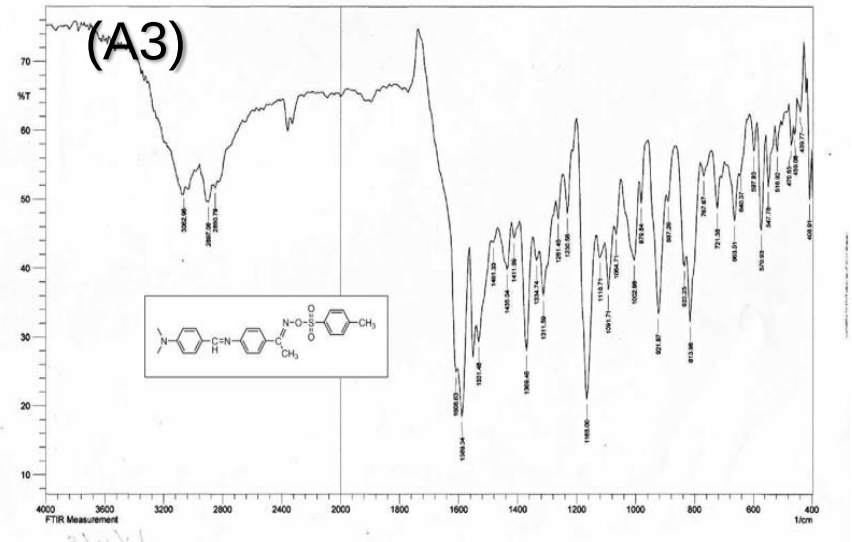


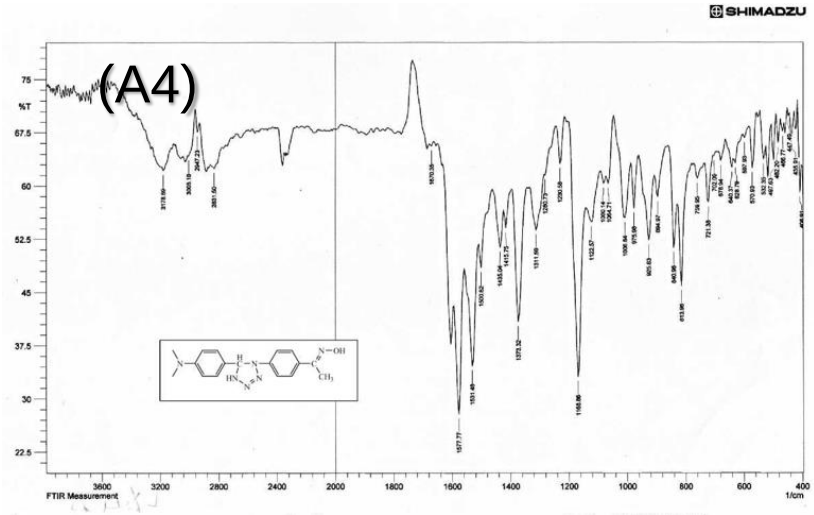
Fig. 8. Biological activity of bacterial and fungal.

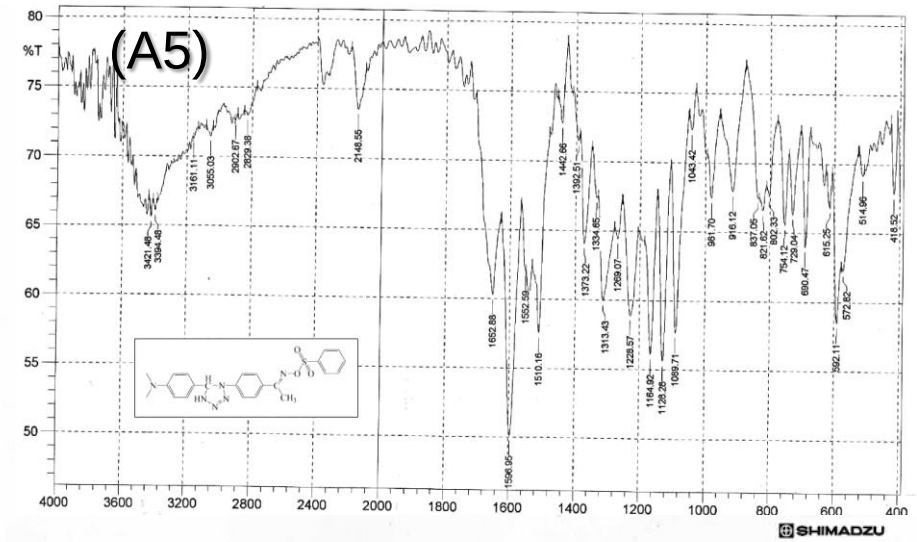

(A)
%T
FTIR Measurement
1/cm

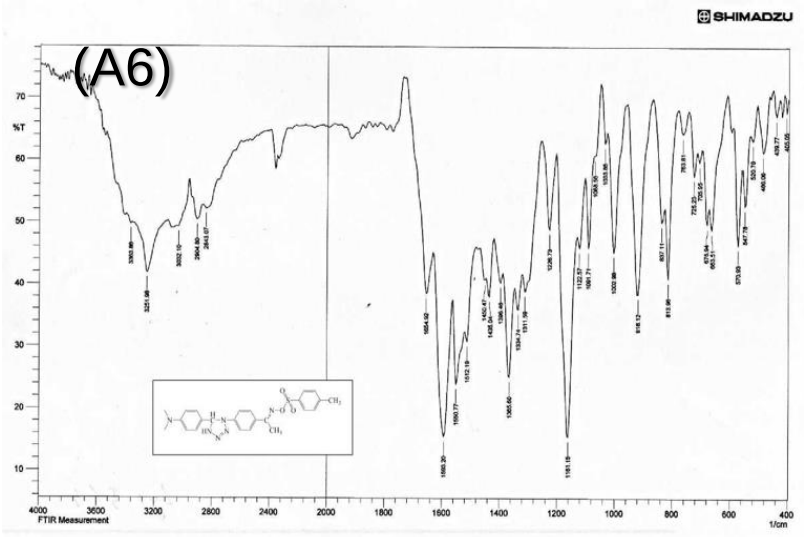

(A1)
SHIMADZU
%T
FTIR Measurement
1/cm

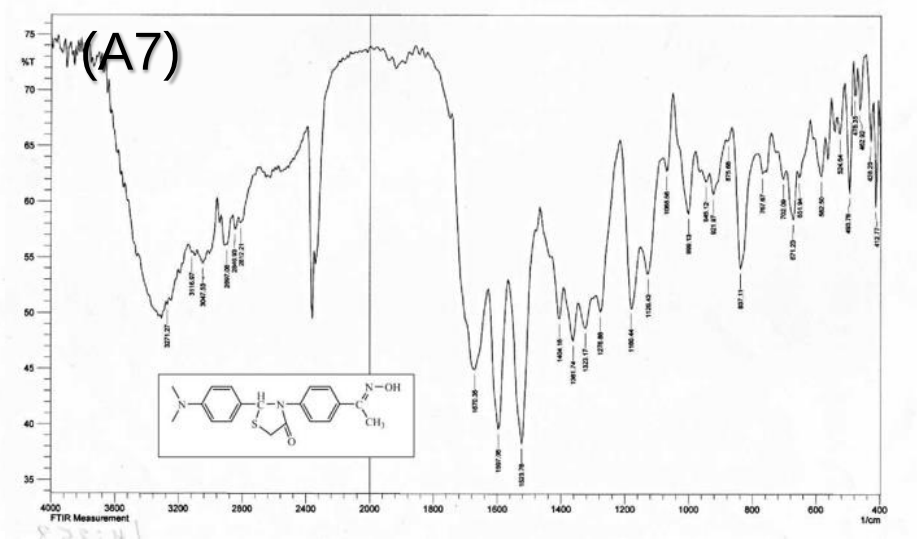

(A2)
SHIMADZU
%T
FTIR Measurement
1/cm


(A3)
%T
FTIR Measurement
1/cm


SHIMADZU
(A4)
%T
FTIR Measurement
1/cm


(A5)
%T
SHIMADZU


SHIMADZU
(A6)
%T
FTIR Measurement
1/cm


(A7)
%T
FTIR Measurement
1/cm

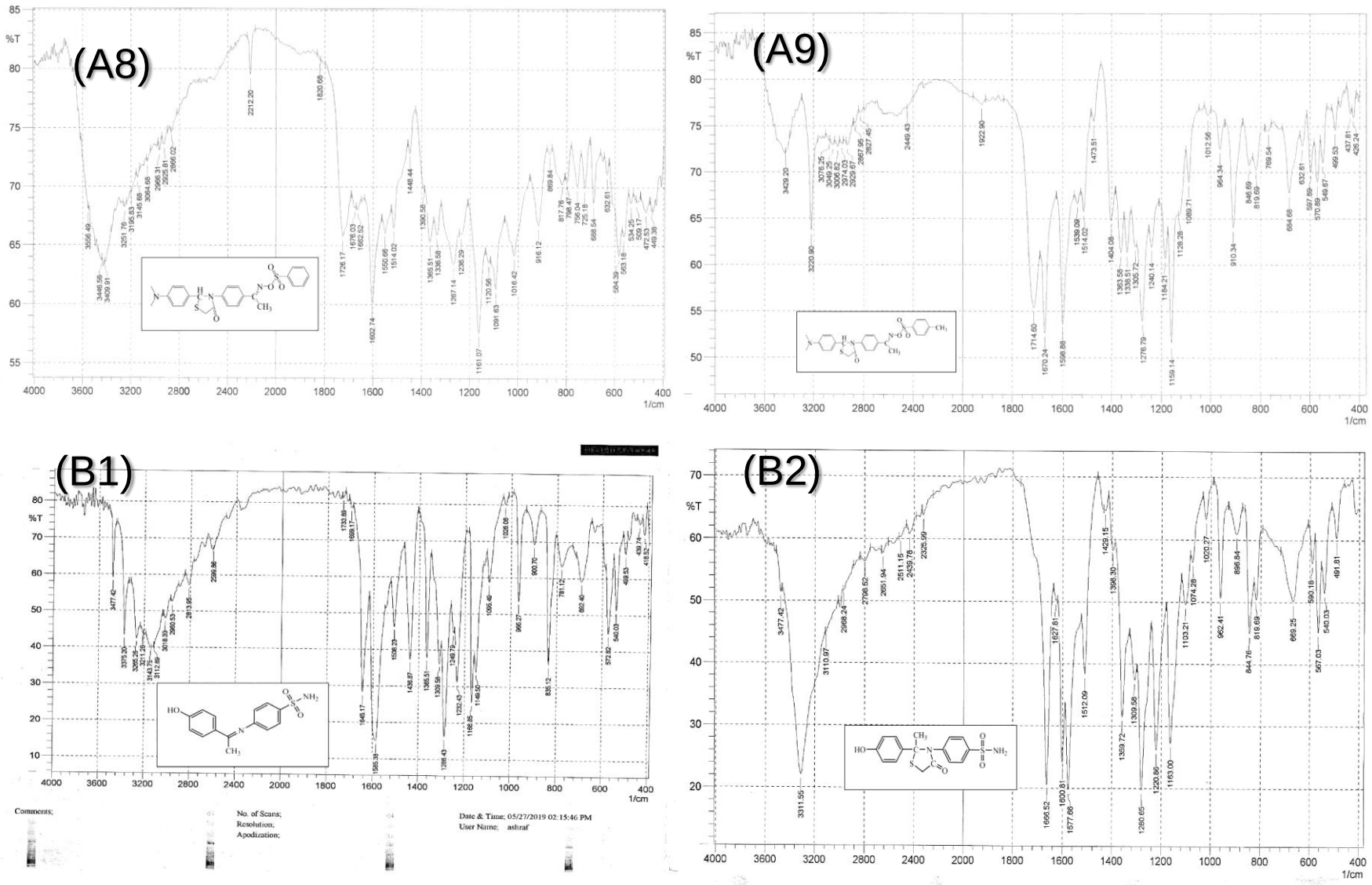


Fig. 9. FTIR spectrum of Compounds.

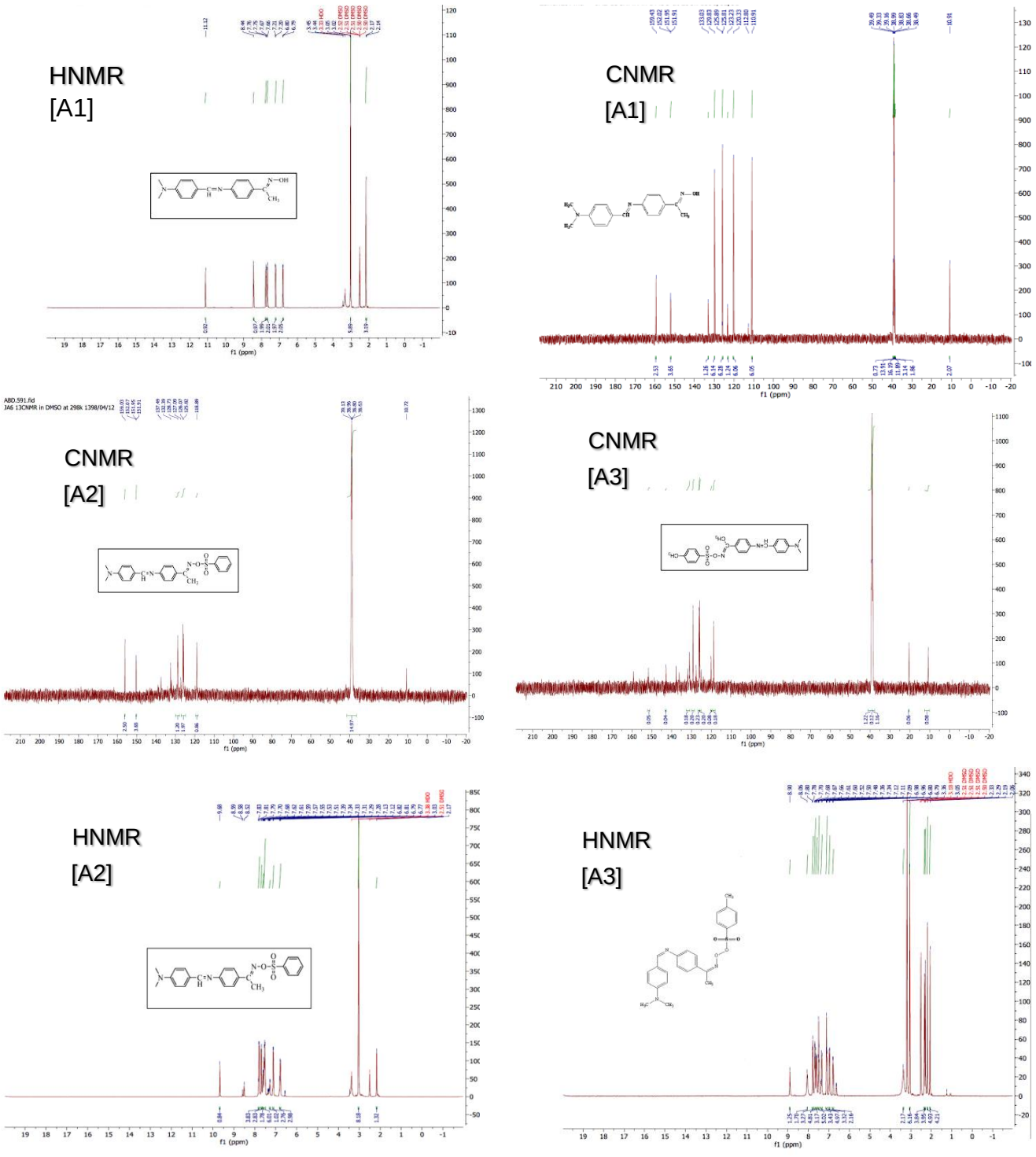


Fig. 10. HNMR & CNMR spectrums of [A1, A2, A3].

4. Conclusion

The present work for the synthesis and characterization of some new Schiff base derivatives with possible bioactivities was undertaken. A series of Schiff base compounds, [A1], [A2], and [A3], have been synthesized readily through oxime [A] condensation with a sequence of aldehydes through sequential sulfonylation reactions. Synthesis processes were straightforward and inexpensive so that the molecules become easily accessible for future studies.The synthesized Schiff base compounds were very well characterized with various spectroscopic techniques, namely FT-IR, ^{1}H NMR, and ^{2}CNMR. The spectra revealed successful generation of the targeted structures and detection of significant functional groups such as the azomethine (-C=N-) group, the sulfonyl (-SO□-) groups, and the N,N-dimethylamino groups.

These results vindicated the structural stability of the compounds synthesized. The Schiff base derivatives synthesized in the present work have shown much potential towards various biological activities like antiviral, antioxidant, antifungal, anticancer, and antibacterial activity. The results indicate that the compounds can be used as good bioactive cores to design novel drugs for therapy, demonstrating their significance in medicinal chemistry. The prospect of Schiff bases and their derivatives as a tool towards medicinal chemistry was stressed more vigorously in this work. Simpleness of synthesis and multitude of bioactivities are the grounds upon which such types of molecules make for candidate molecules of probable drug development and for chemosensing too, particularly for metal ion detection.

The paper also emphasized identifying natural compounds and ionic liquids for their possible bioactivity and applications in many fields, i.e., medicines, cosmetics, and biotechnology. Identification of new bioactive compounds from nature and utilization of ionic liquids in the process of drug preparation and delivery systems are of extreme potential for research and development. Lastly, efficient synthesis and characterization of new Schiff base derivatives achieved in this paper contribute to ongoing progress in the field of medicinal chemistry and drug discovery. The findings provide the groundwork for further research on the biological activities and potential applications of the compounds, which can lead to new drugs and new uses in industries.

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