

Synthesis, Characterization, Antimicrobial Activity and Theoretical Studies of New Polymeric Schiff-base

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Summary: A novel Schiff-base compound was synthesized by condensation of 4-hydroxybenzaldehyde and 4-aminoazobenzene. The prepared Schiff-base was converted to a polymer by reaction with formaldehyde and resorcinol. The two types of the prepared compounds were characterized with spectral techniques (FT-IR and ¹H-NMR). The biological activity as antibacterial and antifungal was tested using the cork well diffusion method against some standard microorganisms, which indicate that these compounds showed good antimicrobial activity. HyperChem-8 program has been used to determine total energy, LUMO-HOMO, bond length and angles.

Keywords: Schiff-base, Polymer, Antimicrobial, HyperChem-8, HOMO-LUMO.

Introduction

Some compounds as polymers which containing the system $-C=C-$ and $-C=N-$ bonds in their structure have been interested by the researchers due to their importance in many uses [1–4]. For more than 60 years, Schiff-base which consists in their structure hydroxyl group and conjugated bonds has been investigated by the researchers which acquired different applications in diverse fields [5].

Different spectroscopic techniques have been utilized to characterize many prepared polymers which include azomethine group in their structure [6, 7]. These polymers used in GC-techniques as stationary phase which have thermal stability feature similar to polyamides [8].

The polymers of Schiff-bases are an important type of ligands, which react with transition metals to form complexes, the great interest in coordination chemistry [9–11]. Some polymeric Schiff-bases are synthesized and evaluated as antimicrobial agents against the two types of microorganisms, Gram-positive and Gram-negative strain [12].

In this work, a new polymer of synthesized Schiff-base was prepared. The Schiff-base and its polymer were identified by spectral techniques. The biological activity of the prepared polymer and Schiff-base are evaluated. HyperChem-8 program has

been used to predict the structural geometries of compounds in the gas phase.

Experimental

All reagents were used without further purification. Resorcinol (99%), formaldehyde (37% in water), glacial acetic acid (99%), absolute ethanol (99%), 4-hydroxybenzaldehyde, 4-aminoazobenzene and chloroform (99%).

The melting points were determined in open capillaries and are uncorrected. The IR spectra were recorded on a FT-IR Shimadzu 8400-S. The NMR was measured on BrukerAvance 400 MHz in DMSO using TMS as internal reference. The biological instrument used autoclave type VORY-16B-I (China) and Heratherm Microbiological Incubators (USA).

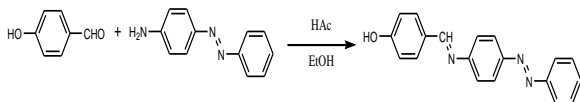
Synthesis of compounds

Synthesis of compound (S) 4-[(E)-(4-[(E)-phenyldiazenyl] phenyl)imino] methyl] - phenol

A solution of 4-hydroxybenz aldehyde 3.944g (0.01 mole) in 25 ml ethanol and an ethanol solution of 4-aminoazobenzene 1.22g (0.01 mole) in 25 ml with few drops of glacial acetic acid was refluxed for 4 hr. On cooling the reaction mixture in ice bath, the orange product was filtered and

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recrystallized from ethanol and then dried [13]. Orange crystals with m.p. 211-213 °C and yield 70%.



Scheme-1: Synthesis of Schiff-base (S).

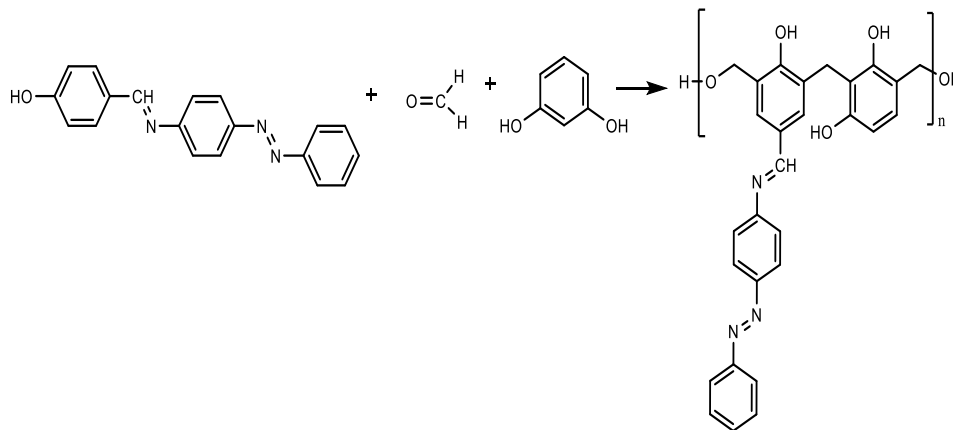
Synthesis of polymer (P)

The mixture of Schiff-base monomer 0.903g (0.03 mol), resorcinol 1.1g (0.01 mol) and 100ml of formaldehyde was refluxed for 5 h. Dark red crystals formed by cooling to room temperature. The solid product was collected and recrystallized from mixture of (7:3) ethanol: chloroform [14]. Pale red crystals with m.p. 308-310 °C and yield 50%.

Antibacterial activity

Preparation of the microbial cultures: The synthesized Schiff-base and its polymer were screened *in vitro* for their antibacterial activity against *E. coli* and *S. aureus* and for their antifungal activity against *C. albicans* with the agar well diffusion method [15]. The wells were dug in the media with the help of a sterile metallic borer with centers of at least 5 mm. The recommended concentration (100 μ L/mL) of the test sample (1, 0.1 and 0.01 mg/mL in DMSO) was introduced into the corresponding wells. Other wells supplemented with DMSO. The plates were incubated immediately at 37°C for 24 h. The activity was determined by measurement of the diameter (millimeters) of zones showing complete inhibition.

Results and Discussion



Scheme-2: Synthesis of the polymer (P).

¹H-NMR Spectra

The ¹H-NMR spectra of Schiff-base and polymer provided direct evidence for poly condensation reaction. The ¹H-NMR spectra of Schiff-base and the polymer are presented in the (Fig 3a & b). Both spectra showed a signals at 2.5 ppm which was due to DMSO solvent and at 3.33 ppm due to dissolved water in DMSO [16].

In the Schiff-base, the azomethine proton (CH=N) was recorded at 8.52 ppm and the hydrogen bonded phenolic proton at 10.20 ppm. A complex set of multiplet signals between 6.85 to 7.91 ppm was due to coupling of the protons of aromatic rings.

On condensation of the Schiff-base with formaldehyde and resorcinol, the aromatic ring protons appeared in the range 6.79-7.76 ppm as a multiplet signals and the azomethine proton appeared at 8.46 ppm. A number of additional signals appeared at 4.02 ppm and 4.61 ppm. These were assigned to the bridging methylene (Φ -CH₂- Φ) and methylene group and hydrogen bonded terminal methylol functions (Φ -CH₂-OH), respectively. A two singlet signals of two types of phenolic groups appeared at 5.44 and 5.47 ppm. As shown in Fig 1-2 and Table-1.

Table-1: ¹H-NMR data of Schiff-base and its polymer.

Compd.	δ ppm				
	-CH ₂ -	-O-CH ₂ -	Aromatic system	-N=CH-	-OH
S	-	-	6.85-7.91 (m)	8.52 (s)	10.20 (s)
P	4.02 (s)	4.61 (s)	6.79-7.76 (m)	8.46 (s)	5.47 (s) 5.44 (s)

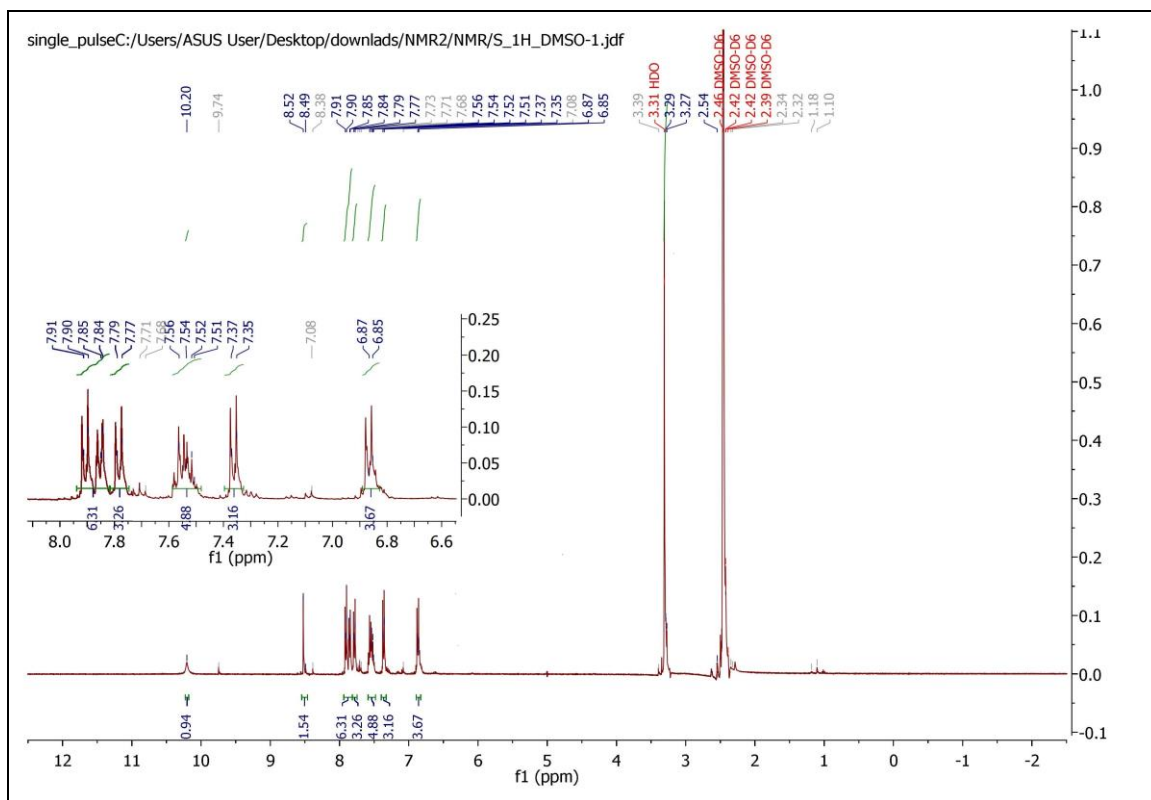


Fig. 1: The ¹H-NMR spectrum of Schiff-base.

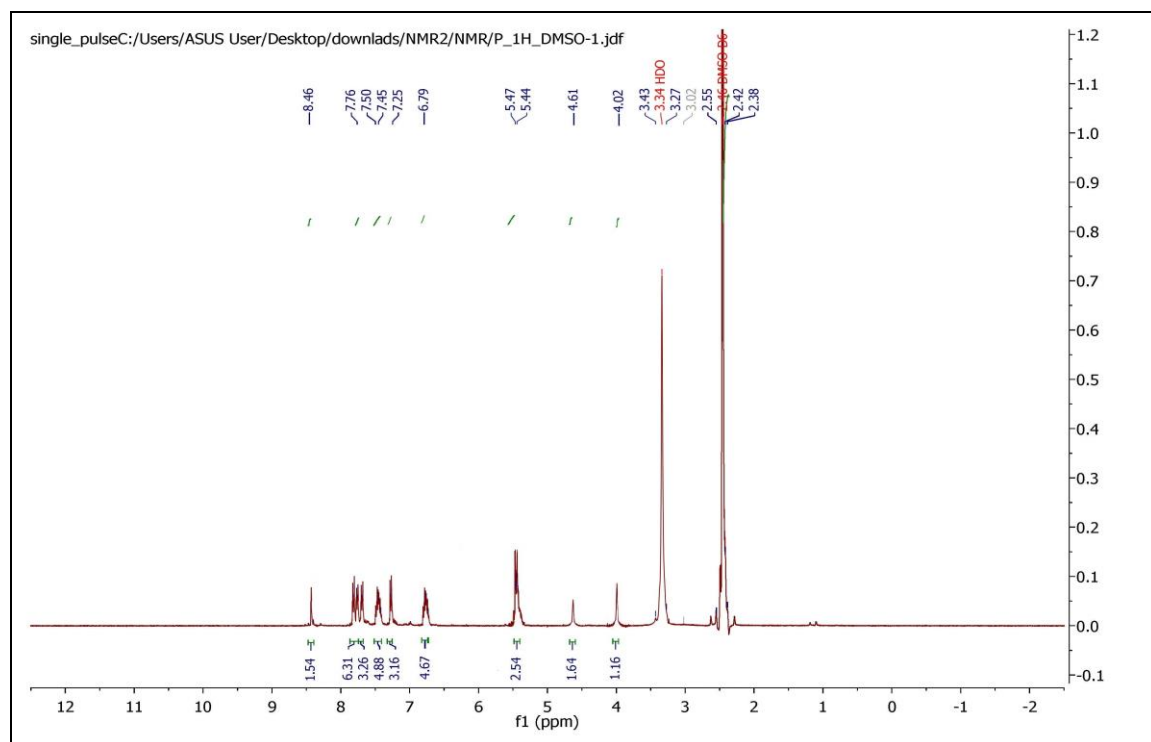


Fig 2: The ¹H-NMR spectrum of polymer.

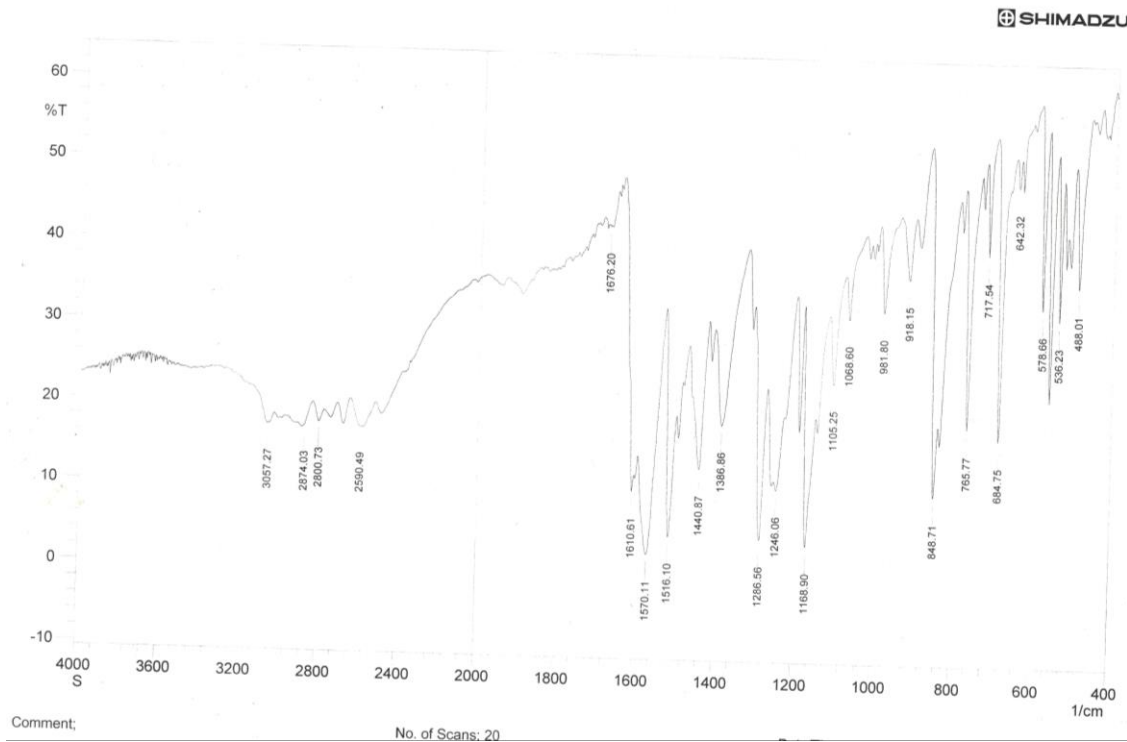


Fig. 3: The FT-IR spectrum of Schiff-base.

FT-IR Spectra

In the FT-IR spectra of Schiff-base, several characteristic absorption of starting materials (aldehyde and amine) vanished and new absorption bands appeared. The carbonyl vibration of 4-hydroxybenzaldehyde and the N-H vibration of 4-aminoazobenzene vanished. The C=N stretch appeared as a sharp band at 1610 cm^{-1} along with the C=C at 1570 and 1516 cm^{-1} . The C-H aromatic bending appeared at 848 cm^{-1} , as shown in Fig 3.

In condensation of Schiff-base with formaldehyde and resorcinol led to the polymer. The FTIR spectrum of this polymer was compared with the FTIR spectrum of the Schiff-base and the formaldehyde. The disappearing of carbonyl stretch as a sharp band at about 1650 cm^{-1} and appearing of medium band at 1386 cm^{-1} may be attributed to C-H stretching of aliphatic $-\text{CH}_2-$ bridge gave good evidence to form the polymer (Fig 4). In the FTIR spectrum of the polymeric Schiff-base, the C=N absorption was seen at 1600 cm^{-1} as a prominent band.

Biological evaluation studies

The Schiff-base and the polymer gave varying degrees of inhibition on the bacterial and

fungal strains growth (Table-2 and Fig 5). The Schiff-base and the polymer were tested to show the antibacterial activity against *E. coli* and *S. aureus* and against *C. albicans* to show their antifungal activity.

According to results (Table-2), the prepared Schiff-base and the polymer possessed good biological activity which decreased with decreasing the concentration. The two types of compounds showed good antibacterial activity on gram negative rather than in gram positive, and more significant antifungal activity. From the results of antimicrobial activity, we saw that the polymeric compound gave good activity in low concentration which may be attributed to the interaction between groups of -OH, -C=N- in this compound and binding sites on the bacterial cell envelop which increased by increasing the molecular weight.

Table-2: Inhibition zone of Schiff-base and its polymer in DMSO at different concentration.

Compound (conc. mg/ml)	Zone diameter (mm)		
	<i>S. aureus</i>	<i>E. coli</i>	<i>C. albicans</i>
Control DMSO	NI*	NI	NI
S	1	13	23
	0.1	NI	19
	0.01	NI	19
P	1	20	25
	0.1	NI	20
	0.01	NI	14

* NI = No Inhibition

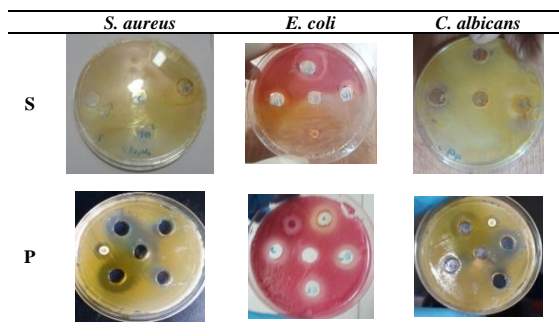


Fig. 5: Antimicrobial activity of Schiff-base and the polymer against *S. aureus*, *E. coli* and *C. albicans*.

Theoretical study

Optimized geometry and energy

The HyperChem-8 program was used for the semi-empirical and molecular mechanic calculations to calculate the total energy, heat of formation and binding energy, for the Schiff-base and its polymer by PM3, as in Table-3.

Table-3: Some calculated values such as total energy, bonding energy, electronic energy, nuclear energy, dipole moment, LUMO-HOMO gap for the Schiff-base and polymer using PM3 semi-empirical method

	Schiff-base	Polymer
Total energy	-75171.85	-130390.21
Binding energy	4336.55	6764.40
Heat of formation	90.44	40.14
Electronic energy	507983.15	1114611.75
Nuclear Energy	984221.56	432811.28
HOMO (eV)	-8.83	-8.489
LUMO (eV)	-0.9774	-0.9189
Δ LUMO-HOMO (eV)	7.8674	7.5719
log P	0.83	1.92

Electrostatic potential (E.P.)

This study show the interaction of the molecular system energy with a positive charge point, which refers the practical importance for finding reaction sites in molecular positive charge species. They tend to resolve the attack a molecule between powerfully negative and positive interactions. The E.P of Schiff-base and part of polymer are plotted as 3D contour to investigate the reactive sites of the molecules via adopting HyperChem-8 program, shown in Fig. 6.

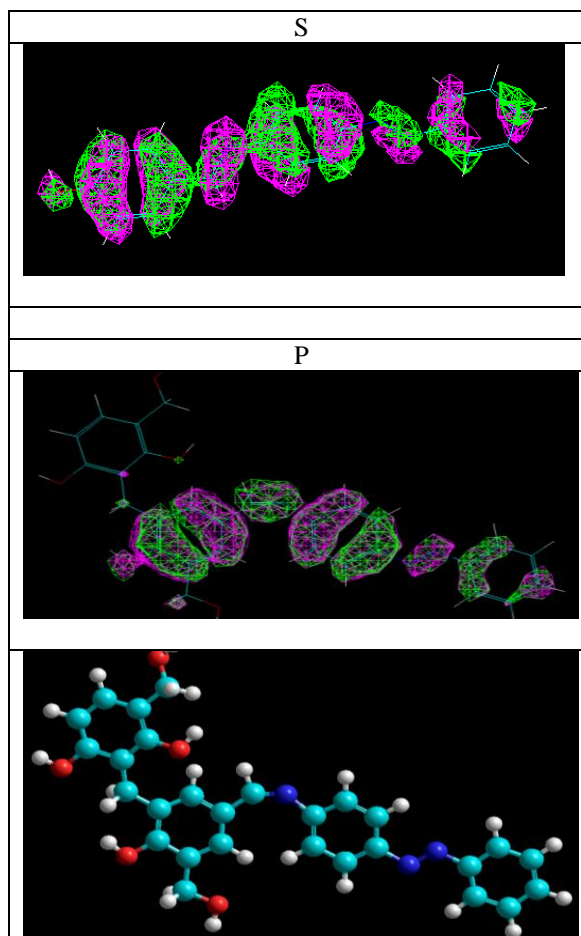


Fig 6: Most Table conformer and Electrostatic potential (E.P.) of Schiff-base (S) and polymer (P) obtained through Molecular Dynamics studies

Frontier Molecular Orbitals (FMOs)

FMOs (HOMOs and LUMOs) are the frontier molecular orbitals taking part in the chemical reactions and have importance in electronic and optical properties of compound [17-19]. The HOMOs are electron donors which referring the electron donating ability and LUMOs are electron acceptors representing the ability of orbital to obtain an electron. The levels of HOMO and LUMO are clearly related to the ionization potentials and electron affinities [20]. The FMOs surfaces and energies were obtained using DFT method presented in Fig. 7. The HOMO energy was calculated as -8.83 and the LUMO energy was also calculated as -0.9774.

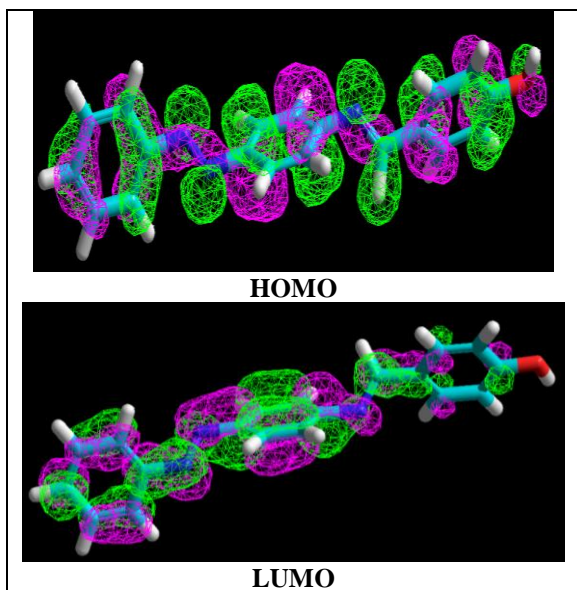


Fig. 7: Electrostatic potential (HOMO and LUMO) for compound S

Bond lengths measurements for the Schiff-base

Another employ of HyperChem-8 program this study to give optimization geometry for the model systems which represented in Fig 8. The calculated bond lengths, bond angles and dihedral angles for Schiff-base were using the semi-empirical (PM3, AM1 and MNDO) methods at geometry optimization (0.001 Kcal / mol), Table-4. The results showed that there are good agreements between the three theoretical methods.

Table-4: Some values such as bond lengths, bond angles and dihedral angles obtained by PM3, AM1 and MNDO with HyperChem-8 computational programs. The distances between atoms are reported in Angstroms (Å), bond angle and dihedral angle in degrees.

	PM3	AM1	MNDO
Bond length			
N15-N16	1.2283	1.2277	1.2283
N8-C9	1.4331	1.4134	1.4180
C3-O23	1.3676	1.3752	1.3568
C9-C10	1.4000	1.4117	1.4174
C1-C6	1.3973	1.4008	1.4152
C6-C7	1.4737	1.4746	1.4838
bond angles			
C2-C3-O23	116.074	116.382	117.145
C7-N8-C9	122.52	121.728	122.288
C12-C13-N15	116.635	117.423	116.223
C18-C17-N16	116.439	117.024	115.656
C5-C6-C7	120.742	120.498	121.231
dihedral angles			
C1-C2-C3-O23	179.422	179.700	179.478
C5-C6-C7-N8	73.8914	73.9481	75.5804
C17-N16-N15-C13	-179.216	179.020	-179.021
C12-C11-C9-N8	174.791	173.282	174.780
C14-C13-N15-N16	-50.0026	-49.9975	-53.8212

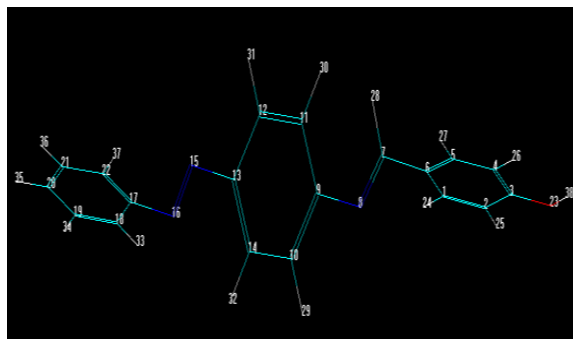


Fig. 8: Calculated optimized geometry of Schiff-base.

Conclusions

The novel Schiff-base and its polymeric derivative were synthesized and characterized. The bonding mode and the structure of Schiff-base and polymer were determined through spectroscopic methods. The theoretical program of HyperChem-8 has been employed to prognosticate structural geometries of the Schiff-base and the polymer in gas phase. On the other hand, Schiff-base and its polymer show significant antimicrobial activity.

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