Synthesis, spectroscopic (FT-IR, FT-Raman, NMR & UV-Vis), reactive (ELF, LOL, Fukui), drug likeness and molecular docking insights on novel 4-[3-(3-methoxy-phenyl)-3-oxo-propenyl]-benzonitrile by experimental and computational methods

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ABSTRACT

The spectroscopic analysis such as FT-IR, FT-Raman, UV-Vis and NMR are conducted for the synthesized molecule by both experimental and theoretical approach. The theoretical computations were achieved by DFT method with B3LYP functional and 6-311\textsuperset{+}\textsuperscript{+}G (d, p) basis set. Firstly the geometrical parameters obtained by DFT are compared with the related experimental parameters. Experimental FT-IR and FT-Raman spectra of the title molecule have been acquired. The vibrational analysis is conducted and the assignments concerned to the observed bands are mentioned through the potential energy distribution (PED). The GIAO method was employed for theoretical NMR analysis and the results are compared with experimental chemical shifts. In accumulation to these analyses NLO, NBO, FMO and MEP analysis have been conducted to understand the nature of the molecule. ELF and LOL were performed. The drug likeness and molecular docking studies also conducted. The potency of inhibition of molecule against M\textsuperscript{PRO} and PL\textsuperscript{PRO} receptors has been performed using molecular docking studies.

1. Introduction

Nonlinear optical materials have gained huge consideration of the scientist and engineers due to their enormous applications in the field of photonics and optoelectronics [1, 2, 3, 4, 5]. Among all the organic NLO materials, chalcones exhibit outstanding NLO properties [6, 7]. Chalcones also display the photochemical and photo physical properties because of their donor-π-acceptor moieties. Chalcone derivatives contain two phenyl rings connected by ethylenic bridge of conjugated double bond. NLO properties can be improved by adding appropriate electron acceptor and electron donor groups at the different end of the ethylenic bridge. Besides the NLO properties chalcones also exhibit certain biological properties such as anticancer [8], antiviral, antiulcer, bactericidal [9], Fungicidal [10], anti malarial [11] and antitumor [12].

The above said features have enlightened us to perform the research work on the chalcone molecules. Hence in this study we have started our research work from synthesis of the on 4-[3-(3-methoxy-phenyl)-3-oxo-propenyl]-benzonitrile (4MPPB) molecule and conducted several analysis. According to conducted literature review up to here know one have conducted the experimental and computational spectral, nonlinear optical and electronic studies on the selected compound. For this reason in the present work we have concentrated on several experimental and computational studies. The experimental FT-IR, FT-Raman, UV-Vis and NMR spectral studies have been conducted at the same time the quantum computational studies have been performed by Gaussian software. The detailed vibrational (FT-IR, FT-Raman) analysis have been conducted and complete vibrational assignments have been established by VEDA 04 software. The NMR (\textsuperscript{1}H and \textsuperscript{13}C) chemical shift values have been established by experimental and computational method. The HOMO-
LUMO analysis is helpful to determine the charge transfer properties of the selected molecule. MEP surface analysis has been found on optimized structure of the title molecule. Electron localization function (ELF) and localized orbital locator (LOL) analysis have helpful to determine the regions of bond pairs, lone pairs and size of the bonding the molecule. Along with these properties Fukui function, drug likeness and molecular docking studies have been performed.

2. Materials and methods

2.1. Material

The synthesis of -[3-(3-Methoxy-phenyl)-3-oxo-propenyl]-benzonitrile (4MPPB) molecule have been performed by the following process as per the literature [13, 14]. Equimolar quantities of 3-methoxy aceto-phenone and 4-cyanobenzaldehyde are dissolved in ethanol 20 ml aqueous sodium hydroxide solution 2ml (40%) is added dropwise with stirring for 10 min. The stirring is continued at room temperature for 5 h. TLC (5% ethyl acetate in hexane) is confirmed the completion of the reaction. The reaction quenched in ice, solid separated is filtered and dried. Purified by recrystallisation in 10% ethyl acetate and hexane mixture to give yellow-coloured crystals. The NMR and IR spectral data of the selected molecule have been helpful to determine the molecular structural properties and structure is mentioned in Figure 1.

2.2. Experimental methods

The PerkinElmer spectrometer is used to obtain the FT-IR spectrum at room temperature in the range 4000-400 cm⁻¹ along with the 100 number of scans and 2.0 cm⁻¹ resolution. The UV-Visible spectrometer (Model: Agilent Technology’s Cary series) is used to obtain the absorption spectra of the title molecule in the region 900-100 nm. FT-Raman spectrum is measured in the range 4000-100 cm⁻¹ with the help of BRUKER RFS 27: stand-alone FT-Raman spectrometer model. The signals measured at room temperature along with the 100 scan numbers and 2 cm⁻¹ resolution. ¹H and ¹³C NMR spectra are measured at 500 MHz in DMSO-d₆ with the help of JNM-EZC400S FT-NMR spectrometer model, TMS taken as the standard reference. The chemical shifts are expressed in δ ppm.

2.3. Computational methods

The complete theoretical computations achieved with the help of DFT method with B3LYP functional and 6-311 +G (d, p) basis set available in Gaussian 09w software [15]. Gauss View 5.0 [16] is utilized to visualize the molecule. The complete optimization of the structure is carried out. The optimization process provides the minimum energy confirmation of the structure. The computation of theoretical and experimental wave numbers is achieved at same basis level. Generally computed vibrational wavenumbers are found to be greater than the experimentally obtained wavenumbers. Hence to obtain proper comparison between experimental and theoretical wave numbers, the theoretical wavenumbers are scaled by the scaling factor of 0.9614 [17]. The entire
| Parameter | DFT | XRD |
|-----------|-----|-----|
| **Bond lengths (Å)** | | |
| C1-C2     | 1.54 | 1.40 |
| C1-C6     | 1.36 | 1.37 |
| C1-C11    | 1.54 | 1.48 |
| C2-C3     | 1.36 | 1.37 |
| C2-H7     | 1.07 | 0.93 |
| C3-C4     | 1.54 | 1.41 |
| C3-O29    | 1.43 | 1.36 |
| C4-C5     | 1.36 | 1.38 |
| C4-H8     | 1.07 | 1.38 |
| C5-C6     | 1.54 | 0.93 |
| C5-H9     | 1.07 | 0.93 |
| C6-H10    | 1.54 | 1.48 |
| C11-C12   | 1.26 | 1.22 |
| C11-O26   | 1.36 | 1.32 |
| C12-C13   | 1.07 | 0.93 |
| C12-H28   | 1.54 | 1.47 |
| C13-C16   | 1.07 | 0.93 |
| C13-H27   | 1.54 | 1.39 |
| C14-C15   | 1.07 | 0.93 |
| C14-H20   | 1.07 | 0.93 |
| C15-C16   | 1.54 | 1.39 |
| C15-H21   | 1.07 | 0.93 |
| C16-C17   | 1.36 | 1.39 |
| C17-C18   | 1.07 | 1.38 |
| C17-H22   | 1.36 | 1.37 |
| C18-C19   | 1.07 | 0.93 |
| C18-H23   | 1.54 | 1.48 |
| C19-C24   | 1.54 | 1.42 |
| C24-N25   | 1.43 | 1.42 |
| O29-C30   | 1.07 | 0.96 |
| C30-H31   | 1.07 | 0.96 |
| C30-H32   | 1.07 | 0.96 |
| **Bond angles (°)** | | |
| C2-C1-C6  | 120.00 | 121.50 |
| C2-C1-C11 | 120.00 | 117.40 |
| C6-C1-C11 | 120.00 | 124.30 |
| C1-C2-C3  | 120.00 | 121.50 |
| C1-C2-H7  | 120.00 | 119.20 |
| C3-C2-H7  | 120.00 | 119.20 |
| C2-C3-C4  | 120.00 | 119.60 |
| C2-C3-O29 | 120.00 | 125.10 |
| C4-C3-O29 | 120.00 | 115.30 |
| C5-C4-C5  | 120.00 | 119.20 |
| C5-C4-H8  | 120.00 | 120.00 |
| C4-C5-C6  | 120.00 | 120.50 |
| C4-C5-H9  | 120.00 | 119.80 |
| C6-C5-H9  | 120.00 | 119.70 |
| C1-C6-C5  | 120.00 | 120.90 |
| C1-C6-H10 | 120.00 | 119.50 |
| C5-C6-H10 | 120.00 | 119.60 |
| C1-C11-C12| 120.00 | 119.60 |
| C1-C11-O26| 120.00 | 120.20 |
| C12-C11-O26| 120.00 | 120.20 |
| C11-C12-C13| 120.00 | 121.20 |

**Table 1 (continued)**

| Parameter | DFT | XRD |
|-----------|-----|-----|
| **Bond lengths (Å)** | | |
| C11-C12-H28| 120.00 | 119.40 |
| C13-C12-H28| 120.00 | 119.40 |
| C12-C13-C16| 120.00 | 127.40 |
| C12-C13-H27| 120.00 | 116.30 |
| C16-C13-H27| 120.00 | 116.30 |
| C15-I4-C19  | 120.00 | 118.90 |
| C15-C14-H20| 120.00 | 120.60 |
| C19-C14-H20| 120.00 | 120.60 |
| C14-C15-C16| 120.00 | 120.90 |
| C14-C15-H21| 120.00 | 119.50 |
| C16-C15-H21| 120.00 | 119.50 |
| C13-C16-C15| 120.00 | 119.10 |
| C13-C16-C17| 120.00 | 123.10 |
| C15-C16-C17| 120.00 | 119.10 |
| C16-C17-C18| 120.00 | 121.60 |
| C16-C17-H22| 120.00 | 119.20 |
| C18-C17-H22| 120.00 | 120.90 |
| C17-C18-C19| 120.00 | 118.20 |
| C17-C18-H23| 120.00 | 120.90 |
| C19-C18-H23| 120.00 | 120.90 |
| C14-C19-C18| 120.00 | 122.60 |
| C14-C19-C24| 120.00 | 120.00 |
| C18-C19-C24| 120.00 | 120.00 |
| C3-O29-C30 | 109.47 | 117.30 |
| O29-C30-H31 | 83.95 | 109.50 |
| O29-C30-H32 | 140.09 | 109.50 |
| O29-C30-H33 | 82.58 | 109.50 |
| H31-C30-H32 | 84.36 | 109.40 |
| H31-C30-H33 | 139.36 | 109.50 |
| H32-C30-H33 | 81.92 | 109.50 |
| **Dihedral angles (°)** | | |
| C6-C1-C2-C3 | 0.00 | 1.40 |
| C6-C1-C2-H7 | -180.00 | -178.50 |
| C11-C1-C2-C3 | -180.00 | -175.90 |
| C11-C1-C2-H7 | 0.00 | 4.20 |
| C2-C1-C6-C5 | 0.00 | -1.10 |
| C2-C1-C6-H10 | -180.00 | 178.90 |
| C11-C1-C6-C5 | -180.00 | 176.00 |
| C11-C1-C6-H10 | 0.00 | -4.00 |
| C2-C1-C11-C12 | 180.00 | 179.40 |
| C2-C1-C11-O26 | 0.00 | 17.20 |
| C6-C1-C11-C12 | 0.00 | 2.30 |
| C6-C1-C11-O26 | 180.00 | -177.30 |
| C1-C2-C3-C4 | 0.00 | -0.40 |
| C1-C2-C3-O29 | 180.00 | 179.70 |
| H7-C2-C3-C4 | 180.00 | 179.60 |
| H7-C2-C3-O29 | 0.00 | -0.30 |
| C2-C3-C4-C5 | 0.00 | -1.00 |
| C2-C3-C4-H8 | -180.00 | 178.90 |
| O29-C3-C4-C5 | -180.00 | 178.90 |
| O29-C3-C4-H8 | 0.00 | 178.90 |
| C3-C4-C5-C6 | 0.00 | 1.40 |
| C3-C4-C5-H9 | 180.00 | -178.60 |
| H8-C4-C5-C6 | 180.00 | 179.70 |
| H8-C4-C5-H9 | 0.00 | 179.70 |
| C4-C5-C6-C1 | 0.00 | -0.30 |
| C4-C5-C6-H10 | 180.00 | 179.70 |
| H9-C5-C6-C1 | -180.00 | 179.60 |

(continued on next page)
vibrational assignments for the computed wave numbers of the title molecule are conducted with the help of PED (%) acquired by VEDA 04 software [18]. The NMR \(^1\)H, \(^{13}\)C NMR) chemical shift values are acquired with help of GIAO method with the same basis level. The TD-DFT method [19] is used to estimate the theoretical UV-Vis spectral parameters at same basis level. The NBO, HOMO-LUMO, MEP and NLO properties have been obtained by optimized structure with the help of suitable methods in the Gaussian tool. Multitfn software is employed to conduct the Fukui function analysis [20].

3. Results and discussion

3.1. Molecular geometry

Optimized molecular geometrical structure with numbering of atoms and the geometrical parameters like bond angle, bond length and dihedral angles of the present molecule are obtained from DFT method with B3LYP functional and 6–311 + + G (d, P) basis set and 3D picture presented in Figure 2. The experimental geometrical parameters of the title molecule are not available. So for comparison study, we have taken the experimental geometrical parameters of the similar reported molecules. The bond angles, bond lengths and dihedral angles obtained by theoretical computation are compared with the reported XRD data [21]. Both the experimental as well as geometrical parameters are mentioned in Table 1. There is small variation in the theoretical and experimental results because the experimental part has been performed in the solid phase and theoretical calculation has been conducted in the gas phase [22].

The 4MPPB is made up of 34 bonds; they are seventeen C–C, thirteen C–H, three C–O bonds and one C≡N bond. In the title molecule the bond length of the C11 = O26 in the ethylenic bridge is 1.258 Å in DFT and 1.224 Å in XRD. The C–C bond length in the title molecule lies in the range of 1.355–1.54 Å. The ethylenic group act as the bridge between phenyl ring and benzonitrile, so the bond lengths and dihedral angle of this ethylene bridge become important. The C–C, C–C–O bond angle in ethylenic bridge are C11–C12–C13 (120/121.2), C11–C11–C12 (119.99/119.6), C12–C13–C16 (119.99/127.4), C11–C12–C12 (120/120.2), C12–C11–O26 (120/120.2). The important dihedral angle (DFT/XRD) in ethylenic bridge are C1–C1–C12–C13 is 179.9987–163.2, C12–C12–C13–C16 is -180/178.5. All the bond length, bond angle and dihedral angles are presented in Table 1.

3.2. Vibrational assignment

The synthesized 4MPPB has been characterized by FT-IR, FT-Raman analysis; the spectra obtained by experimental techniques are compared with computational spectra. The 4MPPB is consists of 33 atoms having 99 fundamental vibrational modes. The experimental and theoretical spectra of FT-IR, FT-Raman analysis are displayed in figures 3 and 4. Theoretically computed wavenumbers (scaled and unscaled), experimentally obtained FT-Raman and FT-IR wavenumbers, detailed vibrational assignments (PED %) are mentioned in Table 2. There is small discrepancy in the theoretical and experimental results because the experimental part taken in the solid phase and theoretical calculation conducted in the gas phase.

3.2.1. Ethylenic bridge

The carbonyl structure in ethylenic bridge acts as prominent role in the process of charge transfer. C=O stretching in experimental spectra can be easily identified due to its higher strength, degree of conjugation and better polarization nature [23]. C=O is formed due to the conjugation of \(\pi\) bond among carbon and oxygen. The uneven sharing of bonding electrons occurs because of the difference in electro negativity’s of the carbon atom and oxygen atom. The occurrence of the lone pair of electrons on the oxygen atom is amicable the polar nature of carbonyl group. According to the previous studies elevated peaks indicating C=O stretching are observed in the IR around 1600-1850 cm\(^{-1}\) [24].

In the present study, stretching of C=O appeared at 1655 cm\(^{-1}\) in FT-Raman and occurred as strong band at 1648 cm\(^{-1}\) in IR. The computational peak found at 1652 cm\(^{-1}\). The C11 – C12 stretching is appeared as strong peak at 1601 cm\(^{-1}\) in Raman and 1595 cm\(^{-1}\) in IR. The computational peak found at 1587 cm\(^{-1}\). The C–H stretching is occurred at 3040 cm\(^{-1}\) and DFT peak found at 3029 cm\(^{-1}\). The C–H in plane bending commonly occur around 1300-1000 cm\(^{-1}\) [25]. In 4MPPB, CH in-plane bending are theoretically computed at 1303, 1298 cm\(^{-1}\) and corresponding Raman peak found at 1289 cm\(^{-1}\). The peaks C–H out of plane bending mode identified at 961 cm\(^{-1}\) in FT-IR and is matched with the DFT wave number at 984 cm\(^{-1}\).

3.2.2. Phenyl ring 1

The C–H stretching concerned to the phenyl ring takes place in the span of 3010–3120 cm\(^{-1}\) [26–27]. In title molecule, the stretching of C–H vibrations are computed at 3096, 3089, 3073, 3069, 3051 cm\(^{-1}\), the IR peaks recognized at 3070 cm\(^{-1}\). The C–H in plane bending vibrations
marginally merged along C–C stretching vibrations are appear in the span of 1500-1000 cm$^{-1}$ [28]. The C–H in plane bending peaks obtained at 1454, 1312, 1022 cm$^{-1}$ in IR and 1460, 1410, 1321, 1264, 1053 cm$^{-1}$ in Raman, the hypothetical peaks observed at 1461, 1400, 1315, 1262, 1141, 1063, 1032 cm$^{-1}$. The out of plane C–H bendings commonly predicted in the span of 1000-675 cm$^{-1}$ [29]. The out of plane C–H bendings computed at 948, 881, 868, 771, 727 cm$^{-1}$, the FT-IR and FT-Raman bands found at 783, 736 and 867 cm$^{-1}$ respectively. The breathing mode in ring is observed at 970 cm$^{-1}$ in DFT. The phenyl ring undergoing torsion is observed at cm$^{-1}$ 409, 530 cm$^{-1}$ in FT-Raman, 539

Figure 3. Experimental and simulated FT-IR spectra of 4MPPB.

Figure 4. Experimental and simulated FT-Raman spectra of 4MPPB.
Table 2. Detailed assignments of experimental and theoretical wave numbers of 4MPPB with 6–311++G (d, p) basis set.

| Modes | Experimental wavenumber | Theoretical wavenumber | Assignments with PED (≤10%) |
|-------|-------------------------|------------------------|-----------------------------|
|       | FT-IR                   | FT-Raman               | B3LYP unscaled              | B3LYP scaled          |
| 92    | -                       | 3220                   | 3096                        | 8.6047                | 47.4955               |
| 92    | -                       | 3213                   | 3089                        | 13.7733               | 97.1245               |
| 91    | 3077 ms                 | 3201                   | 3077                        | 0.7026                | 72.5263               |
| 90    | -                       | 3199                   | 3075                        | 3.2535                | 144.0192              |
| 89    | -                       | 3197                   | 3073                        | 4.4628                | 147.3629              |
| 88    | 3070 vw                 | 3193                   | 3069                        | 5.3318                | 102.1866              |
| 87    | -                       | 3184                   | 3061                        | 2.6989                | 20.0804               |
| 86    | -                       | 3177                   | 3054                        | 3.3331                | 50.6895               |
| 85    | -                       | 3174                   | 3051                        | 7.541                 | 85.3187               |
| 84    | 3040 vw                 | 3151                   | 3029                        | 0.3548                | 29.1694               |
| 83    | 3011 w                  | 3138                   | 3017                        | 24.833                | 176.812               |
| 82    | 2917 w                  | 3073                   | 2954                        | 31.3761               | 43.2945               |
| 81    | 2840 w                  | 3012                   | 2895                        | 43.6096               | 160.923               |
| 80    | 2222 w                  | 2330                   | 2240                        | 66.1368               | 1812.584              |
| 79    | 1648 s                  | 1718                   | 1652                        | 144.7216              | 155.169               |
| 78    | 1595 s                  | 1651                   | 1587                        | 127.5997              | 307.8876              |
| 77    | -                       | 1641                   | 1577                        | 11.2544               | 597.712               |
| 76    | 1568 vs                 | 1626                   | 1563                        | 295.3045              | 2530.055              |
| 75    | -                       | 1561 w                 | 1560                        | 4.4711                | 526.996               |
| 74    | 1511 vw                 | 1585                   | 1524                        | 24.317                | 231.256               |
| 73    | 1485 ms                 | 1537                   | 1478                        | 22.0895               | 43.6817               |
| 72    | 1454 ms                 | 1520                   | 1461                        | 33.9723               | 1.6229                |
| 71    | -                       | 1503                   | 1445                        | 77.2819               | 5.3039                |
| 70    | 1430 s                  | 1493                   | 1436                        | 10.1068               | 14.5821               |
| 69    | -                       | 1483                   | 1426                        | 10.0879               | 20.7665               |
| 68    | -                       | 1410 vw                | 1456                        | 1400                   | 1044.9845             | 42.7728               |
| 67    | -                       | 1441                   | 1385                        | 14.2101               | 103.3619              |
| 66    | 1312 s                  | 1367                   | 1315                        | 87.2703               | 145.6859              |
| 65    | -                       | 1355                   | 1303                        | 106.7004              | 96.7983               |
| 64    | -                       | 1289 vw                | 1350                        | 1298                   | 61.3795               | 160.7505              |
| 63    | 1283 s                  | 1330                   | 1278                        | 43.9422               | 13.4793               |
| 62    | -                       | 1264 vw                | 1312                        | 1262                   | 19.4434               | 157.0654              |
| 61    | 1253 vs                 | 1308                   | 1258                        | 133.1824              | 125                   |
| 60    | -                       | 1282                   | 1233                        | 354.6277              | 42.9982               |
| 59    | 1199 s                  | 1235                   | 1187                        | 1.7516                | 169                   |
| 58    | 1177 ms                 | 1227                   | 1180                        | 28.6016               | 42                   |
| 57    | -                       | 1174 ms                | 1214                        | 1167                   | 46.5069               | 21                   |
| 56    | -                       | 1199                   | 1153                        | 1.6901                | 747                   |
| 55    | -                       | 1191                   | 1145                        | 64.8019               | 97                   |

(continued on next page)
| Modes | Experimental wavenumber | Theoretical wavenumber | Assignments with PED (>10%) |
|-------|--------------------------|------------------------|-----------------------------|
|       | FT-IR | FT-Raman | B3LYP unscaled | B3LYP scaled | \(\Delta\) | S^2 |
| 54    | -    | -    | 1187 | 1141 | 62.0445 | 112.5933 |
| 53    | 1118 w | -    | 1168 | 1123 | 0.6538 | 2.3331 |
| 52    | -    | -    | 1138 | 1094 | 4.6425 | 9.4374 |
| 51    | -    | 1053 vw | 1106 | 1063 | 2.0945 | 1.7938 |
| 50    | 1022 vs | -    | 1074 | 1032 | 24.9272 | 83.0071 |
| 49    | -    | 1017 w | 1051 | 1011 | 129.6362 | 62.357 |
| 48    | -    | 993 ms | 1033 | 993 | 1.9975 | 7.0399 |
| 47    | 981 s | -    | 1023 | 984 | 28.9288 | 15.2745 |
| 46    | -    | -    | 1009 | 970 | 8.2727 | 67.5657 |
| 45    | -    | -    | 998 | 950 | 0.0454 | 0.1505 |
| 44    | -    | -    | 986 | 948 | 0.0609 | 0.7039 |
| 43    | -    | -    | 976 | 938 | 3.1999 | 1.0611 |
| 42    | 894 ms | -    | 925 | 889 | 23.0105 | 45.2102 |
| 41    | -    | -    | 916 | 881 | 2.8944 | 9.927 |
| 40    | -    | 867 vw | 903 | 868 | 7.8366 | 0.2369 |
| 39    | -    | 849 w | 895 | 860 | 5.3325 | 7.0893 |
| 38    | 849 ms | 830 vw | 867 | 824 | 28.5889 | 71.9506 |
| 37    | 828 s | -    | 851 | 818 | 45.1784 | 2.3376 |
| 36    | -    | 811 vw | 845 | 812 | 6.663 | 0.0778 |
| 35    | 783 vs | -    | 802 | 771 | 33.062 | 3.8629 |
| 34    | -    | -    | 799 | 768 | 46.5276 | 2.8832 |
| 33    | 736 ms | -    | 756 | 727 | 13.2282 | 4.8338 |
| 32    | 700 ms | -    | 719 | 691 | 25.7869 | 31.4713 |
| 31    | 685 ms | -    | 714 | 687 | 4.9249 | 0.0873 |
| 30    | -    | -    | 690 | 663 | 13.6472 | 0.383 |
| 29    | 645 w | -    | 664 | 638 | 8.5712 | 10.4341 |
| 28    | 608 vw | -    | 659 | 633 | 18.0973 | 4.3737 |
| 27    | 571 vw | 568 vw | 585 | 563 | 9.4812 | 18.0052 |

(continued on next page)
Table 2 (continued)

| Modes  | Experimental wavenumber | Theoretical wavenumber | Assignments with PED (>10%) |
|--------|-------------------------|------------------------|-----------------------------|
|        | FT-IR                   | FT-Raman               | B3LYP unscaled  | B3LYP scaled | I²b     | S²      |
| 26     | -                       | 552 vw                 | 572             | 550          | 10.8447 | 3.693   | β(C19-C24-N25) (15),τ(C14-C19-C24-N25) (17), τ(C15-C14-C19-C18) (12),τ(C15-C14-C19-C24) (18) |
| 25     | -                       | -                      | 570             | 548          | 4.1883  | 5.5499  | β(C19-C24-N25) (24),β(C14-C19-C24) (22), τ(C14-C19-C24-N25) (13) |
| 24     | 539 s                   | 530 w                  | 552             | 530          | 8.3195  | 1.1162  | τ(C1-C6-C5-C6) (24),τ(C26-C1-C12-C11) (10), τ(C5-C4-C3-O29) (15) |
| 23     | -                       | 482 vw                 | 517             | 497          | 1.7041  | 20.3067 | β(C12-C13-C16) (19),β(C1-C11-C12) (18) |
| 22     | -                       | 458 vw                 | 477             | 458          | 14      | 11.4766 | τ(C19-C24) (20),β(C1-C11-O268) (21) |
| 21     | -                       | -                      | 468             | 450          | 3       | 2.1128  | τ(C14-C19-C24-N25) (16),τ(C13-C16-C15-C14) (17), τ(C15-C14-C19-C18) (35) |
| 20     | -                       | -                      | 458             | 440          | 1       | 3.6384  | τ(C29-C3) (10),β(C2-C3-C4) (12),β(C4-C3-O29) (32), β(C3-O29-C30) (15) |
| 19     | -                       | 409 vw                 | 438             | 421          | 1       | 0.157   | τ(C2-C3-C4-C5) (11),τ(C1-C6-C5-C4) (14),τ(C3-C4-C5-C6) (46) |
| 18     | -                       | -                      | 413             | 397          | 5.0793  | 1.4136  | τ(C1-C11) (18),β(C2-C1-C6) (21),τ(C13-C16-C15) (14) |
| 17     | -                       | -                      | 408             | 392          | 0.0431  | 0.0652  | β(C16-C17-C18-C19) (49),τ(C16-C15-C14-C19) (35) |
| 16     | -                       | 316 vw                 | 328             | 315          | 1.8685  | 3.3338  | β(C2-C1-C11) (26),β(C3-O29-C30) (25) |
| 15     | -                       | 286 w                  | 292             | 281          | 1.8652  | 0.0527  | τ(C14-C19-C24-N25) (17),τ(C13-C16-C15-C14) (27), τ(C15-C14-C19-C18) (16),τ(C11-C12-C13-C16) (35) |
| 14     | -                       | -                      | 266             | 256          | 0.9444  | 0.4347  | τ(H31-C30-C29-C3) (58),τ(C2-C3-C4-C5) (12), τ(C5-C4-C3-O29) (19) |
| 13     | -                       | -                      | 247             | 237          | 3.1439  | 1.4504  | β(C13-C16-C15) (15),β(C4-C3-O29) (13), β(C1-C11-C12) (13),β(C3-O29-C30) (14) |
| 12     | -                       | 225 w                  | 211             | 202          | 1.6906  | 4.6926  | τ(C13) (46) |
| 11     | -                       | 188 w                  | 202             | 194          | 1.221   | 0.4981  | β(C1-C12-C13) (11),τ(C5-C4-C3-O29) (13) |
| 10     | -                       | 165 w                  | 166             | 159          | 0.7645  | 5.0236  | τ(C1-C11-C12-C13) (12),τ(C3-C2-C1-C11) (46) |
| 9      | -                       | -                      | 154             | 148          | 2.4301  | 1.6375  | β(C19-C24-N25) (11),τ(C14-C19-C24) (14),τ(C4-C3-O29) (12) |
| 8      | -                       | 140 w                  | 145             | 140          | 1.2482  | 0.0352  | τ(C14-C19-C24-N25) (12),τ(C11-C12-C13-C16) (24),τ(C15-C14-C19-C24) (37) |
| 7      | -                       | -                      | 123             | 118          | 6.1941  | 2.6467  | β(C19-C24-N27) (11),τ(C14-C19-C24) (13), τ(C2-C1-C11) (18) |
| 6      | -                       | -                      | 95              | 92           | 2.3064  | 0.9486  | τ(C1-C1-C1-C1) (70) |
| 5      | -                       | 86 ms                  | 85              | 82           | 4.5456  | 0.9362  | τ(C1-C11-C12-C13) (16),τ(C12-C13-C16-C15) (16),τ(C11-C12-C13-C16) (11),τ(C4-C3-O29-C30) (13),τ(C2-C1-C11) (13) |
| 4      | -                       | 67 ms                  | 54              | 52           | 4.7615  | 1.0696  | τ(C1-C11-C12-C13) (21),τ(C13-C16-C15-C14) (32), τ(C15-C14-C19-C24) (14) |
| 3      | -                       | -                      | 42              | 41           | 0.6424  | 2.196   | β(C1-C12-C13) (25),β(C13-C16-C15) (10), β(C12-C13-C16) (27),β(C1-C11-C12) (15) |
| 2      | -                       | -                      | 17              | 16           | 0.0094  | 1.7473  | τ(C1-C11-C12-C13) (30),τ(C12-C13-C16-C15) (46), τ(C2-C1-C11-C12) (10) |
| 1      | -                       | -                      | 12              | 11           | 0.0413  | 1.4211  | τ(C12-C13-C16-C15) (14),τ(C2-C1-C11-C12) (66) |

vs: very strong; s: strong; ms: medium strong; w: weak; vw: very weak [ν = stretching, β = Bending, τ = torsion, λ = out of plane bending, δ = rocking; sym = symmetric; asym = asymmetric]; I²b:IR intensity; S²:Raman activity.
The CH₃ torsion mode for the title molecule is found at 225 cm⁻¹ in Raman and calculated at 202 cm⁻¹. All vibrations are well matched with the literature [33].

### 3.3. NMR spectral calculations

The optimized structure of the molecule is used along with the GIAO method to obtain the chemical shift data of the 4MPPB. The experimental data acquired from DMSO dimethyl sulfoxide solvent. The both obtained data are presented in Table 3. The NMR (1H and 13C) computational and experimental spectra are shown in Figures 3 and 6. The C11 available in the carbonyl group having the signal 192.33 ppm in theoretical spectrum and 198.49 ppm in experimental. These data are well matched with literature [34]. The aromatic carbon chemical shift values are usually arising in the region 175-100 ppm [35]. The carbon atoms in the phenyl ring having chemical shift values in the region 144.2 to 112.5 ppm. The C16 atom having highest deshielded signal at 142.11 ppm in experimental and 144.85 ppm in computational section due to the presence of oxygen atom adjacent to it. The C30 atom executed signal at 142.88 ppm in theoretical and 155.55 ppm in experimental part because of the existence of the hydrogen atoms nearer to the C30 atom. Hence in this molecule the C20 and C11 atoms had highest deshielded and shielded signal respectively. The hydrogen atoms present in the title molecule having the chemical shift values in the region of 7.79 to 3.89 ppm in experimental and 8.44 to 3.82 ppm in computational section.

### 3.4. UV-Vis analysis

The UV-Visible spectral studies performed to determine the charge transfer nature of the title molecule. The experimental studies carried out in DMSO solvent. The previous studies reveal that the TD-DFT is most suitable computational tool to determine the dynamic and static properties of the organic compounds in excited state [36, 37, 38]. The computational absorption maximum, excitation energy, oscillator strength and band gap energy of the 4MPPB are carried out by TD-DFT method in two different correlations functional like CAM-B3LYP and B3LYP with same basis level in IEFPCM model. The computational (CAM-B3LYP) and experimental spectra is presented in Figure 7. The oscillator strengths (f), absorption wavelengths (λ), excitation energies (E) and the major contributions to the electronic transition are mentioned in Table 4.

In the 4MPPB, the experimental absorption peaks observed at 305, 259 nm. The corresponding computational peaks found at 339.71, 319.25, 297.93 nm in CAM-B3LYP method and 399, 376.13, 337.01 nm in B3LYP method. Both the theoretical results are compared and it is found that, the CAM-B3LYP results are well matched with the experimental results. For this reason ultimately experimental and CAM-B3LYP results are compared with each other. The maximum absorption peak in experimental is 305 nm and related theoretical peak found at 297.93 nm. The corresponding oscillator strength is 0.5118 and major contribution of maximum wavelength is H-1- > LUMO (70%), HOMO- > LUMO (13%).

### 3.5. HOMO-LUMO studies

HOMO and LUMO provide information about the electron affinity and ionization potential of the molecule. The electron accepting ability, electron-donating ability and kinetic stability concerned to the molecule is attained by HOMO-LUMO energy gap [39, 40]. The energy difference between HOMO and LUMO indicating energy gap and it is calculated using the DFT method [41]. The LUMO-3, LUMO-2, LUMO-1, LUMO, HOMO-3, HOMO-2, HOMO-1, HOMO energies and the energy gap for the 4MPPB molecule has been calculated. Figure 8 shows the two dimensional image of the LUMO, LUMO-1, LUMO-2, LUMO-3 and HOMO, HOMO-1, HOMO-2, HOMO-3 orbitals obtained in gas phase using optimized structure of the molecule. The energies of HOMO, LUMO, HOMO-1, HOMO-2, HOMO-3, LUMO, LUMO-1, LUMO-2, LUMO-3, HOMO, HOMO-1, HOMO-2, HOMO-3 orbitals obtained in gas phase using optimized structure of the molecule.
HOMO-1, HOMO-2, HOMO-3 are \(-6.66, -7.15, -7.37, -7.51\) eV respectively and the energies of LUMO, LUMO+1, LUMO+2, LUMO+3 are \(-3.06, -1.73, -1.37, -0.55\) eV respectively. The energy gap between HOMO-LUMO is 3.6 eV. The small energy gap indicates high polarizability and hence this considered chalcone expected promising NLO futures. The ionization potential and chemical hardness of the molecule are calculated by Koopman’s theorem [42] presented in Table 5. Large energy gap indicate molecule is hard and soft indicates energy gap is small.

The energy gap of the 4MPPB is 3.6 eV. Hence we can say the molecule is soft as well as reactive.

3.6. Molecular electrostatic potential surface (MEP) analysis

The MEP analysis is employed to study the relative reactivity positions for nucleophilic and electrophilic attack [43]. The MEP surface map of the title molecule is obtained by DFT calculation using optimized...
structure and presented in Figure 9. MEP map provides the most vital information regarding the shape, size and charge region existing in the molecule and also offers information regarding the total charge distribution which results in the net electrostatic effect [44]. The obtained MEP map presented with various colors from red to blue. The electrostatic potential is responsible for color coding of the surface (more electron rich region noticed by the red color and more electron poor region noticed by the blue color). Color code indicating increasing order of electrostatic potential is red < orange < yellow < green < blue.

In the title molecule, the electropositive sites moderately spread over the hydrogen atoms. Uppermost electropositive area is located about the H28 hydrogen atom present in the ethylenic bridge because this atom is present with highly electronegative oxygen atom. The nitrogen atom in C=C having uppermost electronegative and next uppermost electronegative area exists around oxygen atom in carbonyl group. The small amount of electronegative region is situated around the oxygen atom in the methoxy group.

3.7. Natural bond orbital (NBO) analysis

Investigation of NBO is proficient tool to determine inter and intra molecular bonding interactions, and also offers an appropriate foundation for studying the charge transfer in molecular structure [45].

To understand numerous second order interaction amid the unfilled orbital of the one subsystem to the packed orbital of the other subsystem the NBO 3.1 [46] is used with DFT method and it deduce the hyper-conjugation. Hyperconjugative interaction energy of 4MPPB is
predicted using the second order perturbation. The hyper-conjugation interaction results in stable outcome of the molecule; this outcome is a result of the overlap of filled orbital by means of the very subsequent electron deficient orbital. This interaction of non-covalent bonding neatly articulated by NBO examination in second order perturbation interaction energy \( E(2) \). Larger the value of \( E(2) \) represents that electron donor and electron acceptors present in the molecule have high capability of interaction. The available serious interactions are collected in Table 6.

In the present study, the intensive interaction present among \( \pi(C2-C3) \to \pi^*(C1-C6/C4-C5) \) \((21.18/17.68 \text{ kJ/mol})\) \((C4-C5)\to\pi^*(C1-C6/C2-C3) \) \((18.73/19.85 \text{ kJ/mol})\). Along with them, certain major lone pair interactions are also listed in Table 6 such as LP \((1)C19\to \pi^*(C14-C15/C17-C18) \) \((61.36/59.22 \text{ kJ/mol})\) be there. Among these every interaction the lone pair carbon in phenyl ring attached to C≡N is having the highest \( E(2) \) \(61.36 \text{ kJ/mol}\).

### 3.8. NLO studies

Nonlinear optical analysis is prominent notion in the current years because of the impact in area of optoelectronics. According to data of previous studies there are no NLO studies took on the present molecule. Thus focus is to calculate mean first-order hyperpolarizability \( (\beta) \), the mean polarizability \( (\alpha) \) and total static dipole moment \( (\mu) \) of the molecule.
using DFT method. The results have been presented in Table 7. The consequential values obtained from Gaussian are in form of atomic units (a.u.). The acquired data are articulated in terms of standard units by using the relation 1 a.u. = 2.5412 Debye, 1 a.u. = 0.1482 × 10⁻²⁴ esu and 1 a.u. = 8.6393 × 10⁻³³ esu for μ, α and β respectively [47]. To examine the NLO characteristics of organic compounds urea is taken as standard molecule. Thus for comparative study urea is computed through same basis set. The μ of 4MPPB acquired by DFT method is 4.2369 D and equated through urea (μ = 3.8903 D) and the β of 4MPPB is 10.0499 × 10⁻²⁴ esu and is equated with urea (βtot = 0.6218 × 10⁻³⁰ esu). Hence Hyperpolarizability of present molecule is found to be 16 times greater than the reference material urea. Ram Kumar et al. [25] reported the comparable type of the molecule possessing βtot is 10.0499 × 10⁻²⁴ esu and μ = 1.7188 D. Pramod et al. [48] studied the NLO characteristics of the same derivatives; the βtot is 16.45 × 10⁻³⁰ esu and μ = 4.72 D. The

**Table 5.** Calculated energy values of 4MPPB molecule by DFT/B3LYP/6-311++G (d, p) method.

| Parameters            | DFT (eV) |
|-----------------------|----------|
| E_HOMO (eV)           | -6.66    |
| E_LUMO (eV)           | -3.06    |
| Ionization potential  | 6.66     |
| Electron affinity     | 3.06     |
| Energy gap            | 3.6      |
| Electronegativity     | 4.86     |
| Chemical potential    | -4.86    |
| Chemical hardness     | 1.8      |
| Chemical softness     | 0.555 (eV)⁻¹ |
| Electrophilicity index| 6.561    |

Figure 8. HOMO-LUMO orbitals of 4MPPB.
4MPPB values are comparable with the reported data. Therefore, it can be stated that 4MPPB can be utilized to investigate the profoundly nonlinear optical properties.

### 3.9. ELF and LOL analysis

Electron localization function (ELF) and localized orbital locator (LOL) are carried out by Multiwfn software. ELF and LOL tools are useful to recognize the places of bond pairs, lone pairs and size of the bonding the title molecule [49]. Color map of ELF and LOL gives information concerned to the electron density charge distribution. Figure 10 (a) and 10 (b) represents the two dimensional color shade maps of the ELF and LOL. The ELF map lies in the range 0.0–1.0. In the ELF map the white color indicates upper limit of the ELF scale (1.0) whereas middle ELF scale (0.5) is represented by yellow to green and blue color indicates the lower limit of the ELF scale. In the color map, completely delocalised electron regions are indicated by smaller value of (<0.5) of ELF but the greater value (>1.0) of ELF indicates nonbonding and bonding localized electron areas. ELF and LOL values are in the similar range. In Figure 10(a), the high ELF regions are observed about the hydrogen atom which indicates the high localization of bonding and non-bonding electrons. The presence of delocalisation cloud is indicated by blue region present around oxygen and carbon atoms. In Figure 10(b), covalent regions are observed between carbon and carbon atoms of the benzene ring which is represented by red color with high LOL value.

### 3.10. Fukui function analysis

Fukui function is employed to explore the local reactivity parameters of the molecule. These functions are obtained via clear difference when an electron is removed or added from molecule. The dissimilarity in charge density among charged and neutral molecules gives the Fukui...
function. In the singlet state the neutral 4MPPB posses lowest energy. In the doublet state the charge densities of cation and anion of 4MPPB can be evaluated [50].

Fukui function is calculated by

\[
 f_c^+ = q_c(N + 1) - q_c(N) 
\]

(1)

\[
 f_c^- = q_c(N - 1) - q_c(N) 
\]

(2)

\[
 \Delta f(r) = f_c^+ - f_c^- 
\]

(3)

The dual descriptor \( \Delta f \) envisage the reactive sites of the title molecule in an efficient manner. The spot is suitable for a nucleophilic attack if \( \Delta f(r) > 0 \) whereas spot is suitable for an electrophilic attack is given by \( \Delta f(r) < 0 \). The Fukui functions \( f_c^+, f_c^-, f_c^0 \) and dual descriptor \( \Delta f \) of the present molecule is calculated and mentioned in Table 8. The atoms with \( \Delta f_c^+ > 0 \) data are expected in the order of \( O_{29} > H_{33} = H_{10} > H_{31} > H_{20} = H_{21} > C_6 > H_{32} \) and these sites are appropriate for nucleophilic attack. The atoms having values of \( \Delta f_c^- < 0 \) values are expected in the order of \( O_{26} > H_{28} > C_{30} > C_{13} > C_{11} \) and are possible spots for nucleophilic attack.

3.11. Drug-likeness

The important ADME variables like Hydrogen bond donors (HBD), hydrogen bond acceptors (HBA), Blood-brain barrier penetration (BBB), molar refractivity (MR), logkp, Topological polar surface area (TPSA) and bioavailability score of 4MPPB are computed and shown in Table 9. From the literature it is analyzed that values of HBA and HBD values should be less than 10 and 5 respectively. For the title molecule HBA and HBD values are calculated as 3 and 0. The highest value of TPSA is 140 Å² and in the present work it is calculated as 50.09 Å². The value of molar refractivity lies in the range of 40 and 130. The MR value of the title molecule is 77.46. Table 9 reflects that high GI absorption side, skin permeability (log Kp) observed as-5.51 and bioavailability value of 0.55. The above said results depicts that the 4MPPB has agreeable biological properties.
3.12. Molecular docking studies

Severe acute respiratory syndrome corona virus (SARS-CoV) is global problem across world. Corona viruses belong to the family of Corona viridae, which is a group of enveloped single stranded-positive sense RNA virus SARS-CoV spreads commonly from person to person and is quickly evolving the globes most important source of bereavement. Preclinical symptoms of this disease include high fever, headache, dry cough, and shortness of breath. Severe infection leads to pneumonia and kidney failure [51, 52, 53]. Currently, no effective antiviral medication are existing for SARS-CoV-2, and they need to be developed immediately. Viral proteases have been recognized as the reliable targets for the SARS-CoV-2. Inhibitors of viral proteases are largely valuable drugs and are extensively used in field of clinical practice. Generally, these viruses harvest quite a few polypeptides that encourage proteolytic collapse to generate 20 extra proteins in the time of their lifecycle.

Table 8. Local reactivity descriptors of 4MPPB molecule.

| Atom | Mulliken Atomic Charge | Fukui Functions | Δf = f_c - f_o |
|------|-----------------------|----------------|----------------|
|      | Neutral q(N) | Cation q (N-1) | Anion q (N + 1) | Nucleophilic attack (f^+_c) | Electrophilic attack (f^-_c) | Radical attack (f_0^-c) |
| C1   | 0.027     | 0.030 | 0.028 | 0.002 | -0.001 | 0.001 | 0.003 |
| C2   | -0.152    | -0.180 | -0.110 | -0.028 | -0.041 | -0.035 | 0.013 |
| C3   | 0.270     | 0.261 | 0.279 | -0.009 | -0.009 | -0.009 | 0.000 |
| C4   | -0.101    | -0.126 | -0.064 | -0.025 | -0.037 | -0.031 | 0.012 |
| C5   | -0.145    | -0.150 | -0.136 | -0.005 | -0.009 | -0.007 | 0.004 |
| C6   | -0.127    | -0.138 | -0.086 | -0.011 | -0.041 | -0.026 | 0.030 |
| H7   | 0.171     | 0.144 | 0.216 | -0.027 | -0.044 | -0.036 | 0.018 |
| H8   | 0.147     | 0.097 | 0.210 | -0.050 | -0.063 | -0.057 | 0.013 |
| H9   | 0.133     | 0.090 | 0.192 | -0.042 | -0.059 | -0.051 | 0.017 |
| H10  | 0.130     | 0.112 | 0.182 | -0.017 | -0.055 | -0.035 | 0.035 |
| C11  | 0.225     | 0.186 | 0.241 | -0.039 | -0.017 | -0.028 | -0.223 |
| C12  | -0.119    | -0.152 | -0.100 | -0.033 | -0.019 | -0.026 | -0.014 |
| C13  | -0.139    | -0.186 | -0.119 | -0.047 | -0.021 | -0.034 | -0.026 |
| C14  | -0.093    | -0.112 | -0.079 | -0.019 | -0.014 | -0.016 | -0.005 |
| C15  | -0.180    | -0.198 | -0.161 | -0.018 | -0.019 | -0.019 | 0.001 |
| C16  | 0.109     | 0.113 | 0.108 | -0.005 | 0.000 | 0.002 | 0.004 |
| C17  | -0.146    | -0.171 | -0.130 | -0.025 | -0.016 | -0.020 | -0.010 |
| C18  | -0.095    | -0.109 | -0.081 | -0.014 | -0.014 | -0.014 | -0.001 |
| C19  | 0.104     | 0.071 | 0.125 | -0.033 | -0.021 | -0.027 | -0.012 |
| H20  | 0.164     | 0.109 | 0.204 | -0.055 | -0.039 | -0.047 | -0.016 |
| H21  | 0.152     | 0.104 | 0.187 | -0.048 | -0.035 | -0.041 | -0.014 |
| H22  | 0.142     | 0.104 | 0.163 | -0.039 | -0.021 | -0.030 | -0.018 |
| C23  | 0.162     | 0.110 | 0.198 | -0.052 | -0.036 | -0.044 | -0.016 |
| C24  | -0.066    | -0.117 | -0.030 | -0.051 | -0.036 | -0.044 | -0.015 |
| N25  | -0.212    | -0.286 | -0.156 | -0.073 | -0.057 | -0.065 | -0.016 |
| O26  | -0.423    | -0.512 | -0.385 | -0.089 | -0.038 | -0.063 | -0.051 |
| H27  | 0.170     | 0.115 | 0.207 | -0.055 | -0.037 | -0.046 | -0.018 |
| H28  | 0.140     | 0.087 | 0.164 | -0.053 | -0.024 | -0.039 | -0.029 |
| O29  | -0.551    | -0.569 | -0.466 | -0.018 | -0.086 | -0.052 | 0.068 |
| C30  | -0.174    | -0.158 | -0.218 | 0.016 | 0.044 | 0.030 | -0.028 |
| H31  | 0.156     | 0.147 | 0.199 | -0.009 | -0.043 | -0.026 | 0.034 |
| H32  | 0.170     | 0.139 | 0.222 | -0.031 | -0.052 | -0.041 | 0.021 |
| H33  | 0.154     | 0.145 | 0.197 | -0.008 | -0.043 | -0.026 | 0.035 |

Table 9. ADME properties of 4MPPB.

| Compound | HBD | HBA | MR | TPSA | GI absorption | BBB | CYP1A2 inhibitor | Log Kp | Lipinski violations | Bioavailability |
|----------|-----|-----|----|------|--------------|-----|-----------------|-------|---------------------|----------------|
| 4MPPB    | 0   | 3   | 77.46 | 50.09 | High | Yes | Yes | 5.51 | 0 | 0.55 |

D - Hydrogen Bond Donor, HBA - Hydrogen bond acceptor, MR - Molar refractivity, TPSA - Topological polar surface area, GI - Gastrointestinal, BBB - blood–brain barrier penetration, log kp – skin permeability.

Among them two proteases are vital for virus replication which includes chief protease (M^PRO) defined as 3 C-like protease (3CL^PRO) and papain-like protease (PL^PRO) [54, 55, 56]. M^PRO and PL^PRO process the polypeptide pp1a and pp1ab in a sequence specific manner to generate 16 dissimilar non-structural proteins. M^PRO is long 306 amino acid and it comprises of three domains N-terminal domain-I, N-terminal domain-II, and C-terminal domain-III. On the other hand, PL^PRO is an essential component of the replicase-transcriptase complex. The PL^PRO processes the poly protein which generates non-structural proteins 1–4. The two proteases M^PRO and PL^PRO are evenly vital for viral lifecycle and their genome encyrcps two poly proteins, pp1a and pp1ab for the period of their conversion phase throughout ribosomal frame shifting method [57]. The development of small molecule inhibitors against M^PRO and PL^PRO is considered to have possible therapeutic objective for the dealing of SARS-CoV-2. At the phase of drug design for SARS-CoV-2, primary troubles know the interface among the drugs and their receptors.
Molecular docking is one of the techniques used to investigate the interaction of drug receptor complex.

Molecular docking is important method employed for designing of drug that is effectively utilized to envisage the chosen binding orientation of tiny compounds on the protein surface to create a constant complex. Crystal structure of MPRO (PDB ID: 6LU7) and PLPRO (PDB ID: 6WUU) receptors are recorded by PDB. Docking computations are performed by Auto Dock 4.2 program. The ensuing docking validations are consequently grouped with a RMSD and are graded with the help of binding energy values. PyMol [58] software is used to visualise the docked results. In the current investigation, the potency of inhibition of 4MPPB against MPRO and PLPRO receptors has been performed using molecular docking studies. Figure 11 depicts the formation of hydrogen bonds via length of the hydrogen bonds by means of amino acid protein

![Figure 11](image)

**Table 10.** The obtained docking parameters of the 4MPPB and their rank calculated by Autodock.

| Ligand | Target protein (receptor) | Protein (PDB ID) | Docking Parameters based on the rank |
|--------|---------------------------|------------------|-------------------------------------|
|        |                           |                  | Binding energy (Kcal/mol)          |
|        |                           |                  | 1        | 2        | 3        |
|        |                           |                  | Estimated Inhibition constant (micromolar - μm) |
|        |                           |                  | 1        | 2        | 3        |
|        |                           |                  | Intermolecular energy (Kcal/mol)    |
|        |                           |                  | 1        | 2        | 3        |
| 4MPPB  | MPRO                      | 6LU7             | -7.76    | -7.19    | -7.12    |
|        |                           |                  | 2.05     | 5.40     | 6.04     |
|        |                           |                  | -8.95    | -8.38    | -8.31    |
|        | PLPRO                     | 6WUU             | -6.50    | -6.27    | -5.86    |
|        |                           |                  | 17.27    | 25.43    | 50.83    |
|        |                           |                  | -7.69    | -7.46    | -7.05    |

Figure 11. Lowest energy docked poses of the 4MPPB with various protein target of (a) MPRO and (b) PLPRO.
molecule. The hydrogen bond formation among target protein and ligand is indicated by dotted yellow lines. By performing docking studies, we can obtain the values of binding interactions, together with inhibition constant, binding energy, and intermolecular energy among MPR and P1PR receptors and 4MPPB ligand in the most excellent results are collected in Table 10. The performed docking studies reveal that 4MPPB ligand exhibits excellent inhibiting characteristic for the cure of SARS-CoV-2.

4. Conclusion

The successful syntheses of the title molecule is followed by its characterization using various spectroscopic techniques. The computational and experimental geometrical parameters are in good agreement. FT-Raman and FT-IR spectral values procured by experimental study are comparable to computed spectral data acquired by DFT technique. In NMR studies, we observed that major shielded signal is present around C16 atom. The experimental absorption wavelength and theoretical FT-Raman and FT-IR spectral values procured by experimental study are proportional and experimental geometrical parameters are in good agreement.

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