

Synthesis, Structural Study and Spectroscopic Characterization of a Quinolin-8-Yloxy Derivative with Potential Biological Properties

Elida Romano¹, María V. Castillo¹, Jorgelina L. Pergomet², Juan Zinczuk², Silvia A. Brandán^{1*}

¹Faculty of Biochemistry, Chemistry and Pharmacy of the National University of Tucumán, Tucumán, R. Argentina

²Chemistry Rosario Institute (CONICET-UNR), Faculty of Biochemistry and Pharmacists Sciences, Rosario, R. Argentina

Email: *sbrandan@fbqf.unt.edu.ar

Received November 14, 2012; revised December 16, 2012; accepted December 25, 2012

ABSTRACT

We have prepared the (5-chloro-quinolin-8-yloxy) acetic acid and characterized it by using infrared, Raman and multi-dimensional nuclear magnetic resonance spectroscopies. The density functional theory (DFT) together with the 6-31G* and 6-311++G** basis sets were used to study its structure and vibrational properties. Three stable conformations of the compound were theoretically determined in gas phase and probably these conformations are present in the solid phase. The harmonic vibrational wavenumbers for the optimized geometries were calculated at the same theory levels. For a complete assignment of the observed bands in the vibrational spectra, the DFT calculations were combined with Pulay's scaled quantum mechanical force field (SQMFF) methodology in order to fit the theoretical wavenumber values to the experimental ones. Besides, the force constants of the three conformers of (5-chloro-quinolin-8-yloxy) acetic acid were calculated and compared with those obtained by us for the 2-(quinolin-8-yloxy) acetic acid. In addition, the characteristics of the electronic delocalization of those structures were performed by using natural bond orbital (NBO), while the corresponding topological properties of electronic charge density are analysed by employing *Bader's* atoms in molecules theory (AIM).

Keywords: (5-Chloro-Quinolin-8-Yloxy) Acetic Acid; Vibrational Spectra; Molecular Structure; Force Field; DFT Calculations

1. Introduction

Heterocyclic compounds that contain the (quinolin-8-yloxy) moiety exhibit a wide range of biological properties [1-5], such as the 2-(quinolin-8-yloxy) acetohydrazones that have antiamoebic activities [5] for which, the structural and vibrational study of these types of compounds are of great chemical and pharmaceutical importance. Recently, a complete vibrational analysis of all observed bands in the vibrational spectra of 2-(quinolin-8-yloxy)-acetic acid [6] was performed by means of the DFT calculations combined with Pulay's scaled quantum mechanical force field (SQMFF) methodology [7-9]. In that study, the normal mode calculations were accomplished by using a generalized valence force field (GVFF) [8,9] considering three different structures for the anhydrous and monohydrated compounds. In the present work, we report an experimental and theoretical vibrational study of (5-chloro-quinolin-8-yloxy) acetic acid (CQA) by means of the B3LYP calculations using 6-31G* and

6-311++G** basis sets. For a complete assignment of the compound, the DFT calculations were combined with the SQMFF methodology [7-9] in order to fit the theoretical wavenumber values to the experimental ones. So far, the crystal and molecular structure of (5-chloro-quinolin-8-yloxy) acetic acid has not been determined. First, we have synthesized and characterized the compound and then, the optimized geometries and frequencies for the normal modes of vibration of CQA considering three different stable structures were calculated in order to carry out a complete assignment of all observed bands in the infrared and Raman spectra. Here, the normal mode calculations and the force fields for those structures were obtained by using the transferable scaling factors of Rauhut and Pulay [9] while the harmonic force constants were subsequently scaled to reproduce as well as possible the experimental frequencies. Thus, a complete assignment of the compound in terms of the potential energy distribution was performed. Furthermore, when the forces constants values of this compound were compared with those corresponding to the 2-(quinolin-8-yloxy)-

*Corresponding author.

acetic acid [6] numerous changes in the structural, topological and vibrational properties attributed to the chloro atom were observed. Additionally, the nature of the different rings and bonds of the three studied structures of (5-chloro-quinolin-8-yloxy) acetic acid were analyzed by means of the NBO studies [10-12] while the topological properties of electronic charge density were determined employing the Bader's atoms in molecules theory (AIM) [13].

2. Experimental Methods

2.1. Synthesis

(5-chloroquinolin-8-yloxy) acetic acid was obtained according to Cho *et al.* [1] using the following procedure.

2.1.1. (5-Chloroquinolin-8-Yloxy) Acetic Acid Methyl Ester

A mixture of 5-chloro 8-hydroxyquinoline (3.6 g, 20 mmol), methyl bromoacetate (3.7 g, 24 mmol) and K_2CO_3 (5.52 g, 40 mmol) in acetone (50 mL) was heated for 3 h under reflux, filtered and concentrated *in vacuo*. The residue was partitioned between ethyl acetate and brine, and the organic layer was dried with $MgSO_4$, filtered, and concentrated *in vacuo*. The residue was purified by crystallization from isopropyl ether to give (5-chloroquinolin-8-yloxy) acetic acid methyl ester 3584 g (71%) m.p. 102.1°C - 102.3°C.

2.1.2. (5-Chloroquinolin-8-Yloxy) Acetic Acid (CQA)

A mixture of ester ((1.26 g, 5 mmol) and $LiOH \cdot H_2O$ (352 mg, 8.40 mmol) in 75 mL of $THF/CH_3OH/H_2O$ (1:1:1, 6) was stirred and heated at reflux for 1 h and concentrated. The aqueous layer was washed with ether and adjusted to pH 3 with 1 N HCl. The precipitate was filtered and dried to give (5-chloroquinolin-8-yloxy) acetic acid (1085 g, 91%) m.p. 219.5°C - 221°C.

2.2. NMR Spectra

1H NMR (300 MHz, $CDCl_3$) δ : 4.92 (2H, s, O- CH_2); 7.08 (1H, d, J = 8.48, H_7), 7.64 (1H, d, J = 8.48, H_6); 8.47 (1H, d, J = 8.58, H_4); 7.70 (1H, dd, J = 4.18, J = 8.58, H_3); 8.94 (1H, d, J = 4.18, H_2).

^{13}C NMR (75 MHz, $CDCl_3$) δ : 65.94 (CH_2); 110.54 (C7); 121.69 (C5); 123.53 (C3); 126.66 (C4a); 127.07 (C6); 132.64 (C4); 140.55 (C8a); 150.28(C2); 153.54 (C8); 170.34 (CO_2H) (Atom numbering according to naphthalene).

2.3. Infrared and Raman Spectra

The infrared spectrum of the solid substance was recorded in KBr pellets in the wavenumbers range from 4000 to 400 cm^{-1} with a FT-IR Perkin Elmer spectrome-

ter, provided with a Globar source and a DGTS detector. FT-Raman spectrum of the crystalline solid was recorded on a Bruker RFA 106/S FT-Raman instrument using the 1064 nm excitation line from an Nd: YAG laser in the region of 4000 - 0 cm^{-1} . Two hundred scans were accumulated at 4 cm^{-1} resolution using a laser power of 150 mW.

3. Computational Details

The potential energy curves associated with the internal rotation described by the C21-C18-O17-C10 dihedral angle for CQA were studied at the B3LYP/6-31G* and 6-311++G** theory levels. With both calculations, two conformations stable, named, C_I and C_{II} , according to the position of the OH group in relation to the N atom of the ring were obtained. Another plane structure was also considered (C_{III}) in agreement with the experimental structure of the 8-(carboxymethoxy) quinolinium nitrate monohydrate compound [14]. The structures and labelling of the atoms for all conformers of CQA can be seen in Figure 1. The electronic charge density topological analysis for those structures were performed by using the AIM200 program package [15] while the NBO calculations were obtained by means of the NBO 3.1 [16] program, as implemented in the GAUSSIAN 03 package [17]. The natural internal coordinates for the compound have been defined as those reported in the literature [7,8,18] and are listed in the Supporting Material as Table S1. The resulting force fields were transformed to “natural” internal coordinates by using the MOLVIB program [19,20]. Then, following the SQMFF procedure [7-9,21], the harmonic force fields for those structures were evaluated at the B3LYP/6-31G* level. The potential energy distribution components (PED) higher than or equal to 10% were subsequently calculated with the resulting SQMFF. The nature of all vibration modes was carried out by means of the Gauss View program [22].

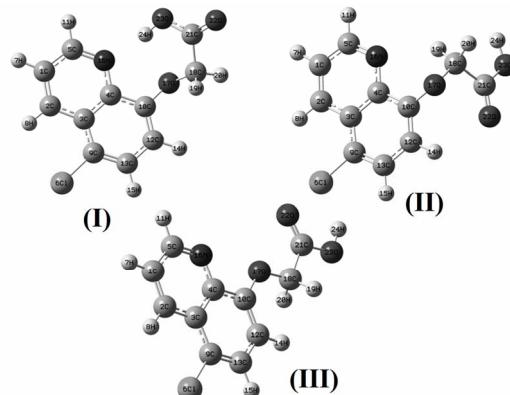


Figure 1. Theoretical structures and labelling of the atoms for the stable C_I , C_{II} and C_{III} conformers of (5-chloro-quinolin-8-yloxy) acetic acid.

4. Results and Discussion

4.1. Geometry

Table S2 (Supporting Material) shows the comparison of the total energies for the compound, and the corresponding dipole moment values for the C₁, C_{II} and C_{III} conformers of C₁ symmetries. With both methods, the energy of the C₁ is lower than the other ones, as was observed in the compound without chlorine [6], and the potential energy difference between the C₁ and C_{II} forms, by using the B3LYP/6-31G* and B3LYP/6-311++G** methods, are -43.80 and -46.43 kJ/mol, respectively. When the C₁ conformer is compared with the planar ones the potential energy difference values slightly by using both basis sets decrease up to -27.80 and -32.36 kJ/mol, respectively.

Also, in this case, the high values of the dipolar moments for the C₁ structures could probably explain its stabilities, as was observed in similar molecules [6,23-25].

Table 1 shows a comparison of the calculated geometrical parameters for all structures of CQA, with the ones corresponding to that observed from X-ray diffraction for the 8-(carboxymethoxy) quinolinium nitrate monohydrate compound [14] by means of the root mean of square deviations (rmsd) values. Note that the 6-311++G** basis set reproduce reasonably well the theoretical bond lengths for the C₁ structure (0.019 Å) and the bond angles for the C_{III} structure (2.00°), as is expected because this last conformer is planar as that compared compound [14]. Besides, the calculation predicts that the C₁ and C_{III} conformers are the most stable and probably both are present in the crystalline state.

The stabilities of the C_{II} and C_{III} structures of CQA, in relation to the C₁ structure, were investigated by using the natural atomic charges [26-29] and the results are given in **Table S3**. Note that the natural charges values (NPA) corresponding to the C21 atoms have the most positive values in all structures while the most negative values correspond to the O23 atoms. In this compound, as in 2-(quinolin-8-yloxy)-acetic acid [6], the higher NPA charges observed on the O17 and O22 atoms in the C_{II} structure justified the repulsion between those atoms. This way, the C_{II} structure is more unstable than the corresponding to the C₁ and C_{III} conformers. The bond orders, expressed by Wiberg's index for all conformers of CQA are given in **Table S4**. The bond order values for the O23 atoms in all conformers have the lowest values (belong to the COO groups) than the other ones (the O17 and O22 atoms belongs to the heterocyclic rings), while the bond orders for the N16 atoms have higher values.

4.2. NBO Study

The stability of the three structures of CQA was also

investigated by means of NBO calculations [10-12]. The second order perturbation energies E⁽²⁾ (donor → acceptor) that involve the most important delocalization all conformers of CQA are given in **Tables S5, S6**. The contributions of the stabilization energies for the $\Delta ET_{\sigma \rightarrow \sigma^*}$ charge transfers are similar to those obtained for the 2-(quinolin-8-yloxy)-acetic acid compound [6].

Here, the delocalizations $\Delta ET_{LP \rightarrow \sigma^*}$ for the C_{II} structure has lower values than the $\Delta ET_{\sigma \rightarrow \sigma^*}$ delocalizations, and the calculated total energy values favours to the C₁ and C_{III} conformers, which structures are the most stable in the gas phase. Thus, the total energy values clearly show the higher stability of the C₁ conformer however, by using the 6-311++G** basis set, the C_{II} and C_{III} conformers have the same ones approximately total energy values.

4.3. AIM Analysis

Furthermore, the three structures of CQA were analysed by means of Bader's charge electron density topological analysis [13]. The calculated electron density, (ρ) and the Laplacian values, $\nabla^2 \rho(r)$ in the bond critical points (BCPs) and ring critical points (RCPs) for those structures are shown in **Table S7**. The BCP has the typical properties of the closed-shell interaction and for this, the value of $\rho(r)$ is relatively low, the relationship $|\lambda_1|/\lambda_3$ is <1 and $\nabla^2 \rho(r)$ is positive indicating that the interaction is dominated by the charge contraction away from the interatomic surface toward each nucleus. Note that the results are clearly dependent of the size basis set. Thus, the analysis shows two BCPS and RCPs in the C₁ structure when the 6-31G* basis set is employed but, only one BCP and RCP when the 6-311++G** basis set is used. On the contrary, for the C_{II} structure with both basis sets only one BCP and RCP are observed while for the C_{III} structure there is one BCP with the 6-31G* basis set. These results, together to the NBO analysis, justify the stabilities of the C₁ and C_{II} structures due to the presence of short intramolecular O17-H24 and N16-H24 bonds, in the first case and only a N16-H19 bonds in the second one, as observed in **Table S7**.

4.4. Vibrational Analysis

The **Figures 2, 3** show the registered infrared and Raman spectra for the compound in solid phase. In this study, in accordance with the NBO and AIM results, the three structures for the compound in gas phase were considered. The CQA's structures have C₁ symmetries and 66 normal vibration modes, all active in the infrared and Raman spectra. Probably, the three species are present in the solid phase because the comparison of each vibrational spectrum with the corresponding experimental one is very different among them, as observed in **Figure 4**, however, a comparison between the average calculated

Table 1. Calculated geometrical parameters for the conformers of (5-chloro-quinolin-8-yloxy) acetic acid.

Parameter	^a 6-31G*			^a 6-311++G**			^b Exp.
	C _I	C _{II}	C _{III}	C _I	C _{II}	C _{III}	
Bond length (Å)							
C3-C4	1.432	1.437	1.434	1.430	1.434	1.432	1.402 (3)
C4-N16	1.362	1.363	1.357	1.360	1.365	1.354	1.368 (2)
C5-N16	1.319	1.318	1.318	1.317	1.318	1.315	1.317 (2)
C4-C10	1.429	1.431	1.439	1.427	1.431	1.437	1.411 (3)
C9-Cl6	1.758	1.762	1.763	1.758	1.758	1.763	
C10-O17	1.367	1.374	1.357	1.367	1.377	1.356	1.362 (2)
C18-O17	1.433	1.413	1.407	1.432	1.412	1.406	1.424 (2)
C18-C21	1.537	1.531	1.520	1.535	1.530	1.518	1.498 (3)
C21-O22	1.210	1.202	1.203	1.205	1.202	1.196	1.203 (2)
C21-O23	1.331	1.362	1.358	1.329	1.363	1.359	1.303 (2)
RMSD	0.020	0.027	0.025	0.019	0.027	0.025	
Bond angle (degrees)							
C4-N16-C5	118.7	118.4	118.2	118.9	118.2	118.5	122.98 (19)
C4-C10-C12	119.9	120.1	119.8	119.9	120.3	119.7	118.90 (19)
C4-C10-O17	117.6	121.8	115.3	117.8	121.8	115.5	114.39 (17)
C12-C10-O17	122.4	117.9	124.9	122.2	117.7	124.8	126.71 (18)
C10-O17-C18	119.2	118.5	117.8	119.7	118.4	118.0	117.04 (15)
O17-C18-C21	112.5	112.3	108.6	113.1	112.4	109.0	108.78 (16)
C18-C21-O23	117.4	114.0	108.8	117.7	113.9	108.7	110.57 (19)
C18-C21-O22	119.3	125.2	127.2	119.2	125.3	127.4	125.03 (19)
O22-C21-O23	123.3	120.8	124.0	123.0	120.8	123.9	124.40 (2)
RMSD	4.05	4.65	2.01	4.24	4.71	2.00	
Dihedral angles (degrees)							
C21-C18-O17-C10	-112.8	-76.7	-180.0	-112.4	-76.7	-180.0	-178.52 (17)
C4-C10-O17-C18	110.4	-63.4	180.0	107.8	-62.0	180.0	176.72 (17)
C12-C10-O17-C18	-73.2	121.9	0.0	-76.4	123.3	0.0	-3.3 (3)
RMSD	67.3	167.0	2.8	69.4	166.7	2.8	

infrared spectra (from B3LYP/6-31G* level for the C_I, C_{II} and C_{III} conformers) by using average wavenumbers

and intensities with the corresponding experimental one demonstrate a good correlation, as observed in **Figure S1**.

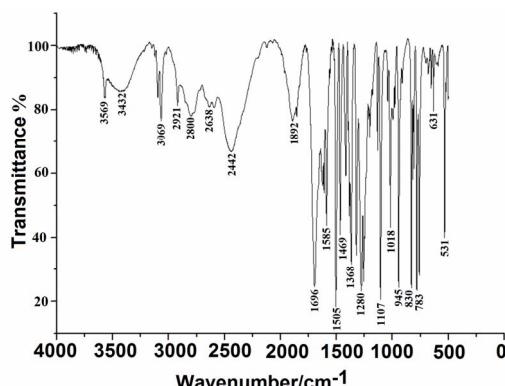


Figure 2. Experimental infrared spectrum of the solid (5-chloro-quinolin-8-yloxy) in KBr pellets.

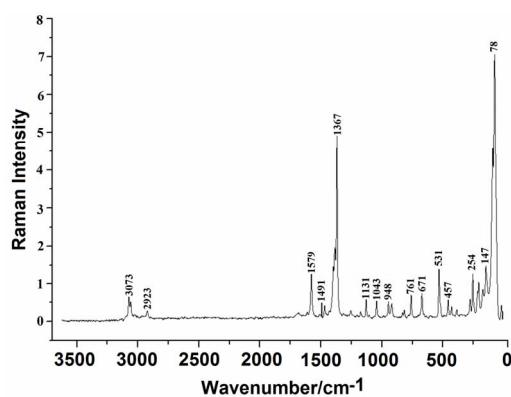


Figure 3. Experimental Raman spectrum of the solid (5-chloro-quinolin-8-yloxy) in a glass capillary.

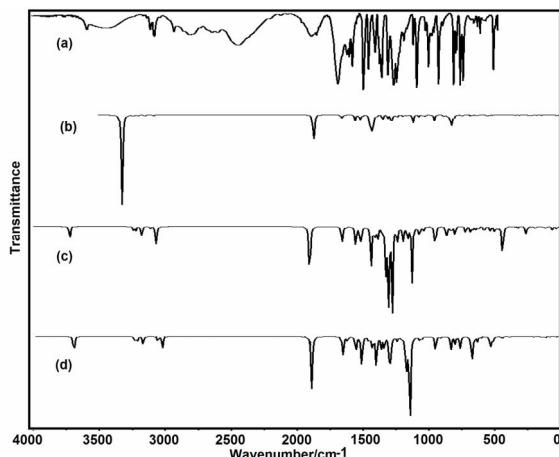


Figure 4. Comparison between: a) the experimental infrared spectrum of the solid (5-chloro-quinolin-8-yloxy) with, the theoretical spectra corresponding to the b) conformer C_I; c) conformer C_{II}, and; d) conformer C_{III} by using B3LYP/6-31G* level.

Thus, the resulting IR spectrum reproduces rather well some bands of the experimental spectrum, especially in the 2000 - 400 cm⁻¹ region. The assignment of the experimental bands to the expected normal vibration modes

were made on the basis of the PED in terms of symmetry coordinates and taking into account the corresponding assignment of related molecules [6,30-34]. **Tables 2, S8-S10** show the experimental and calculated frequencies, potential energy distribution based on the 6-31G* basis set, and assignment for the C_I, C_{II} and C_{III} structures of CQA. In a similar way as observed in the molecular packing of the 2-(2'-furyl)-1H-imidazole [23], 2-(2'-furyl)-4,5-1H-dihydroimidazole [27] and tolazoline hydrochloride molecules [35,36], the broad band with several shoulders between 2800 and 1900 cm⁻¹ can be attributed to the N-H and O-H hydrogen bondings formed by the spatial arrangement of molecules in the lattice crystal.

Here, the B3LYP/6-31G* calculations were considered because the used scale factors are defined for this basis set. The SQM force fields for this compound can be obtained upon request. Below we discuss the assignment of the most important groups.

4.4.1. Assignments

4.4.1.1. OH Modes

The weak bands in the IR spectra at 3569, 3432 and 3149 cm⁻¹, in accordance to the values reported for similar molecules [30,33,34], can be assigned to the O-H stretching vibrations of the three conformers, as observed in **Table 2**. The width and shape of these bands shows clearly the typical spectroscopic signature of an H-bond interaction (inter or intramolecular). In accordance to that reported value for the benzoic acid [33,34] and to the theoretical calculations, the corresponding deformation modes of this group are assigned, for those conformers, to the strong IR bands at 1368, 1280 and 1254 cm⁻¹, for the C_I, C_{III} and C_{II} conformers, respectively. The out-of-plane deformation mode (γ OH or δ OH) in the 4-hydroxybenzoic acid dimer [28] is calculated at 877 cm⁻¹ while in CQA that mode is assigned for the C_I conformers to the strong band in the IR spectrum at 760 cm⁻¹ and to the very weak band in the same spectrum at 504 cm⁻¹ for the C_{III} conformer while for the C_{II} conformers that mode is assigned to the shoulder in the Raman spectrum at 409 cm⁻¹. This last band in the C_p conformer of 2-(quinolin-8-yloxy)-acetic acid [6] is assigned to the weak IR band at 497 cm⁻¹.

4.4.1.2. CH Modes

The C-H stretching modes can be clearly assigned, for their positions, to the group of bands in the 3125 - 3025 cm⁻¹ region of the IR and Raman spectra. The in-plane deformation modes of the phenyl ring, in similar compounds are observed between 1267 and 1042 cm⁻¹ [31] while in this compound those modes are assigned to the IR bands between 1505 and 1176 cm⁻¹, as observed in **Table 2**. On the other hand, the six expected out-of-plane

Table 2. Observed and calculated wavenumbers (cm^{-1}) and assignment for the (5-chloro-quinolin-8-yloxy) acetic acid.

Experimental ^a		C _I	C _{II}		C _{III}		
IR solid	Raman solid	SQM ^b	Assignment	SQM ^b	Assignment	SQM ^b	Assignment
3569 w				3558	$\nu(\text{O23-H24})$		
3432 w,br						3541	$\nu(\text{O23-H24})$
3149 vvw	3145 vvw	3175	$\nu(\text{O23-H24})$				
3125 vvw	3130 vvw	3100	$\nu(\text{C2-H8})$	3109	$\nu(\text{C12-H14})$	3102	$\nu(\text{C12-H14})$
3100 w		3096	$\nu(\text{C13-H15})$	3097	$\nu(\text{C2-H8})$	3096	$\nu(\text{C2-H8})$
	3098 vvw	3085	$\nu(\text{C1-H7})$	3092	$\nu(\text{C13-H15})$	3086	$\nu(\text{C13-H15})$
3069 w	3073 w	3081	$\nu(\text{C12-H14})$	3079	$\nu(\text{C1-H7})$	3076	$\nu(\text{C1-H7})$
	3057 w	3056	$\nu(\text{C5-H11})$				
3025 vvw	3028 vw			3036	$\nu(\text{C5-H11})$	3037	$\nu(\text{C5-H11})$
	3006 vvw	3006	$\nu_a \text{CH}_2$				
	2981 vw			2974	$\nu_a \text{CH}_2$		
	2966 vw	2946	$\nu_s \text{CH}_2$				
	2943 vvw			2931	$\nu_s \text{CH}_2$	2931	$\nu_a \text{CH}_2$
2921 vw	2923 vw					2895	$\nu_s \text{CH}_2$
1892 m,br				1823	$\nu(\text{C21-O22})$		
1854 m						1814	$\nu(\text{C21-O22})$
1696 s	1687 vw	1792	$\nu(\text{C21-O22})$				
1626 m	1646 vw	1613	$\nu(\text{C2-C3})$	1613	$\nu(\text{C2-C3})$	1614	$\nu(\text{C2-C3})$
1608 m	1610 vw	1599	$\nu(\text{C1-C2})$	1600	$\nu(\text{C1-C2})$	1601	$\nu(\text{C13-C9})$
1585 m	1579 m	1575	$\nu(\text{C13-C9})$	1570	$\nu(\text{C13-C9})$	1572	$\nu(\text{C13-C12})$
1505 vs	1491 vw	1509	$\beta\text{C1-H7}$	1508	$\beta\text{C1-H7}$	1513	$\beta\text{C1-H7}$
1469 s	1470 vw	1482	$\beta\text{C5-H11}$	1480	$\beta\text{C5-H11}$	1485	$\beta\text{C5-H11}$
	1431 vw			1446	δCH_2	1453	δCH_2
1423 sh		1433	δCH_2			1431	wag CH_2
1417 m		1408	$\beta\text{C2-H8}$	1408	$\beta\text{C2-H8}$		
1395 sh	1398 m	1402	$\nu(\text{C5-N16})$	1403	$\nu(\text{C5-N16})$	1407	$\nu(\text{C10-C4})$
1386 m	1386 m	1374	wag CH_2	1390	wag CH_2	1405	$\beta\text{C2-H8}$
1368 s	1367 s	1353	δOH			1350	$\nu(\text{C3-C4}),$ $\nu(\text{C12-C10})$
1324 s		1340	$\nu(\text{C3-C4})$	1336	$\nu(\text{C3-C4})$	1320	$\nu(\text{C10-O17})$
	1317 vvw			1305	$\nu(\text{C12-C10})$		
1280 s	1278 vvw	1305	$\nu(\text{C12-C10})$	1279	ρCH_2	1289	δOH
1254 s	1255 vw	1269	ρCH_2	1254	δOH	1259	$\nu(\text{C4-N16})$
1251 sh	1253 w	1251	$\nu(\text{C4-N16})$	1250	$\nu(\text{C4-N16})$	1252	$\nu(\text{C5-N16})$
						1251	ρCH_2
1238 sh		1238	$\nu(\text{C10-C4})$	1234	$\nu(\text{C10-C4})$		
	1219 vvw	1221	$\nu(\text{C21-O23})$			1212	$\beta\text{C13-H15}$

Continued

1202 w	1202 vvw	1207	β C13-H15, ν (C3-C9)	1207	β C13-H15, ν (C3-C9)		
1176 vw	1174 vw	1166	β C12-H14	1167	β C12-H14	1180	β C12-H14
1133 m	1131 w	1131	R ₁ (A2)	1136	R ₁ (A2)	1143	ν (C1-C2)
1107 s	1105 vvw	1083	ν (C13-C12)	1112 1086	ν (C21-O23) ν (C13-C12)	1128 1104	ν (C13-C12), δ OH, ν (C21-O23)
1042 vw	1043 w	1037	ν (C1-C5)	1036	ν (C1-C5)	1035	ν (C1-C5)
1018 m	1012 vvw			1029	ν (C18-O17)	1029	ν (C18-O17)
996 w		998	ν (C18-O17)				
981 w		993	γ C1-H7	991	γ C2-H8	991	γ C2-H8
954 sh	967 sh	963	γ C5-H11	967	w CH ₂	962	w CH ₂
948 sh	948 vw	961	w CH ₂	960	γ C5-H11	959	γ C5-H11
945 s		937	γ C13-H15	939	γ C12-H14	926	R ₁ (A2)
913 vw	919 vw	925	ν (C9-Cl6)	921	R ₁ (A1)	915	γ C13-H15
836 sh		851	ν (C18-C21)	847	γ C13-H15	884	ν (C18-C21)
830 s	833 vw	839	γ C12-H14	838	ν (C18-C21)	818	β R ₃ (A2)
820 m	817 vw	817	R ₁ (A1)	816	R ₃ (A2)	818	γ C12-H14
806 m		812	γ C2-H8	809	γ C1-H7	809	γ C1-H7
783 s	785 vw	778	τ R ₁ (A2)	774	τ R ₁ (A2)	777	τ R ₁ (A1)
760 s	761 w	737	τ OH			742	R ₁ (A1)
701 vw		720	ν (C10-O17)				
680 vvw				699	ν (C10-O17)		
	671 w	665	R ₂ (A1)	666	γ C10-O17	655	R ₂ (A1)
654 vvw	655 vvw	649	γ C10-O17	650	R ₂ (A1)		
631 w	633 vvw	624	δ COO	624	τ R ₁ (A1)	632 620	τ R ₁ (A2) δ COO
613 vw	613 vvw					619	γ COO
606 vw	600 vvw	601	τ R ₁ (A1)	595	γ C9-Cl6	597	R ₂ (A2)
590 vvw		572	R ₃ (A2)	569	ρ C10-O17, R ₂ (A2)	585	γ C10-O17
531 m	531 m	534	γ COO	544	γ COO		
520 vvw	522 sh	528	R ₂ (A2)	522	R ₂ (A2)	526	ν (C3-C9)
504 vvw		503	R ₃ (A1)	490	δ COO	508 495	R ₃ (A1) τ OH
	488 vvw	469	τ R ₃ (A1)	480	R ₃ (A1)		
	457 m	457	τ R ₂ (A1)	460	τ R ₂ (A1)	463	τ R ₂ (A2)
	431 vw			415	τ R ₃ (A2)	439	ρ COO
	409 sh	416	τ R ₃ (A2)	399	τ OH	418	τ R ₃ (A2)
	386 vvw	388	γ C9-Cl6	385	ν (C9-Cl6)	378	ν (C9-Cl6)
	356 vvw	335	ρ COO	330	ρ COO	346	γ C9-Cl6
	278 w	312	ρ C10-O17	314	δ CCO		

Continued

254 s	240	δ CCO	254	δ COC	252	β C9-Cl6
216 w	225	β C9-Cl6	219	β C9-Cl6	223	ρ C10-O17
208 m	207	δ COC	196	ρ C10-O17	199	δ CCO
173 w	168	Butt	174	Butt	188	Butt
147 m	135	τ R ₂ (A2)	123	τ R ₂ (A2)	135	τ R ₃ (A1)
92 s	88	CCOC, w COO	102	τ R ₃ (A1)	116 109	w Ring τ R ₂ (A1)
78 vs	87	w COO	54	w COO	80	δ COC
	48	w Ring	36	CCOC	33	CCOC
20 vw	22	CCOC	24	w Ring	25	w COO

deformations of C-H group for the three conformers of CQA are assigned to the IR and Raman bands located between 981 and 806 cm⁻¹.

4.4.1.3. CH₂ Modes

The group of bands in the 3006 - 2923 cm⁻¹ region of the Raman spectra are assigned to the antisymmetric and symmetric stretching modes of this group in agreement to similar compounds [26,32]. The scissoring modes for the three conformers of CQA can be assigned to the shoulder in the IR spectrum and to the weak Raman band respectively at 1423 and 1431 cm⁻¹. The shoulder in the IR spectrum and the weak Raman band at 1423 cm⁻¹ and the band of medium intensity at 1386 cm⁻¹ are assigned to the wagging modes of this group, as predicted by calculation, while the strong bands and the shoulder at 1280, 1254 and 1251 cm⁻¹ are assigned to the rocking modes. The twisting mode for all CQA conformers are associated with the shoulders in the IR spectrum at 954 and 948 cm⁻¹ as was observed in the 2-(quinolin-8-yloxy)-acetic acid [6].

4.4.1.4. COO Modes

The C=O stretching mode, for the C_I conformer of CQA is calculated at 1792 cm⁻¹, it is at lower wavenumber than the other conformers (1823 and 1814 cm⁻¹, C_{II} and C_{III} conformers, respectively). On the other hand, for the benzoic acid the C=O stretching mode is predicted between 1786 and 1608 cm⁻¹ while the C-O stretching mode are assigned between 1359 and 1334 cm⁻¹ [33,34]. Hence, the IR bands of the media intensities and the strong IR band at 1892, 1854 and 1696 cm⁻¹ are clearly assigned to the C=O stretching modes, as predicted by the calculations while the the Raman and IR bands respectively at 1219 and 1107 cm⁻¹ are assigned to the C-O stretching mode corresponding to the three conformers of CQA. In the 4-hydroxybenzoic acid dimer [30] the two γ (COO) modes are predict at 772 cm⁻¹, whereas the two δ (COO) modes at 771 and 620 cm⁻¹. Here, those modes

are predict at different wavenumbers, hence the IR bands at 613 and 531 cm⁻¹ are associated with the γ (COO) modes while the IR bands at 631 and 504 cm⁻¹ are assigned to the δ (COO) modes, as observed in **Table 2**. The rocking modes of COO groups are predicted between 439 and 335 cm⁻¹, as in similar compounds [30,33,34], hence, they are assigned to the IR bands at 431 and 356 cm⁻¹. The SQM clearly predict the twisting modes between 87 and 25 cm⁻¹, accordingly, these modes are associated to the very strong and very weak Raman bands at 78 and 20 cm⁻¹, respectively.

4.4.1.5. Skeletal Modes

Here, the skeletal stretching modes in the three CQA's conformers are predicted strongly mixed among them (**Tables S8-S10**). In agreement to the values reported for similar molecules [30-34] and our theoretical results, the IR bands of the media intensities at 1626, 1608 and 1585 cm⁻¹ are mainly associated to a C=C stretchings. Also, the IR bands at 1368, 1324, 1202, 1133, 1107, 1042, 913 and 830 cm⁻¹, and the shoulders in the same spectrum at 1395, 1238 and 836 cm⁻¹ are associated to the C-C stretching modes, as observed in **Table 2**. The strong band and the shoulders in the IR spectrum respectively at 1254, 1395 and 1251 cm⁻¹ are associated to the C-N stretching modes. A very important observation in this compound is related to the C-Cl stretchings mode because for the C_I conformer is predicting at higher wavenumber than the other ones. Thus, the IR band at 813 cm⁻¹ is assigned to that mode for the C_I conformer while the very weak Raman band at 386 cm⁻¹ are assigned to those modes for the remains conformers. The six phenyl ring deformations and torsions modes for the three CQA's conformers, as the calculation predicts and taking into account the assignments for similar molecules [30-34], are assigned in the expected regions, as observed in **Table 2**. Finally, the butterfly modes are predicted by the calculations between 188 and 168 cm⁻¹, for this, they are assigned to the weak Raman band at 173

cm^{-1} , as observed in **Table 2**.

4.5. Force Field

The calculated forces constants for the three CQA's conformers are given in **Table 3** and they were calculated by means of the scaling procedure of Pulay *et al.* [7,8] with the MOLVIB program [19,20]. The $\text{C}=\text{O}$ stretching force constants values for the C_{II} and C_{III} conformers (14.16 and 14.10 $\text{mdyn}\cdot\text{\AA}^{-1}$, respectively) are higher than the corresponding to the C_1 structure (13.62 $\text{mdyn}\cdot\text{\AA}^{-1}$) because the calculated $\text{C}=\text{O}$ distances in those conformers are lower (1.202 and 1.203 \AA , respectively) than the corresponding to C_1 conformer (1.210 \AA). Also, these same reasons justify the higher $f(\text{C}-\text{O})$ force constant value in the C_1 structure (6.33 $\text{mdyn}\cdot\text{\AA}^{-1}$) in relation to the others (see **Table 1**). The formation of a H bond ($\text{OH}-\text{O}$) in the C_1 structure through the OH group and the lower $\text{C}-\text{O}-\text{H}$ angle value in this structure (112.4°) justifies the lower $f(\nu\text{OH})$ force constant value in this structure (6.11 $\text{mdyn}\cdot\text{\AA}^{-1}$) in reference to the others. The differences between the $f(\text{O}=\text{C}=\text{O})$, $f(\text{H}-\text{C}-\text{H})$ and $f(\text{C}-\text{O}-\text{H})$ force constant values for the C_1 structure in relation to the others are also attributed to the geometrical parameters. On the other hand, the analysis of the force constants for all conformers of this compound with the values for 2-(quinolin-8-yloxy) acetic acid [6] show that the values

are higher in CQA, with exception of the $f(\text{C}-\text{O})$ force constant. An explanation can be probably due to that the chloro atom increase the topological properties of the RCPs in the C_1 conformer and as consequence decrease the $\text{O}-\text{H}$ distance increasing the $\text{C}-\text{O}$ distance in this conformer in relation to the 2-(quinolin-8-yloxy) acetic acid [6].

4.6. HOMO-LUMO Energy Gap

The frontier molecular HOMO and LUMO orbitals were calculated for 2-(quinolin-8-yloxy) acetic acid and compared with the corresponding values for the (5-chloro-quinolin-8-yloxy) acetic acid [37], as observed in **Table S11**. The results show clearly that both orbitals are mainly localized on the rings, indicating that the HOMO-LUMO are mostly the π -antibonding type orbitals and that the values of the energy separation between those orbitals are higher in the 2-(quinolin-8-yloxy) acetic acid than in CQA. This large HOMO-LUMO gap for the 2-(quinolin-8-yloxy) acetic acid automatically means high excitation energies for many excited states, a good stability and a high chemical hardness. For these reasons, the presence of a Cl atom in CQA increases the reactivity compared to the 2-(quinolin-8-yloxy) acetic acid.

4.7. NMR Analysis

Tables 4, 5 show a comparison between the experimental and calculated chemical shifts for the ^1H and ^{13}C nuclei, respectively. The calculated chemical shifts for the H nuclei show a reasonable agreement in relation to experimental values with observed RMSD values between 0.578 and 0.174 ppm, while the chemical shifts for the carbon nuclei show higher RMSD values (7.325 and 0.254 ppm). The calculated ^1H chemical and ^{13}C shifts show a good concordance for the three conformers when the 6-311++G** basis set is used. Thus, **Table 4** shows that the calculated ^{13}C chemical shifts with the GIAO method using the 6-311++G** basis set are in accordance with the experimental values. In general, the calculated shifts for the ^{13}C nuclei are higher than the corresponding experimental values.

5. Conclusion

The (5-chloro-quinolin-8-yloxy) acetic acid was synthesized and characterized by infrared, Raman and NMR spectroscopic techniques. The presence of C_1 , C_{II} and C_{III} conformers was detected in both spectra, and a complete assignment of the vibrational modes was accomplished. The B3LYP/6-31G* and B3LYP/6-311++G** calculations suggest the existence of three conformers for CQA in the gas phase and, probably, the three are present in the solid state. An SQM/B3LYP/6-31G* force field was

Table 3. Comparison of scaled internal force constants for the three conformers of (5-chloro-quinolin-8-yloxy) acetic acid.

Force constant	B3LYP/6-31G*				
	(5-chloro-quinolin-8-yloxy) acetic acid			2-(8-quinolinyloxy) acetic acid ^b	
	C_1	C_{II}	C_{III}	C_1	C_{II}
$f(\text{C}=\text{O})$	13.62	14.16	14.10	12.53	13.07
$f(\text{C}-\text{O})$	6.33	5.93	6.15	6.73	5.50
$f(\text{O}-\text{H})$	6.11	7.71	7.65	5.55	7.10
$f(\text{C}-\text{H}_2)$	5.31	5.23	5.10	4.87	4.80
$f(\text{C}-\text{H})$	5.68	5.67	5.66	5.17	5.16
$f(\text{C}-\text{Cl})$	3.51	3.49	3.42	-	-
$f(\text{C}-\text{N})$	7.90	7.77	7.84	7.26	7.12
$f(\text{C}-\text{C})$	6.65	6.59	6.61	6.22	6.17
$f(\text{O}=\text{C}=\text{O})$	1.33	1.24	1.26	1.33	1.23
$f(\text{H}-\text{C}-\text{H})$	0.91	0.87	0.88	0.84	0.80
$f(\text{C}-\text{O}-\text{H})$	1.01	0.79	0.77	0.91	0.70
$f(\text{C}-\text{O}-\text{C})$	0.99	1.16	1.46	0.98	1.18

Units are $\text{mdyn}\cdot\text{\AA}^{-1}$ for stretching and stretching/stretching interaction and $\text{mdyn}\cdot\text{\AA}\cdot\text{rad}^{-2}$ for angle deformations; ^aThis work; ^bAnhydrous from Ref [6].

obtained for the three structures of CQA after adjusting the force constants obtained theoretically to minimize the difference between the observed and calculated wavenumbers. Also, the principal force constants for the stretching and deformation modes of CQA were determined. The NBO and AIM analysis confirm the O-H and N-H bonds in the three conformers of CQA while the HOMO-LUMO study shows that the Cl atom increases the reactivity of CQA, as compared with 2-(quinolin-8-yloxy) acetic acid.

6. Acknowledgements

This work was supported with grants from CIUNT (Consejo de Investigaciones, Universidad Nacional de Tucumán) and CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas, R. Argentina). The authors thank Prof. Tom Sundius for his permission to use MOLVIB and the Dr. Jorge Güida for the Raman spectrum.

REFERENCES

- [1] S. Y. Cho, J. H. Ahn, J. D. Ha, S. K. Kang, J. Y. Baek, S. S. Han, E. Y. Shin, S. S. Kim, K. R. Kim, H. G. Cheon and J. K. Choi, "Protein Tyrosine Phosphatase 1B Inhibitors: Heterocyclic Carboxylic Acids," *Bulletin of the Korean Chemical Society*, Vol. 24, No. 10, 2003, pp. 1455-1464. [doi:10.5012/bkcs.2003.24.10.1455](https://doi.org/10.5012/bkcs.2003.24.10.1455)
- [2] B. P. Kennedy and C. Ramachandran, "Protein Tyrosine Phosphatase-1B in Diabetes," *Biochemical Pharmacology*, Vol. 60, No. 7, 2000, pp. 877-883. [doi:10.1016/S0006-2952\(00\)00305-1](https://doi.org/10.1016/S0006-2952(00)00305-1)
- [3] N. Moller, L. Iversen, H. Andersen, J. McCormack, "Protein Tyrosine Phosphatases (PTPs) as Drug Targets: Inhibitors of PTP-1 for the Treatment of Diabetes," *Current Opinion in Drug Discovery & Development*, Vol. 3, No. 5, 2000, pp. 527-540.
- [4] A. Hubale, "Use of Quinoline Derivatives for the Protection of Cultivated Plants from Herbicides," US Patent No. 4902340, 1990.
- [5] F. Hayat, A. Salahuddin, J. Zargan and A. Azam, "Synthesis, Characterization, Antiamoebic Activity and Cytotoxicity of Novel 2-(Quinolin-8-Yloxy) Acetohydrazones and Their Cyclized Products (1,2,3-Thiadiazole and 1,2,3-Selenadiazole Derivatives)," *European Journal of Medicinal Chemistry*, Vol. 45, No. 12, 2010, pp. 6127-6134. [doi:10.1016/j.ejmech.2010.09.066](https://doi.org/10.1016/j.ejmech.2010.09.066)
- [6] G. R. Argañaraz, E. Romano, J. Zinczuk and S. A. Brandan, "Structural and Vibrational Study of 2-(Quinolin-8-yloxy)-Acetic Acid Based on FT-IR-Raman Spectroscopy and DFT Calculations," *Journal of Chemistry and Chemical Engineering*, Vol. 5, No. 8, 2011, pp. 747-758.
- [7] P. Pulay, G. Fogarasi, F. Pang and E. J. Boggs, "Systematic *ab Initio* Gradient Calculation of Molecular Geometries, Force Constants, and Dipole Moment Derivatives," *Journal of the American Chemical Society*, Vol. 101, No. 10, 1979, pp. 2550-2560. [doi:10.1021/ja00504a009](https://doi.org/10.1021/ja00504a009)
- [8] P. Pulay, G. Fogarasi, G. Pongor, J. E. Boggs and A. Varga, "Combination of Theoretical *ab Initio* and Experimental Information to Obtain Reliable Harmonic Force Constants. Scaled Quantum Mechanical (QM) Force Fields for Glyoxal, Acrolein, Butadiene, Formaldehyde, and Ethylene," *Journal of the American Chemical Society*, Vol. 105, No. 24, 1983, pp. 7037-7047. [doi:10.1021/ja00362a005](https://doi.org/10.1021/ja00362a005)
- [9] G. Rauhut and P. Pulay, "Transferable Scaling Factors for Density Functional Derived Vibrational Force Fields," *The Journal of Physical Chemistry*, Vol. 99, No. 39, 1995, pp. 3093-3100. [doi:10.1021/j100039a056](https://doi.org/10.1021/j100039a056)
- [10] A. E. Reed, L. A. Curtis and F. Weinhold, "Intermolecular Interactions from a Natural Bond Orbital, Donor-Acceptor Viewpoint," *Chemical Review*, Vol. 88, No. 6, 1988, pp. 899-926. [doi:10.1021/cr00088a005](https://doi.org/10.1021/cr00088a005)
- [11] J. P. Foster and F. J. Weinhold, "Natural Hybrid Orbitals," *Journal of the American Chemical Society*, Vol. 102, No. 24, 1980, pp. 7211-7218. [doi:10.1021/ja00544a007](https://doi.org/10.1021/ja00544a007)
- [12] A. E. Reed and F. Weinhold, "Natural Localized Molecular Orbitals," *Chemical Physics*, Vol. 83, No. 4, 1985, pp. 1736-1740.
- [13] R. F. W. Bader, "Atoms in Molecules: A Quantum Theory," Oxford University Press, Oxford, 1990.
- [14] F. Sun, L. Chen, H. C. Fang, X. M. Lin and Y. P. Cai, "8-(Carboxymethoxy)Quinolinium Nitrate Monohydrate," *Acta Crystallographica*, Vol. 64, 2008, p. 1641.
- [15] F. Biegler-König, J. Schönbohm and D. Bayles, "AIM 2000—A Program to Analyze and Visualize Atoms in Molecules," *Journal of Computational Chemistry*, Vol. 22, No. 5, 2001, pp. 545-559.
- [16] E. D. Glendening, J. K. Badenhoop, A. D. Reed, J. E. Carpenter and F. Weinhold, "Natural Bond Orbital: NBO 3.1," University of Wisconsin, Madison, 1996.
- [17] M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, J. A. Montgomery, T. Vreven, K. N. Kudin, J. C. Burant, J. M. Millam, S. S. Iyengar, J. Tomasi, V. Barone, B. Mennucci, M. Cossi, G. Scalmani, N. Rega, G. A. Petersson, H. Nakatsuji, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, M. Klene, X. Li, J. E. Knox, H. P. Hratchian, J. B. Cross, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, P. Y. Ayala, K. Morokuma, G. A. Voth, P. Salvador, J. J. Dannenberg, V. G. Zakrzewski, S. Dapprich, A. D. Daniels, M. C. Strain, O. Farkas, D. K. Malick, A. D. Rabuck, K. Raghavachari, J. B. Foresman, J. V. Ortiz, Q. Cui, A. G. Baboul, S. Clifford, J. Cioslowski, B. B. Stefanov, G. Liu, A. Liashenko, P. Piskorz, I. Komaromi, R. L. Martin, D. J. Fox, T. Keith, M. A. Al-Laham, C. Y. Peng, A. Nanayakkara, M. Challacombe, P. M. W. Gill, B. Johnson, W. Chen, M. W. Wong, C. Gonzalez and J. A. Pople, "Gaussian 03, Revision B.01," Gaussian, Inc., Pittsburgh, 2003.
- [18] G. Fogarasi, X. Zhou, P. Taylor and P. Pulay, "The Calculation of *Ab Initio* Molecular Geometries: Efficient Optimization by Natural Internal Coordinates and Empirical Correction by Offset Forces," *Journal of the Ameri-*

- can Chemical Society*, Vol. 114, No. 21, 1992, pp. 8191-8201.
[doi:10.1021/ja00047a032](https://doi.org/10.1021/ja00047a032)
- [19] T. Sundius, "Molvib—A Flexible Program for Force Field Calculations," *Journal of Molecular Structure*, Vol. 218, No. 1-2, 1990, pp. 321-326.
[doi:10.1016/0022-2860\(90\)80287-T](https://doi.org/10.1016/0022-2860(90)80287-T)
- [20] T. Sundius, "Scaling of *Ab Initio* Force Fields by MOLVIB," *Vibrational Spectroscopy*, Vol. 29, No. 1-2, 2002, pp. 89-95.
[doi:10.1016/S0924-2031\(01\)00189-8](https://doi.org/10.1016/S0924-2031(01)00189-8)
- [21] F. Kalincsák and G. Pongor, "Extension of the Density Functional Derived Scaled Quantum Mechanical Force Field Procedure," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, Vol. 58, No. 5, 2002, pp. 999-1011.
[doi:10.1016/S1386-1425\(01\)00572-8](https://doi.org/10.1016/S1386-1425(01)00572-8)
- [22] A. B. Nielsen and A. J. Holder, "Gauss View, User's Reference," GAUSSIAN, Inc., Pittsburgh, 1997-1998.
- [23] A. E. Ledesma, S. A. Brandán, J. Zinczuk, O. Piro, J. J. L. González, A. B. Altabef, "Structural and Vibrational Study of 2-(2'-Furyl)-1H-Imidazole," *Journal of Physical Organic Chemistry*, Vol. 21, No. 12, 2008, pp. 1086-1097.
[doi:10.1002/poc.1449](https://doi.org/10.1002/poc.1449)
- [24] E. Romano, A. B. Raschi, A. Benavente and S. A. Brandán, "Structural Analysis, Vibrational Spectra and Coordinated Normal of 2R-(–)-6-Hydroxytremetone," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, Vol. 84, No. 1, 2011, pp. 111-116.
[doi:10.1016/j.saa.2011.09.011](https://doi.org/10.1016/j.saa.2011.09.011)
- [25] S. A. Brandán, G. Benzal, et al., "Theoretical and Experimental Atudy of the Vibrational Apects of 1,5-Sime-thylcytosine," *Vibrational Spectroscopy*, Vol. 46, No. 2, 2008, pp. 89-99.
[doi:10.1016/j.vibspec.2007.11.001](https://doi.org/10.1016/j.vibspec.2007.11.001)
- [26] A. E. Ledesma, J. Zinczuk, A. B. Altabef, J. J. López-González and S. A. Brandán, "Synthesis and Vibrational Analysis of N-(2'-Furyl)-Imidazole," *Journal of Raman Spectroscopy*, Vol. 40, No. 8, 2009, pp. 1004-1010.
- [27] J. Zinczuk, A. E. Ledesma, S. A. Brandán, O. E. Piro, J. J. López-González, A. B. Altabef, "Structural and Vibrational Study of 2-(2'-Furyl)-4,5-1H-Dihydroimidazole," *Journal of Physical Organic Chemistry*, Vol. 22, No. 12, pp. 1166-1167.
[doi:10.1002/poc.1572](https://doi.org/10.1002/poc.1572)
- [28] S. A. Brandán, E. Eroglu, A. E. Ledesma, O. Oltulu and O. B. Yalçınkaya, "A New Vibrational Study of Acetazolamide Compound Based on Normal Coordinate Analysis and DFT Calculations," *Journal of Molecular Structure*, Vol. 993, No. 1-3, 2011, pp. 225-231.
[doi:10.1016/j.molstruc.2010.11.012](https://doi.org/10.1016/j.molstruc.2010.11.012)
- [29] L. C. Bichara, H. E. Lanús, C. G. Nieto and S. A. Brandán, "Density Functional Theory Calculations of the Molecular Force Field of l-Ascorbic Acid, Vitamin C," *The Journal of Physical Chemistry A*, Vol. 114, No. 14, 2010, pp. 4997-5004.
[doi:10.1021/jp912251g](https://doi.org/10.1021/jp912251g)
- [30] S. A. Brandán, F. M. López and M. Montejo, J. J. L. González, A. B. Altabef, "Theoretical and Experimental Vibrational Spectrum Study of 4-Hydroxybenzoic Acid as Monomer and Dimer," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, Vol. 75, No. 5, 2010, pp. 1422-1434.
[doi:10.1016/j.saa.2010.01.012](https://doi.org/10.1016/j.saa.2010.01.012)
- [31] A. E. Ledesma, C. Contreras, J. Svoboda, A. Vektariene and S. A. Brandán, "Theoretical Structures and Experimental Vibrational Spectra of Isomeric Benzofused thieno [3,2-b] Furan Compounds," *Journal of Molecular Structure*, Vol. 967, No. 1-3, 2010, pp. 159-165.
[doi:10.1016/j.molstruc.2009.12.050](https://doi.org/10.1016/j.molstruc.2009.12.050)
- [32] C. D. Contreras and M. Montejo, J. J. L. González, J. Zinczuk and S. A. Brandán, "Structural and Vibrational Analyses of 2-(2-Benzofuranyl)-2-Imidazoline," *Journal of Raman Spectroscopy*, Vol. 42, No. 1, 2011, pp. 108-116.
[doi:10.1002/jrs.2659](https://doi.org/10.1002/jrs.2659)
- [33] J. Antony, G. V. Helden, G. Meijer and B. Schmidt, "Anharmonic Midinfrared Vibrational Spectra of Benzoic Acid Monomer and Dimer," *Journal of Chemical Physics*, Vol. 123, No. 1, 2005, pp. 14305-14311.
[doi:10.1063/1.1947191](https://doi.org/10.1063/1.1947191)
- [34] C. D. Contreras, A. E. Ledesma, H. E. Lanús, J. Zinczuk and S. A. Brandán, "Hydration of L-Tyrosine in Aqueous Medium. An Experimental and Theoretical Study by Mixed Quantum Mechanical/Molecular Mechanics Methods," *Vibrational Spectroscopy*, Vol. 57, No. 1, 2011, pp. 108-115.
- [35] S. Ghose and J. K. Dattagupta, "Crystal Structure of Tolazoline Hydrochloride (Priscoline), an α -Adrenergic Antagonist," *Journal of the Chemical Society, Perkin Transactions 2*, Vol. 200, No. 1-2, 1989, pp. 599-601.
- [36] C. D. Contreras, A. E. Ledesma, J. Zinczuk and S. A. Brandán, "Vibrational Study of Tolazoline Hydrochloride by Using FTIR-Raman and DFT Calculations," *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy*, Vol. 79, No. 5, 2011, pp. 1710-1714.
[doi:10.1016/j.saa.2011.05.041](https://doi.org/10.1016/j.saa.2011.05.041)
- [37] E. Romano, M. V. Castillo, J. L. Pergomet, J. Zinczuk and S. A. Brandán, "Synthesis and Structural and Vibrational Analysis of (5,7-Dichloro-Quinolin-8-Yloxy) Acetic Acid," *Journal of Molecular Structure*, Vol. 1018, No. 27, 2012, pp. 149-155.
[doi:10.1016/j.molstruc.2012.03.013](https://doi.org/10.1016/j.molstruc.2012.03.013)

Supplement

Table S1. Definition of natural internal coordinates for (5-chloro-quinolin-8-yloxy) acetic acid compound.

Mode	Internal coordinate	Definition
S ₁	$r(\text{O23-H24})$	$\nu(\text{O23-H24})$
S ₂	$r(\text{C1-H7})$	$\nu(\text{C1-H7})$
S ₃	$r(\text{C2-H8})$	$\nu(\text{C2-H8})$
S ₄	$r(\text{C5-H11})$	$\nu(\text{C5-H11})$
S ₅	$r(\text{C9-Cl6})$	$\nu(\text{C9-Cl6})$
S ₆	$r(\text{C12-H14})$	$\nu(\text{C12-H14})$
S ₇	$r(\text{C13-H15})$	$\nu(\text{C13-H15})$
S ₈	$r(\text{C18-H19}) + r(\text{C18-H20})$	$\nu_s \text{CH}_2$
S ₉	$r(\text{C18-H19}) - r(\text{C18-H20})$	$\nu_a \text{CH}_2$
S ₁₀	$r(\text{C4-N16})$	$\nu(\text{C4-N16})$
S ₁₁	$\nu(\text{C5-N16})$	$\nu(\text{C5-N16})$
S ₁₂	$r(\text{C21-O23})$	$\nu(\text{C21-O23})$
S ₁₃	$r(\text{C21-O22})$	$\nu(\text{C21-O22})$
S ₁₄	$r(\text{C10-O17})$	$\nu(\text{C10-O17})$
S ₁₅	$r(\text{C18-O17})$	$\nu(\text{C18-O17})$
S ₁₆	$r(\text{C1-C5})$	$\nu(\text{C1-C5})$
S ₁₇	$r(\text{C1-C2})$	$\nu(\text{C1-C2})$
S ₁₈	$r(\text{C2-C3})$	$\nu(\text{C2-C3})$
S ₁₉	$r(\text{C3-C4})$	$\nu(\text{C3-C4})$
S ₂₀	$r(\text{C3-C9})$	$\nu(\text{C3-C9})$
S ₂₁	$r(\text{C13-C9})$	$\nu(\text{C13-C9})$
S ₂₂	$r(\text{C13-C12})$	$\nu(\text{C13-C12})$
S ₂₃	$r(\text{C12-C10})$	$\nu(\text{C12-C10})$
S ₂₄	$r(\text{C10-C4})$	$\nu(\text{C10-C4})$
S ₂₅	$r(\text{C18-C21})$	$\nu(\text{C18-C21})$
S ₂₆	$\alpha(\text{C21-O23-H24})$	δOH
S ₂₇	$\alpha(\text{C10-O17-C18})$	δCOC
S ₂₈	$5\alpha(\text{H19-C18-H20}) + \alpha(\text{C21-C18-H20})$	δCH_2
S ₂₉	$\alpha(\text{H11-C5-C1}) - \alpha(\text{H11-C5-N16})$	$\beta \text{C5-H11}$
S ₃₀	$\alpha(\text{H7-C1-C2}) - \alpha(\text{H7-C1-C5})$	$\beta \text{C1-H7}$
S ₃₁	$\alpha(\text{H8-C2-C3}) - \alpha(\text{H8-C2-C1})$	$\beta \text{C2-H8}$
S ₃₂	$\alpha(\text{Cl6-C9-C13}) - \alpha(\text{Cl6-C9-C3})$	$\beta \text{C9-Cl6}$
S ₃₃	$\alpha(\text{H15-C13-C12}) - \alpha(\text{H15-C13-C9})$	$\beta \text{C13-H15}$
S ₃₄	$\alpha(\text{H14-C12-C10}) - \alpha(\text{H14-C12-C13})$	$\beta \text{C12-H14}$
S ₃₅	$2\alpha(\text{O23-C21-O22}) - \alpha(\text{O23-C21-C18}) - \alpha(\text{O22-C21-C18})$	δCOO

Continued

S ₃₆	$\alpha(O23-C21-C18) - \alpha(O22-C21-C18)$	ρCOO
S ₃₇	$5\alpha(C21-C18-H20) + \alpha(H19-C18-H20)$	δCCO
S ₃₈	$\alpha(C4-C10-O17) - \alpha(C12-C10-O17)$	$\rho C10-O17$
S ₃₉	$\tau(C4-C10-O17-C18) + \tau(C12-C10-O17-C18)$	w Ring
S ₄₀	$\alpha(H19-C18-O17) + \alpha(H20-C18-C21) - \alpha(H20-C18-O17) - \alpha(H19-C18-C21)$	wag CH ₂
S ₄₁	$\alpha(H19-C18-O17) + \alpha(H20-C18-O17) - \alpha(H20-C18-C21) - \alpha(H19-C18-C21)$	ρCH_2
S ₄₂	$\alpha(H19-C18-O17) + \alpha(H19-C18-C21) - \alpha(H20-C18-O17) - \alpha(H20-C18-C21)$	w CH ₂
S ₄₃	$6^{-1/2}[\alpha(C3-C9-C13) + \alpha(C13-C12-C10) + \alpha(C10-C4-C3) - \alpha(C9-C13-C12) - \alpha(C12-C10-C4) - \alpha(C4-C3-C9)]$	R ₁ (A1)
S ₄₄	$12^{-1/2}[2\alpha(C3-C9-C13) - \alpha(C9-C13-C12) - \alpha(C13-C12-C10) + 2\alpha(C12-C10-C4) - \alpha(C10-C4-C3) - \alpha(C4-C3-C9)]$	R ₂ (A1)
S ₄₅	$S_{50} = 1/2[\alpha(C9-C13-C12) - \alpha(C13-C12-C10) + \alpha(C10-C4-C3) - \alpha(C4-C3-C9)]$	R ₃ (A1)
S ₄₆	$6^{-1/2}[\alpha(C1-C2-C3) + \alpha(C3-C4-N16) + \alpha(N16-C5-C1) - \alpha(C2-C3-C4) - \alpha(C4-N16-C5) - \alpha(C5-C1-C2)]$	R ₁ (A2)
S ₄₇	$12^{-1/2}[2\alpha(C1-C2-C3) - \alpha(C2-C3-C4) - \alpha(C3-C4-N16) + 2\alpha(C4-N16-C5) - \alpha(N16-C5-C1) - \alpha(C5-C1-C2)]$	R ₂ (A2)
S ₄₈	$S_{50} = 1/2[\alpha(C2-C3-C4) - \alpha(C3-C4-N16) + \alpha(N16-C5-C1) - \alpha(C5-C1-C2)]$	R ₃ (A2)
S ₄₉	$\tau(H14-C12-C13-C10)$	$\gamma C12-H14$
S ₅₀	$\tau(H15-C13-C9-C12)$	$\gamma C13-H15$
S ₅₁	$\tau(Cl6-C9-C3-C13)$	$\gamma C9-Cl6$
S ₅₂	$\tau(H8-C2-C1-C3)$	$\gamma C2-H8$
S ₅₃	$\tau(H7-C1-C5-C2)$	$\gamma C1-H7$
S ₅₄	$\tau(H11-C5-N16-C1)$	$\gamma C5-H11$
S ₅₅	$\tau(C18-C21-O22-O23)$	γCOO
S ₅₆	$\tau(O17-C10-C12-C4)$	$\gamma C10-O17$
S ₅₇	$6^{-1/2}[\tau(C9-C3-C4-C10) - \tau(C4-C10-C12-C13) + \tau(C12-C13-C9-C3) - \tau(C3-C4-C10-C12) + \tau(C10-C12-C13-C9) - \tau(C13-C9-C3-C4)]$	$\tau R_1(A1)$
S ₅₈	$1/2[-\tau(C4-C10-C12-C13) + \tau(C13-C9-C3-C4) - \tau(C9-C3-C4-C10) + \tau(C10-C12-C13-C9)]$	$\tau R_2(A1)$
S ₅₉	$12^{-1/2}[-\tau(C9-C3-C4-C10) + 2\tau(C3-C4-C10-C12) - \tau(C4-C10-C12-C13) - \tau(C10-C12-C13-C9) + 2\tau(C12-C13-C9-C3) - \tau(C13-C9-C3-C4)]$	$\tau R_3(A1)$
S ₆₀	$6^{-1/2}[\tau(C2-C1-C5-N16) - \tau(C5-N16-C4-C3) + \tau(C4-C3-C2-C1) - \tau(C1-C5-N16-C4) + \tau(N16-C4-C3-C2) - \tau(C3-C2-C1-C5)]$	$\tau R_1(A2)$
S ₆₁	$1/2[-\tau(C5-N16-C4-C3) + \tau(C4-C3-C2-C1) - \tau(C2-C1-C5-N16) + \tau(N16-C4-C3-C2)]$	$\tau R_2(A2)$
S ₆₂	$12^{-1/2}[-\tau(C2-C1-C5-N16) + 2\tau(C1-C5-N16-C4) - \tau(C5-N16-C4-C3) - \tau(N16-C4-C3-C2) + 2\tau(C4-C3-C2-C1) - \tau(C3-C2-C1-C5)]$	$\tau R_3(A2)$
S ₆₃	$\tau(O23-C21-C18-O17) + \tau(O23-C21-C18-H19) + \tau(O23-C21-C18-H20) + \tau(O22-C21-C18-O17) + \tau(O22-C21-C18-H19) + \tau(O22-C21-C18-H20)$	w COO
S ₆₄	$\tau(C21-C18-O17-C10)$	CCOC
S ₆₅	$\tau(N16-C4-C3-C9) + \tau(C10-C4-C3-C2)$	Butt
S ₆₆	$\tau(H24-O23-C21-O22) + \tau(H24-O23-C21-C18)$	τOH

Abbreviations: ν , stretching; β , deformation in the plane; γ , deformation out of plane; wag, wagging; τ , torsion; β_R , deformation ring; τ_R , torsion ring; ρ , rocking; twis, twisting; α , angular deformation; δ , deformation; a , antisymmetric; s , symmetric; A1, Ring 1; A2, Ring 2.

Table S2. Calculated total energy (*E*) and dipolar moments for the structures of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Method	(5-chloro-quinolin-8-yloxy) acetic acid							
	C _I		C _{II}		C _{III}			
	<i>E</i> ₁ (Hartrees)	μ (D)	<i>E</i> ₂ (Hartrees)	μ (D)	$\Delta E = E_1 - E_2$ (kJ/mol)	<i>E</i> ₃ (Hartrees)	μ (D)	$\Delta E = E_1 - E_3$ (kJ/mol)
B3LYP/6-31G*	-1164.6146	5.56	-1164.5979	4.19	-43.80	-1164.6040	1.99	-27.80
B3LYP/6-311++G**	-1164.8428	6.07	-1164.8251	4.38	-46.43	-1164.8305	2.08	-32.26

Table S3. Atomic charges (NPA) for the conformers of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Atoms	B3LYP METHOD					
	C _I		C _{II}		C _{III}	
	6-31G*	6-311++G**	6-31G*	6-311++G**	6-31G*	6-311++G**
1 C	-0.268	-0.234	-0.275	-0.241	-0.275	-0.233
2 C	-0.162	-0.125	-0.167	-0.131	-0.167	-0.142
3 C	-0.103	-0.125	-0.106	-0.112	-0.106	-0.108
4 C	0.159	0.160	0.145	0.134	0.145	0.142
5 C	0.064	0.101	0.046	0.082	0.046	0.076
6 Cl	0.004	0.012	-0.006	0.002	-0.006	-0.004
7 H	0.253	0.220	0.247	0.216	0.247	0.214
8 H	0.260	0.228	0.256	0.226	0.256	0.224
9 C	-0.030	0.004	-0.032	-0.024	-0.032	-0.037
10 C	0.319	0.323	0.313	0.337	0.313	0.364
11 H	0.236	0.197	0.224	0.185	0.224	0.187
12 C	-0.262	-0.220	-0.237	-0.205	-0.237	-0.296
13 C	-0.230	-0.215	-0.231	-0.203	-0.231	-0.200
14 H	0.256	0.224	0.267	0.234	0.267	0.214
15 H	0.261	0.227	0.259	0.225	0.259	0.222
16 N	-0.479	-0.488	-0.464	-0.468	-0.464	-0.418
17 O	-0.556	-0.576	-0.531	-0.552	-0.531	-0.503
18 C	-0.215	-0.127	-0.222	-0.142	-0.222	-0.129
19 H	0.236	0.202	0.245	0.219	0.245	0.202
20 H	0.250	0.212	0.246	0.210	0.246	0.202
21 C	0.796	0.772	0.794	0.769	0.794	0.786
22 O	-0.596	-0.590	-0.562	-0.552	-0.562	-0.554
23 O	-0.709	-0.696	-0.700	-0.677	-0.700	-0.698
24 H	0.517	0.513	0.488	0.469	0.488	0.488

Table S4. Wiberg index bond for the conformers of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Atoms	B3LYP METHOD					
	C _I		C _{II}		C _{III}	
	6-31G*	6-311++G**	6-31G*	6-311++G**	6-31G*	6-311++G**
1 C	3.941	3.958	3.942	3.959	3.942	3.960
2 C	3.931	3.950	3.933	3.952	3.933	3.954
3 C	3.991	3.994	3.992	3.992	3.992	3.993
4 C	3.984	3.984	3.987	3.991	3.987	3.997
5 C	3.913	3.930	3.925	3.943	3.925	3.944
6 Cl	1.211	1.224	1.203	1.215	1.203	1.207
7 H	0.937	0.954	0.940	0.956	0.940	0.957
8 H	0.935	0.951	0.936	0.952	0.936	0.953
9 C	4.010	4.010	4.008	4.011	4.008	4.008
10 C	3.919	3.915	3.920	3.914	3.920	3.904
11 H	0.946	0.963	0.952	0.968	0.952	0.968
12 C	3.943	3.960	3.939	3.958	3.939	3.954
13 C	3.939	3.959	3.939	3.957	3.939	3.959
14 H	0.936	0.952	0.930	0.948	0.930	0.957
15 H	0.933	0.951	0.934	0.952	0.934	0.953
16 N	3.118	3.124	3.083	3.090	3.083	3.106
17 O	2.067	2.067	2.088	2.096	2.088	2.178
18 C	3.768	3.807	3.786	3.823	3.786	3.826
19 H	0.947	0.963	0.943	0.957	0.943	0.963
20 H	0.940	0.958	0.941	0.959	0.941	0.963
21 C	3.842	3.854	3.829	3.844	3.829	3.848
22 O	2.035	2.036	2.074	2.084	2.074	2.081
23 O	1.985	2.002	1.966	1.986	1.966	1.965
24 H	0.737	0.741	0.763	0.785	0.763	0.766

Table S5. Main delocalization energy (in kJ/mol) for the C₁ conformer of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Delocalization	B3LYP METHOD	
	6-31G*	C ₁ 6-311++G**
σ C1-C2 → LP(1)C3	165.24	165.90
σ C1-C2 → σ^* C5-N16	108.47	107.93
σ C5-N16 → LP*(1)C4	171.67	171.97
σ C5-N16 → σ^* C1-C2	45.10	43.93
σ C9-C13 → LP(1)C3	159.26	159.80
σ C9-C13 → σ^* C10-C12	63.91	64.41
σ C10-C12 → LP*(1)C4	171.21	171.59
σ C10-C12 → σ^* C9-C13	81.38	80.47
$\Delta E T_{\sigma \rightarrow \sigma^*}$	966.25	966.00
LP(1)C3 → σ^* C1-C2	234.21	238.13
LP(1)C3 → σ^* C9-C13	244.49	250.21
LP(1)C4 → σ^* C5-N16	241.14	244.40
LP(1)C4 → σ^* C10-C12	228.94	227.35
LP(3)Cl6 → σ^* C9-C13	51.75	53.50
LP(1)N16 → σ^* O23-H24	83.68	80.59
LP(2)O22 → σ^* C18-C21	91.17	83.31
LP(2)O22 → σ^* C21-O23	129.91	122.18
LP(2)O23 → σ^* C21-O22	114.53	192.70
$\Delta E T_{LP \rightarrow \sigma^*}$	1419.82	1492.39
ΔE Total	2386.07	2458.38

Table S6. Main delocalization energy (in kJ/mol) for the C_{II} and C_{III} conformers of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Delocalization	B3LYP METHOD			
	C _{II}	C _{III}	6-31G*	6-311++G**
σ C1-C2 → σ^* C3-C4	63.08	63.79	63.08	66.59
σ C1-C2 → σ^* C5-N16	104.75	104.17	104.75	98.27
σ C3-C4 → σ^* C1-C2	74.49	75.78	74.49	73.69
σ C3-C4 → σ^* C5-N16	62.99	63.87	62.99	64.29
σ C3-C4 → σ^* C9-C13	69.68	71.31	69.68	69.85
σ C3-C4 → σ^* C10-C12	64.62	63.70	64.62	70.35
σ C5-N16 → σ^* C1-C2	46.94	45.77	46.94	50.41
σ C5-N16 → σ^* C3-C4	81.47	83.01	81.47	88.16
σ C9-C13 → σ^* C3-C4	68.72	69.30	68.72	67.47
σ C9-C13 → σ^* C10-C12	65.00	65.33	65.00	56.97
σ C10-C12 → σ^* C3-C4	73.40	74.07	73.40	58.19
σ C10-C12 → σ^* C9-C13	83.43	82.64	83.43	83.89
$\Delta E T_{\sigma \rightarrow \sigma^*}$	858.57	862.75	858.57	848.12
LP(1)Cl6 → σ^* C9-C13	49.87	51.50	49.87	50.75
LP(1)N16 → σ^* C1-C5	42.51	39.08	42.51	40.30
LP(1)N16 → σ^* C3-C4	43.35	40.30	43.35	41.80
LP(2)O17 → σ^* C10-C12	52.21	52.38	52.21	135.81
LP(2)O22 → σ^* C18-C21	89.66	84.73	89.66	86.90
LP(2)O22 → σ^* C21-O23	147.39	142.96	147.39	145.05
LP(2)O23 → σ^* C21-O22	186.14	170.42	186.14	176.90
$\Delta E T_{LP \rightarrow \sigma^*}$	611.12	1352.77	611.12	1402.72
ΔE Total	1469.69	2215.53	1469.69	2250.85

Table S7. An analysis of the bond and ring critical points (BCP, RCP) for the conformers of (5-chloro-quinolin-8-yloxy) acetic acid at different theory levels.

Parameter (a.u.)	B3LYP METHOD											
	C _I				C _{II}				C _{III}			
	6-31G*		6-311++G**		6-31G*		6-311++G**		6-31G*		6-31G*	
	N16-H24	O17-H24	RCP ₁	RCP ₂	N16-H24	RCP ₁	N16-H19	RCP ₁	N16-H19	RCP ₁	N16-H ¹ 9	RCP ₁
$\rho(r)$	0.0347	0.0183	0.0146	0.0182	0.0378	0.0142	0.0167	0.0119	0.0165	0.0120	0.0167	0.0119
$\nabla^2 \rho(r)$	0.0939	0.0760	0.0504	0.0889	0.0961	0.0481	0.0556	0.0581	0.0568	0.0616	0.0556	0.0582
λ_1	-0.0511	-0.0201	-0.0139	-0.0183	-0.0584	-0.0129	-0.0169	-0.0060	-0.0164	-0.0056	-0.0169	-0.0060
λ_2	-0.0491	-0.0070	0.0158	0.0093	-0.0557	0.0129	-0.0155	0.0151	-0.0148	0.0173	-0.0155	0.0151
λ_3	0.1941	0.1031	0.0485	0.0979	0.2102	0.0481	0.0880	0.0491	0.0881	0.0499	0.0880	0.0491
$ \lambda_1 /\lambda_3$	0.2632	0.1950	0.2860	0.1873	0.2777	0.2684	0.1925	0.1234	0.1863	0.1114	0.1925	0.1234
Distance (Å)	3.930	2.187			3.883		2.308		2.298		4.598	

Table S8. Observed and calculated wavenumbers (cm^{-1}), potential energy distribution and assignment for the C_1 conformer of (5-chloro-quinolin-8-yloxy) acetic acid.

Mode	IR ^a Solid	Raman ^a solid	Calculated ^b	SQM ^c	IR int. ^d	Raman act. ^e	PED ($\geq 10\%$)
1	3149 vvw	3145 vvw	3312	3175	1074.3	294.7	S_1 (100)
2	3125 vvw	3130 vvw	3234	3100	6.5	150.3	S_3 (75) S_2 (23)
3	3100 w		3230	3096	1.3	143.2	S_7 (81) S_6 (18)
4		3098 vvw	3218	3085	7.7	135.6	S_2 (70) S_3 (24)
5	3069 w	3073 w	3214	3081	4.8	67.3	S_6 (81) S_7 (18)
6		3057 w	3188	3056	10.6	112.3	S_4 (93)
7		3006 vvw	3136	3006	13.5	85.8	S_9 (92)
8		2966 vw	3074	2946	18.4	72.1	S_8 (92)
9	1696 s	1687 vw	1863	1792	366.8	19.3	S_{13} (76)
10	1626 m	1646 vw	1661	1613	11.2	4.7	S_{17} (18) S_{18} (11) S_{48} (11)
11	1608 m	1610 vw	1647	1599	41.8	1.8	S_{23} (24) S_{21} (16)
12	1585 m	1579 m	1621	1575	2.9	102.9	S_{22} (11) S_{19} (11) S_{16} (11) S_{21} (10)
13	1505 vs	1491 vw	1549	1509	61.1	14.2	S_{16} (16) S_{22} (11) S_{30} (11)
14	1469 s	1470 vw	1512	1482	57.3	9.4	S_{29} (15) S_{30} (13) S_{18} (10)
15	1423 sh		1494	1433	21.7	12.5	S_{28} (78)
16	1417 m		1438	1408	81.3	89.2	S_{33} (23) S_{31} (18) S_{20} (12)
17	1395 sh	1398 m	1431	1402	95.6	3.7	S_{29} (22) S_{11} (21) S_{10} (10)
18	1386 m	1386 m	1416	1374	242.4	37.9	S_{41} (76) S_{28} (11)
19	1368 s	1367 s	1390	1353	11.1	94.9	S_{26} (24) S_{12} (17) S_{19} (10)
20	1324 s		1382	1340	9.1	10.1	S_{19} (23) S_{26} (11)
21	1280 s	1278 vvw	1343	1305	54.8	11.2	S_{23} (10)
22	1254 s	1255 vw	1302	1269	37.7	14.6	S_{40} (52)
23	1251 sh	1253 w	1277	1251	44.7	2.2	S_{10} (17) S_{29} (13) S_{40} (10)
24	1238 sh		1273	1238	50.3	0.7	S_{14} (14) S_{24} (12) S_{43} (11) S_{18} (11) S_{11} (10)
25		1219 vw	1264	1221	22.8	5.4	S_{12} (27) S_{26} (26) S_{25} (13)
26	1202 w	1202 vvw	1234	1207	30.6	1.6	S_{33} (27) S_{20} (19)
27	1176 vw	1174 vw	1187	1166	19.4	5.0	S_{30} (21) S_{31} (16) S_{17} (14) S_{34} (10)
28	1133 m	1131 w	1157	1131	12.8	6.1	S_{46} (17) S_{22} (16)
29	1107 s	1105 vvw	1112	1083	104.0	5.9	S_{22} (19) S_{15} (13) S_{46} (10)
30	1042 vw	1043 w	1071	1037	21.6	10.6	S_{16} (53)
31	996 w		1038	998	6.1	1.4	S_{15} (46) S_{46} (17)
32	981 w		1024	993	23.3	8.8	S_{53} (39) S_{52} (39) S_{60} (11) S_{54} (10)
33	954 sh	967 sh	1003	963	0.5	0.3	S_{54} (65) S_{52} (19)
34	948 sh	948 vw	974	961	0.4	1.8	S_{42} (50) S_{55} (15)
35	945 s		952	937	63.1	3.9	S_{50} (41) S_{49} (38)

Continued

36	913 vw	919 vw	946	925	9.7	1.9	S ₅ (16) S ₄₄ (13)
37	836 sh		876	851	21.2	6.8	S ₂₅ (24) S ₁₂ (14) S ₅₀ (14) S ₄₉ (13)
38	830 s	833 vw	852	839	18.5	2.3	S ₄₉ (28) S ₅₀ (25) S ₂₅ (11)
39	820 m	817 vw	834	817	38.3	1.8	S ₄₈ (24) S ₄₆ (13) S ₄₃ (13)
40	806 m		828	812	8.3	3.5	S ₅₃ (21) S ₅₂ (20) S ₆₀ (19) S ₅₄ (12)
41	783 s	785 vw	818	778	118.6	6.8	S ₆₀ (33) S ₅₇ (24) S ₆₁ (13)
42	760 s	761 w	798	737	28.1	2.8	S ₆₆ (81)
43	701 vw		737	720	15.9	17.0	S ₃₇ (12) S ₄₇ (11)
44		671 w	676	665	13.8	6.6	S ₄₇ (22) S ₄₄ (13) S ₆₀ (11)
45	654 vw	655 vvw	661	649	4.1	1.0	S ₆₀ (27) S ₅₆ (19) S ₃₇ (10)
46	631 w	633 vvw	634	624	10.8	0.8	S ₃₅ (32) S ₃₇ (12)
47	606 vw	600 vvw	622	601	2.7	2.2	S ₅₇ (24) S ₅₁ (23) S ₅₉ (13)
48	590 vw		582	572	2.1	5.9	S ₃₈ (27) S ₄₈ (12) S ₄₇ (11)
49	531 m	531 m	553	534	15.8	2.1	S ₅₅ (41) S ₄₂ (19)
50	520 vw	522 sh	536	528	5.7	9.1	S ₄₇ (16) S ₃₂ (16) S ₃₈ (10)
51	504 vw		510	503	6.3	8.1	S ₄₅ (35) S ₃₆ (14) S ₄₈ (11)
52		488 vvw	484	469	1.0	0.9	S ₆₁ (24) S ₅₉ (15)
53		457 m	472	457	0.6	1.7	S ₅₈ (21) S ₆₂ (17) S ₆₁ (10)
54		409 sh	430	416	1.4	1.7	S ₆₂ (44)
55		386 vw	398	388	0.01	2.5	S ₆₂ (15) S ₅ (13) S ₅₁ (11) S ₅₈ (11)
56		356 vvw	338	335	4.7	2.3	S ₃₆ (17) S ₃₇ (13)
57		278 w	308	312	3.2	1.7	S ₃₈ (21) S ₃₇ (18) S ₃₉ (14) S ₆₄ (13)
58		254 s	242	240	4.1	1.1	S ₃₇ (41) S ₃₈ (14) S ₃₆ (13)
59		216 w	228	225	4.8	4.6	S ₃₂ (30) S ₂₇ (11) S ₆₃ (10)
60		208 m	212	207	6.2	1.7	S ₂₇ (15) S ₃₂ (15) S ₆₃ (14) S ₆₁ (10)
61		173 w	179	168	4.6	0.2	S ₆₅ (31) S ₆₂ (13) S ₅₆ (13) S ₅₉ (11)
62		147 m	140	135	3.1	2.3	S ₆₁ (27) S ₆₃ (13) S ₆₆ (11) S ₅₈ (11)
63		92 s	99	88	2.2	1.3	S ₆₄ (34) S ₆₃ (32)
64		78 vs	92	87	2.3	0.4	S ₆₃ (43) S ₆₆ (19) S ₃₉ (12)
65			53	48	0.1	3.8	S ₃₉ (39) S ₆₆ (16) S ₆₃ (12)
66		20 vw	25	22	7.0	2.2	S ₆₃ (40) S ₆₄ (39) S ₃₉ (18)

^aThis work; ^bDFT B3LYP/6-31G*; ^cFrom scaled quantum mechanics force field; ^dUnits are km·mol⁻¹; ^eRaman activities in Å⁴ (amu)⁻¹.

Table S9. Observed and calculated wavenumbers (cm^{-1}), potential energy distribution and assignment for the C_{II} conformer of (5-chloro-quinolin-8-yloxy) acetic acid.

Mode	IR ^a Solid	Raman ^a Solid	Calculated ^b	SQM ^c	IR int. ^d	Raman act. ^e	PED ($\geq 10\%$)
1	3569 w		3711	3558	28.6	69.0	S ₁ (100)
2	3125 vvw	3130 vvw	3243	3109	0.7	148.4	S ₆ (88) S ₇ (11)
3	3100 w		3231	3097	6.1	123.9	S ₃ (83) S ₂ (16)
4		3098 vvw	3225	3092	3.1	79.7	S ₇ (87) S ₆ (12)
5	3069 w	3073 w	3212	3079	10.8	142.3	S ₂ (80) S ₃ (17)
6	3025 vvw	3028 vw	3167	3036	29.0	144.0	S ₄ (96)
7		2981 vw	3103	2974	4.6	63.1	S ₉ (99)
8		2943 vvw	3058	2931	53.6	125.6	S ₈ (99)
9	1892 m,br		1896	1823	158.1	6.6	S ₁₃ (82)
10	1626 m	1646 vw	1661	1613	8.1	5.8	S ₁₇ (19) S ₁₈ (11) S ₄₈ (10)
11	1608 m	1610 vw	1649	1600	38.9	0.8	S ₂₃ (24) S ₂₁ (17)
12	1585 m	1579 m	1616	1570	3.2	89.6	S ₂₂ (13) S ₂₁ (11) S ₁₆ (11)
13	1505 vs	1491 vw	1548	1508	52.4	11.6	S ₁₆ (17) S ₃₀ (14) S ₂₂ (12)
14	1469 s	1470 vw	1514	1480	38.7	4.6	S ₂₉ (18) S ₃₀ (10)
15		1431 vw	1504	1446	30.0	15.3	S ₂₈ (80)
16	1417 m		1437	1408	8.7	86.9	S ₃₃ (21) S ₃₁ (18) S ₂₀ (12)
17	1395 sh	1398 m	1430	1403	90.3	4.9	S ₂₉ (19) S ₁₁ (18) S ₄₁ (10)
18	1386 m	1386 m	1404	1390	33.3	4.7	S ₄₁ (60)
19	1324 s		1383	1336	35.6	107.3	S ₁₉ (29) S ₂₁ (14) S ₂₀ (13)
20		1317 vvw	1345	1305	15.9	4.6	S ₁₁ (10) S ₂₃ (10)
21	1280 s	1278 vvw	1318	1279	134.9	16.0	S ₄₀ (63)
22	1254 s	1255 vw	1298	1254	202.9	27.9	S ₂₆ (30) S ₁₂ (17) S ₄₀ (11)
23	1251 sh	1253 w	1274	1250	0.1	2.1	S ₁₀ (23) S ₂₉ (14) S ₄₃ (12) S ₃₁ (11)
24	1238 sh		1271	1234	202.1	2.2	S ₁₄ (12) S ₂₄ (11) S ₂₆ (10)
25	1202 w	1202 vvw	1233	1207	47.3	0.9	S ₃₃ (29) S ₂₀ (21)
26	1176 vw	1174 vw	1189	1167	37.2	4.9	S ₃₀ (20) S ₃₁ (16) S ₁₇ (12) S ₃₄ (12)
27	1133 m	1131 w	1165	1136	0.4	12.5	S ₁₅ (15) S ₄₆ (11)
28	1107 s	1105 vvw	1154	1112	39.8	2.8	S ₁₂ (31) S ₂₆ (27)
29	1107 s	1105 vvw	1121	1086	137.4	2.9	S ₁₅ (24) S ₂₂ (20)
30	1042 vw	1043 w	1072	1036	14.8	7.6	S ₁₆ (56)
31	1018 m	1012 vvw	1062	1029	11.6	4.6	S ₁₅ (30) S ₄₆ (25)
32	981 w		1033	991	13.6	0.7	S ₅₂ (42) S ₅₃ (38) S ₆₀ (10)
33	954 sh	967 sh	1001	967	0.6	0.3	S ₄₂ (51) S ₅₅ (17)
34	948 sh	948 vw	971	960	0.1	2.8	S ₅₄ (68) S ₅₂ (17)
35	945 s		949	939	1.0	2.6	S ₄₉ (42) S ₅₀ (41)

Continued

36	913 vw	919 vw	946	921	59.2	4.2	S ₅ (18) S ₄₄ (14) S ₄₆ (12) S ₄₃ (10)
37	836 sh		866	847	7.5	8.9	S ₅₀ (37) S ₄₉ (36) S ₅₆ (10)
38	830 s	833 vw	857	838	25.9	2.2	S ₂₅ (52) S ₃₇ (14)
39	820 m	817 vw	829	816	0.4	0.9	S ₄₈ (28), S ₄₃ (16), S ₄₆ (15), S ₄₅ (10), S ₂₄ (10)
40	806 m		825	809	14.5	1.5	S ₅₃ (23) S ₅₂ (21) S ₆₀ (20) S ₅₄ (12)
41	783 s	785 vw	796	774	26.0	2.1	S ₆₀ (38) S ₅₇ (23) S ₆₁ (13)
42	680 vw		716	699	19.7	17.1	S ₄₇ (20) S ₁₉ (11) S ₁₄ (11)
43		671 w	678	666	14.9	3.2	S ₆₀ (22) S ₅₆ (15) S ₂₇ (12) S ₃₅ (10)
44	654 vw	655 vvw	660	650	5.5	3.4	S ₄₇ (21) S ₄₄ (17) S ₅ (13)
45	631 w	633 vvw	639	624	7.1	1.2	S ₆₀ (25) S ₅₇ (22) S ₅₆ (10)
46	606 vw	600 vvw	616	595	5.5	1.3	S ₅₁ (24) S ₅₇ (16) S ₅₉ (15)
47	590 vw		578	569	6.1	6.2	S ₃₈ (29) S ₄₇ (17)
48	531 m	531 m	572	544	6.9	1.2	S ₅₅ (45) S ₄₂ (24)
49	520 vw	522 sh	530	522	9.8	10.3	S ₄₇ (21) S ₃₂ (20) S ₃₈ (11)
50	504 vw		499	490	8.7	2.1	S ₄₅ (26) S ₃₅ (13) S ₄₈ (11)
51		488 vvw	494	480	6.8	4.9	S ₆₁ (12) S ₄₈ (11) S ₄₅ (10) S ₅₉ (10)
52		457 m	475	460	6.1	1.3	S ₅₈ (27) S ₆₁ (19) S ₆₂ (16)
53		431 vw	437	415	85.7	1.5	S ₆₂ (50) S ₆₅ (9)
54		409 sh	429	399	0.5	2.8	S ₆₆ (61) S ₅₅ (17)
55		386 vw	396	385	0.8	3.6	S ₆₂ (13) S ₅ (12) S ₆₆ (11)
56		356 vvw	337	330	1.8	2.6	S ₅₁ (12) S ₆₁ (10) S ₃₆ (10)
57		278 w	320	314	2.6	1.2	S ₃₇ (18) S ₃₈ (16) S ₄₄ (10)
58		254 s	257	254	20.9	4.2	S ₃₆ (25) S ₂₇ (17) S ₃₇ (13) S ₆₁ (11)
59		216 w	221	219	1.4	3.0	S ₃₂ (72)
60		208 m	200	196	2.0	1.3	S ₃₇ (27) S ₃₈ (25) S ₃₆ (10)
61		173 w	187	174	3.8	0.5	S ₆₅ (42) S ₆₂ (17) S ₅₁ (12)
62		147 m	127	123	3.3	2.5	S ₆₁ (46) S ₅₈ (18) S ₆₂ (10)
63		92 s	107	102	4.0	2.0	S ₅₉ (40) S ₆₄ (16) S ₃₉ (15)
64		78 vs	60	54	7.2	1.1	S ₆₃ (49) S ₃₉ (16)
65			38	36	0.9	2.9	S ₆₃ (39) S ₆₄ (22) S ₂₇ (13)
66		20 vw	28	24	4.9	3.6	S ₃₉ (57) S ₆₄ (15) S ₃₈ (12)

^aThis work; ^bDFT B3LYP/6-31G*; ^cFrom scaled quantum mechanics force field; ^dUnits are km·mol⁻¹; ^eRaman activities in Å⁴ (amu)⁻¹.

Table S10. Observed and calculated wavenumbers (cm^{-1}), potential energy distribution and assignment for the C_{II} conformer of (5-chloro-quinolin-8-yloxy) acetic acid.

Mode	IR ^a Solid	Raman ^a Solid	Calculated ^b	SQM ^c	IR int. ^d	Raman act. ^e	PED ($\geq 10\%$)
1	3432 w,br		3694	3541	69.2	191.2	S ₁ (100)
2	3125 vvw	3130 vvw	3236	3102	8.0	143.8	S ₆ (80), S ₇ (19)
3	3100 w		3230	3096	7.4	117.4	S ₃ (84), S ₂ (14)
4		3098 vvw	3219	3086	7.1	66.8	S ₇ (80), S ₆ (19)
5	3069 w	3073 w	3209	3076	14.0	155.6	S ₂ (81), S ₃ (15)
6	3025 vvw	3028 vw	3168	3037	27.3	148.6	S ₄ (95)
7		2943 vvw	3057	2931	17.9	49.6	S ₉ (100)
8	2921 vw	2923 vw	3020	2895	40.2	110.8	S ₈ (99)
9	1854 m		1888	1814	228.8	5.0	S ₁₃ (81)
10	1626 m	1646 vw	1662	1614	10.1	5.3	S ₁₇ (19), S ₁₈ (11), S ₄₈ (10)
11	1608 m	1610 vw	1649	1601	66.6	2.2	S ₂₁ (24), S ₂₃ (17), S ₁₇ (11)
12	1585 m	1579 m	1617	1572	17.1	93.9	S ₂₂ (13)
13	1505 vs	1491 vw	1553	1513	61.4	14.1	S ₁₆ (18), S ₃₀ (12)
14	1469 s	1470 vw	1521	1485	2.6	7.4	S ₃₀ (13), S ₂₉ (12)
15		1431 vw	1508	1453	117.4	8.5	S ₂₈ (56), S ₄₁ (22)
16	1423 sh		1456	1431	20.1	17.1	S ₄₁ (37), S ₂₈ (34), S ₂₅ (12)
17	1395 sh	1398 m	1438	1407	5.6	98.8	S ₂₉ (29), S ₁₁ (11), S ₂₄ (10)
18	1386 m	1386 m	1426	1405	51.8	1.2	S ₃₁ (23), S ₃₃ (22), S ₂₀ (13)
19	1368 s	1367 s	1398	1350	120.6	151.8	S ₁₉ (22), S ₂₁ (18), S ₂₀ (13), S ₂₃ (13)
20	1324 s		1359	1320	43.3	7.0	S ₁₄ (16), S ₃₄ (14), S ₁₉ (13)
21	1280 s	1278 vvw	1337	1289	44.9	4.3	S ₂₆ (32), S ₁₂ (17), S ₃₅ (14), S ₄₁ (13)
22	1254 s	1255 vw	1295	1259	184.9	0.7	S ₁₀ (24)
23	1251 sh	1253 w	1281	1252	4.2	4.3	S ₁₁ (18), S ₄₃ (16), S ₁₄ (10)
24	1251 sh	1253 w	1269	1251	1.8	11.4	S ₄₀ (98)
25		1219 vw	1238	1212	15.4	2.7	S ₃₃ (30), S ₂₀ (20), S ₁₈ (13)
26	1176 vw	1174 vw	1206	1180	6.8	2.7	S ₃₀ (14), S ₄₆ (12), S ₃₁ (12), S ₃₄ (10), S ₁₅ (10)
27	1133 m	1131 w	1173	1143	135.2	3.2	S ₁₅ (19), S ₃₀ (16), S ₁₇ (11)
28	1107 s	1105 vvw	1163	1128	46.3	2.0	S ₂₂ (21), S ₂₆ (15), S ₁₂ (14)
29	1107 s	1105 vvw	1143	1104	376.5	1.4	S ₁₂ (29), S ₂₆ (21), S ₂₂ (10)
30	1042 vw	1043 w	1070	1035	9.7	9.2	S ₁₆ (59)
31	1018 m	1012 vvw	1054	1029	14.8	2.5	S ₁₅ (30), S ₄₆ (28)
32	981 w		1053	991	0.1	0.1	S ₅₃ (41), S ₅₂ (35), S ₅₄ (12), S ₆₀ (11)
33	954 sh	967 sh	1001	962	0.5	0.3	S ₄₂ (75), S ₅₅ (21)
34	948 sh	948 vw	970	959	0.2	2.3	S ₅₄ (66), S ₅₂ (23)
35	945 s		947	926	54.2	2.5	S ₅ (18), S ₄₆ (17), S ₄₃ (15), S ₄₄ (12)

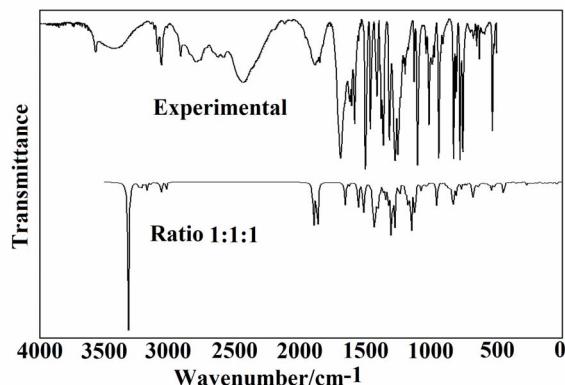
Continued

36	913 vw	919 vw	924	915	0.3	2.4	S ₅₀ (59), S ₄₉ (27)
37	836 sh		910	884	4.5	15.5	S ₂₅ (46), S ₃₇ (16), S ₂₇ (13)
38	830 s	833 vw	833	818	2.0	1.1	S ₄₈ (27), S ₄₆ (15), S ₄₃ (14), S ₂₄ (11)
39	820 m	817 vw	830	818	45.4	0.6	S ₄₉ (46), S ₅₀ (15), S ₅₆ (12)
40	806 m		824	809	0.4	2.6	S ₅₃ (23), S ₅₂ (23), S ₆₀ (16), S ₅₄ (12)
41	783 s	785 vw	799	777	27.0	1.6	S ₆₀ (41), S ₅₇ (22), S ₆₁ (14)
42	760 s	761 w	762	742	44.6	10.1	S ₄₃ (13)
43		671 w	673	655	98.1	1.3	S ₄₇ (40), S ₄₄ (21)
44	631 w	633 vvw	665	632	18.0	11.2	S ₆₀ (37), S ₅₇ (23), S ₅₆ (23)
45	631 w	633 vvw	649	620	7.3	0.9	S ₃₅ (28), S ₄₈ (17), S ₅ (12), S ₄₅ (11)
46	613 vw	613 vvw	630	619	16.4	0.5	S ₆₆ (42), S ₅₅ (34), S ₄₂ (14)
47	606 vw	600 vvw	610	597	0.3	2.9	S ₃₈ (26), S ₃₅ (11), S ₄₇ (11), S ₄₈ (10)
48	590 vw		604	585	6.3	1.5	S ₅₁ (26), S ₅₉ (18), S ₆₅ (12), S ₅₆ (12), S ₅₇ (10)
49	520 vw	522 sh	535	526	8.5	12.5	S ₄₇ (29), S ₃₂ (15), S ₄₄ (11), S ₂₀ (10)
50	504 vw		530	508	28.4	6.8	S ₄₅ (32), S ₃₅ (15), S ₄₈ (14)
51	504 vw		514	495	27.1	6.8	S ₆₆ (45), S ₅₅ (35), S ₄₂ (14)
52		457 m	478	463	0.02	0.3	S ₆₁ (30), S ₅₈ (22), S ₅₉ (11), S ₆₂ (10)
53		431 vw	444	439	6.8	2.4	S ₃₆ (28), S ₄₅ (21), S ₂₇ (13)
54		409 sh	434	418	0.1	3.0	S ₆₂ (57), S ₆₅ (13)
55		386 vw	387	378	3.0	2.5	S ₅ (28), S ₄₄ (20), S ₂₇ (10)
56		356 vvw	354	346	0.3	0.7	S ₅₁ (26), S ₅₈ (16), S ₆₂ (16), S ₆₁ (13)
57		254 s	256	252	0.5	5.0	S ₃₂ (21), S ₂₇ (12), S ₃₈ (10)
58		216 w	225	223	0.5	3.8	S ₃₆ (20), S ₃₇ (19), S ₃₈ (15), S ₃₂ (13), S ₄₅ (10)
59		208 m	203	199	0.4	0.5	S ₃₂ (35), S ₃₇ (17)
60		173 w	202	188	1.1	1.5	S ₆₅ (38), S ₅₁ (16), S ₃₉ (15)
61		147 m	143	135	2.9	0.6	S ₆₁ (26), S ₅₉ (25), S ₆₂ (13), S ₃₉ (12)
62		92 s	127	116	2.4	1.4	S ₃₉ (22), S ₆₄ (22), S ₆₃ (16), S ₅₉ (15)
63		92 s	114	109	4.5	1.2	S ₅₈ (33), S ₆₁ (28)
64		78 vs	80	80	1.7	0.2	S ₂₇ (34), S ₃₇ (30), S ₃₈ (17)
65			36	33	0.4	2.7	S ₆₄ (53), S ₃₉ (38)
66		20 vw	28	25	1.2	0.4	S ₆₃ (55), S ₆₄ (14), S ₅₅ (11)

^aThis work; ^bDFT B3LYP/6-31G*; ^cFrom scaled quantum mechanics force field; ^dUnits are km·mol⁻¹; ^eRaman activities in Å⁴ (amu)⁻¹.

Table S11. The frontier molecular HOMO and LUMO orbitals for both conformers of (5-chloro-quinolin-8-yloxy) acetic acid.

Orbital	2-(quinolin-8-yloxy) acetic acid ^a					
	C _I	C _{II}	C _{III}	C _I	C _{II}	C _{III}
	6-31G*	6-311++G**	6-31G*	6-311++G**	6-31G*	6-311++G**
HOMO (53)	-0.23736	-0.25313	-0.22271	-0.23632	-0.21430	-0.22804
LUMO (54)	-0.07379	-0.08994	-0.05684	-0.07351	-0.04592	-0.06262
GAP (a.u.)	-0.16357	-0.16319	-0.16587	-0.16281	-0.16838	-0.16542
GAP (eV)	-4.45090	-4.44056	-4.51349	-4.43022	-4.58179	-4.50124
(5-chloro-quinolin-8-yloxy) acetic acid ^b						
Orbital	C _I	C _{II}	C _{III}	C _I	C _{II}	C _{III}
	6-31G*	6-311++G**	6-31G*	6-311++G**	6-31G*	6-311++G**
HOMO (61)	-0.24054	-0.25452	-0.22653	-0.23905	-0.22653	-0.23103
LUMO (62)	-0.08310	-0.09854	-0.06683	-0.08283	-0.06683	-0.07230
GAP (a.u.)	-0.15744	-0.15598	-0.15970	-0.15622	-0.15970	-0.15873
GAP (eV)	-4.28410	-4.24443	-4.34566	-4.25096	-4.34570	-4.31926

^aThis work, ^bFrom Ref [37].**Figure S1. Comparison between the infrared experimental spectrum of (5-chloro-quinolin-8-yloxy) acetic acid (upper) with the calculated infrared spectra (bottom) for C_I, C_{II} and C_{III} conformers from B3LYP/6-31G* wavenumbers and intensities using Lorentzian band shapes (for a population relation C_I, C_{II} and C_{III} of 1:1:1 for each conformer).**