

JOURNAL OF DYNAMICS

AND CONTROL

VOLUME 8 ISSUE 11

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Abstract: (s)-2-amino-1-(6-amino-9H-purin-9-yl)-3-(4-hydroxyphenyl) propan-1-one (TYADE) was designed and the conformational analysis of TYADE is carried out by Density Functional Theory (DFT) methods using 6-31 G (d, p) basis set by Gaussian 03 program. The IR frequencies of TYADE were analysed by means of potential energy distribution (PED%) calculation using the vibrational energy distribution analysis (VEDA 4) program. ¹³C and ¹H chemical shift calculations of the molecule TYADE have been made using the same basis set. Nonlinear optical behaviour of the TYADE is also predicted by the values of dipole moment (μ), mean polarizability (α), and first hyperpolarizability (β tot). The stability of the TYADE molecule has been analysed using Natural Bond Orbital (NBO) analysis. Determination of various global and local reactivity descriptors in the context of chemical reactivity is also performed, and the electrophilicity at the vital atomic sites in TYADE is revealed. Bader's Atoms in Molecule (AIM) Theory of TYADE indicated the presence of intramolecular bonding in the molecule. The molecular electrostatic potential (MEP) and HOMO-LUMO orbital analysis are also performed for the molecule TYADE.

Keywords: DFT, IR, AIM, NBO, HOMO-LUMO

1.Introduction

Tyrosine is an indispensable amino acid that easily passes the blood brain barrier (BBB) [1] It is the pioneer for hormones, catechol estrogens, thyroid and melanin. It is a significant amino acid in many peptides, proteins and a natural painkiller. Adenine has functions in protein synthesis and as a chemical component of DNA and RNA. In DNA it binds with thymine through two hydrogens and in RNA it binds with uracil via two hydrogens. It is used to treat acute myeloid leukemia in children. Adenine combine with the sugar ribose to form adenosine which can be bonded with from one to three phosphoric acid units, yields AMP, ADP and ATP. Adenosine causes transient heart block in the AV node of the heart.

The present study aims to investigate the theoretical calculations of TYADE molecule with Density Functional Theory (DFT) by B3LYP level available in Gaussian 03 software.

2. Computational techniques

All the computational studies are carried out at the density functional theory level using Gaussian 03W software. DFT calculations lead to good accuracy and are less time-consuming [2]. The calculations are carried out with Becke's three-parameter exchange functional with the LYP correction (B3LYP), and the basis set 6-31G (d, p) is used in appropriate calculations. The computational work has begun with the conformational analysis of the compounds. IR vibrational frequencies of the molecule are interpreted by means of potential energy distribution (PED%) calculation using the Vibrational Energy Distribution Analysis (VEDA) program. The normal modes assignment of the theoretical IR frequencies is envisioned and validated with the help of the Gauss View 5.0 visualization program. The gauge-independent atomic orbital (GIAO) method. ¹³C and ¹H chemical shift calculations of the molecule TYADE have been made using the same basis set and the scaling factors used at this level are 31.8821 ppm for ¹H NMR and 182.466 ppm for ¹³C NMR chemical shift calculations. The polarizability calculation was done by the DFT method with a route section (polar = enonly). The dipole moment (μ), the mean polarizability (α), and the first hyperpolarizability (β_{tot}) are directly related to the nonlinear optical efficiency of structures. In NBO analysis, the second-order delocalization energies E (2) are representative of the extent of electron delocalization. The larger the E(2) value, the greater the extent of the conjugation of the whole system. The NBO calculation of the molecule and its anionic form are

performed at the same level of computation, and the change in the hybridization during anion formation is discussed. The determination of various global and local reactivity descriptors in the context of chemical reactivity is also performed, and the electrophilicity at the vital atomic sites of the molecule is revealed. The molecular electrostatic potential (MEP) surface has been plotted for the molecule TYADE. Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) pictures are drawn, and the HOMO-LUMO energy gap is calculated.

3. Results and discussion

3.1. Geometry Optimization

Tyrosine and adenine structure are constructed using Gauss view 5 software. Both the structures are combined in the manner with fukui function values of electrophilic and nucleophilic sites with the elimination of water molecule. A positive Δf value for N10 atomic site of adenine indicating that the nitrogen (N10) site is favorable for nucleophilic attack and a negative Δf value for O3 atomic site of tyrosine indicating that the oxygen (O3) atomic site is favorable for electrophilic attack. By considering these values of Δf , the Tyrosinyl-9-adenine (TYADE) molecule is constructed using Gauss view 5 software. The numbering adopted for Tyrosinyl-9-adenine in this study is given in Figure 1. The molecule is set off with the optimization of the conformers A Figure.2 and B Figure.3 in which the dihedral angle of C18-C19-O20-H20 is 0⁰ and 180⁰ respectively. The molecular geometry of A and B are optimized to minimum with the Gaussian 03 program within the DFT approach using B3LYP method with 6-31 G (d,p) basis set [3].The conformer B is found to be the stable conformer which is justify with the heat of formation values. The relative energies of conformer A and B are 2.7 x 10⁻³ a.u and 0 a.u respectively. The selected geometric parameters of bond length, bond angle and torsional angle of the minimum energy optimized geometry of conformer B are given in Table.1.



Figure 1. Numbering of the molecule TYADE



Figure. 2 Optimized Conformer A Figure.3 Optimized conformer B Table 1: Selected geometric parameters Bond length(Å), bond angle (⁰) and torsion angle (⁰) of the molecule TYADE computed by DFT method (B3LYP/6-31G(d,p))

Bond	Bond length(Å)	Bonds	Bond angle(°)	Bonds	Torsional angle(°)
C4-H4	1.09	H4-C4-C5	115.3	C2-N10-C11-012	-14.891
C6-N7	1.36	H4-C4-C3	115.7	H(7a)-N7-C6-N5	10.1
N7-H(7a)	1.01	H(7a)-N7-C6	118	H(7b)-N7-C6-C1	-11.03
N7-H(7b)	1.01	H(7b)-N7-C6	119.3	H(7a)-N7-C6-C1	-171.1

С9-Н9	1.08	H9-C9-N8	125.8	H(7b)-N7-C6-C5	170.1
N10-C11	1.42	H9-C9-N10	120.2	N7-C6-C1-N8	1.34
C11-O12	1.21	C11-C13-C15	110.8	H9-C9-N10-C11	-3.44
C11-C13	1.54	O12-C11-N10	121	C9-N10-C11-O12	163.9
C13-N14	1.47	O12-C11-C13	123	O12-C11-C13-H13	141.2
C13-H13	1.1	H13-C13-C15	108.3	O12-C11-C13-N14	-103.7
C13-C15	1.55	C13-C15-H(15b)	108.4	O12-C11-C13-C15	22.7
N14-H(14a)	1.02	C13-C15-H(15a)	106.6	H13-C13-C15-C16	-45.5
N14-H(14b)	1.02	N14-C13-C11	106.6	H13-C13-C11-O12	141.2
C15-H(15a)	1.1	N14-C13-H13	107.2	H13-C13-C15-H(15a)	75.3
C15-H(15b)	1.1	H(14a)-N14-C13	109.7	H13-C13-C15-H(15b)	-169.37
C15-C16	1.51	H(14b)-N14-C13	109.5	H(14a)-N14-C13-C11	65.4
C17-H17	1.09	H(15a)-C15-C16	109.4	H(14a)-N14-C13-H13	-178.9
C18-H18	1.08	H(15b)-C15-C16	110.7	H(14b)-N14-C13-H11	-62.3
C19-O20	1.37	C15-C16-C17	120.4	H(14b)-N14-C13-C11	-178
O20-H20	0.97	C15-C16-C22	121.7	H(15a)-C15-C16-C17	-33.2
C21-H21	1.09	H20-O20-C19	109	H(15b)-C15-C16-C22	29.9
C22-H22	1.09	O20-C19-C18	117.5	H(15b)-C15-C16-C17	-151.3
		O20-C19-C21	122.9	H(15b)-C15-C16-C22	147.9
				C15-C16-C17-H17	1.84
				C15-C16-C22-H22	-0.41
				H18-C18-C19-O20	-0.24
				H20-O20-C19-C21	0.5
				H20-O20-C19-C18	-179.8

3.2. Vibrational Analysis

The molecule TYADE consists of 36 atoms and hence 102 normal modes of vibrations. The molecule belongs to C1 symmetry. All the modes are IR active. The theoretical vibrational spectra of TYADE have been calculated using DFT method with 6-31 G (d,p) basis set. The calculated IR frequencies are scaled by a factor 0.9614. In addition, theoretical IR vibrational spectra are interpreted by potential energy Distribution (PED%) calculation using vibrational energy distribution (VEDA) program [4]. The normal modes assignment of the theoretical IR frequencies is pictured and validated with Gauss view 5.0 program. The normal modes are given in order of decreasing wavenumber in Table.2. None of the calculated vibrational IR frequencies have any negative frequencies, shows that the optimized structure is locate at the ground state energy and theoretical IR spectra of the molecule is picturized in Figure.4.

The aromatic C-H starching frequencies appear in the range of 3100-3000 cm⁻¹ [5]. The ring C-C stretching vibrations occur in the region 1650-1400 cm⁻¹ [6]. In this study, the mode numbers 94 and 92 corresponds to the theoretical aromatic C-H stretching vibrations. The higher PED% of C-H vibrations in these modes with scaled frequencies ranging from 3058-3044 cm⁻¹, predicts the purity of this aromatic C-H starching vibration in this zone. The aromatic C-C stretching vibrations are found in the mode numbers 87- 77 and scaled frequencies ranging from 1610-1424 cm⁻¹. The aromatic C-C bending vibrations are generally observed in the region 1000-1300 cm⁻¹ [7]. The scaled frequencies 1500,1424,1316,1159,1149 and 1087 (mode no. 81,77,71,61,59 and 57) exhibit the aromatic C-C-H bending vibrations. The ring C-C-C bending vibrations at scaled frequencies are observed in 760,307 and 241cm⁻¹ (mode no. 39,17,13). The carbonyl stretching C=O vibration normally occurs in the region 1715-1680 cm⁻¹. In theoretical investigation the carbonyl C=O stretching vibration observed in the vibration mode 88 with the scaled frequency of 1753 cm⁻¹. The free O-H stretching vibration is generally occur in the range of 3610-3645 cm⁻¹. In theoretical

observation the O-H starching vibration observed in the vibrational mode 102 with the scaled frequencies 3673 cm⁻¹. The higher PED% of the free O-H vibration predicts the purity of this O-H stretching vibration in this region. Generally, the amino group N-H suffer stretching vibration in the region 3400-3500 cm⁻¹ [8]. In theoretical investigation N-H asymmetrical vibration observed in vibrational mode 101 with scaled frequency 3608 and N-H symmetric vibration observed in vibration mode 100 with scaled frequency 3475 cm⁻¹. The C-H stretching vibrations observed in the range 2800-310 cm⁻¹ [9]. In theoretical observed the C-H symmetrical stretching vibration occur in the vibration mode 89 with the scaled frequency 2924 cm⁻¹.



Figure 4. Predicted IR spectra of TYADE

Table 2: Vibrational	wavenumbers	obtained for	the molecule	TYADE at	B3LYP/6-31G (d	,p) level of
calculations.						

MODE No.	Theoretical frequencies (cm ⁻¹) DFT/B3LYP/6-31G(d,p)		Vibrational assignment PED ≥10%
	Unscaled frequencies	Scaled frequency scaling factor = 0.9614	-
102	3821.13	3673.63	$v_{O20-H20}(100\%)$
101	3753.68	3608.79	$v_{asN7-H(7a)}(48\%) + v_{asN7-H(7b)}(52\%)$
100	3615.34	3475.79	$v_{sN7-H(7a)}(52\%) + v_{sN7-H(7b)}(48\%)$
94	3181	3058.21	$v_{C4-H4}(100\%)$
92	3166.3	3044.08	$v_{sC17-H 17}(38\%) + v_{sC17-H 17}(59\%)$
89	3042.02	2924.6	$v_{sC15-H(15a)}(82\%) + v_{sC15-H(15b)}(17\%)$
88	1823.73	1753.33	$v_{012-C11}(89\%)$
87	1675.54	1610.86	$\frac{\nu_{sC2-C1}(12\%) + \nu_{sN7-C6}(18\%)}{\beta_{C6-N5-C4}(11\%) + \beta_{H(7b)-N7-H(7a)}(25\%)}$
86	1674.47	1609.84	$v_{C17-C18}(23\%) + v_{C22-C21}(12\%) + v_{C18-}$ C19(11%)
85	1666.84	1602.5	$\begin{array}{c} \beta_{H(14a)-N14-H(14b)}(73\%) \\ \tau_{H(14a)-N14-C13-C15}(11\%) + \tau_{H(14b)-N14-C13-C15}(10\%) \end{array}$
83	1629.43	1566.53	$v_{N5-C6}(21\%)$ $\beta_{N3-C2-C1}(13\%)$
81	1561.22	1500.96	$ \begin{array}{ c c c c c c c c } \beta_{H22-C22-C21}(15\%) + \beta_{H(18)-C18-C17}(10\%) \\ \beta_{H17-C17-C16}(15\%) + \beta_{H21-C21-C19}(16\%) \\ \beta_{C21-C19-C18}(11\%) \end{array} $

80	1553.22	1493.27	$v_{N8-C9}(54\%)$
			β _{H9-C9-N8} (13%)
79	1512.82	1454.43	$v_{\text{N5-C6}}(18\%) + v_{\text{N7-C6}}(16\%)$
			$\beta_{H(7a)-N7-H(7b)}(15\%) + \beta_{H4-C4-N5}(31\%)$
77	1482.08	1424.87	$v_{C17-C18}(13\%) + v_{C22-C21}(11\%)$
			β _{H18-C18-C17} (11%)
76	1437.9	1382.4	$v_{C2-C1}(17\%)$
			$\beta_{\text{H4-C4-N5}}(12\%) + \beta c_{2\text{-C1-N8}}(10\%)$
74	1394.38	1340.56	$\beta_{H13-C13-N14}(11\%) + \tau_{H13-C13-C11-}$
			_{N10(} 37%)
73	1380.11	1326.84	β _{H4-C4-N5} (10%)
			$\tau_{H13-C13-C11-N10}(13\%)$
72	1377.06	1323.91	$v_{c22,c21}(13\%) + v_{c16,c22}(13\%) + v_{c18}$
			(12%)
			$\beta_{H20-O20-C19}(20\%) + \beta_{H22-C22-C21}(10\%)$
			β _{H17} -C17-C16(14%)
71	1368.86	1316.02	$v_{N3-C2}(12\%) + v_{N5-C4}(18\%)$
			$v_{\rm N8-C1}(19\%)$
			$\beta_{H4-C4-N5}(19\%)$
69	1346.48	1294.51	$v_{N3-C2}(17\%) + v_{N5-C6}(12\%)$
			$v_{N5-C4}(27\%)$
66	1308.8	1258.28	$v_{C17-C18}(10\%) + v_{O20-C19}(49\%)$
65	1281.13	1231.68	$v_{\rm N10-C11}(20\%)$
			$\beta_{N8-C9-N10}(15\%)$
64	1241.08	1193.17	$v_{N3-C4}(12\%) + v_{N8-C1}(22\%)$
			$\beta_{(H7a)-N7-C6}(15\%) + \beta_{H9-C9-N8}(15\%)$
62	1223.01	1175.8	$v_{N10-C9}(50\%)$
61	1206.34	1159.78	$\beta_{\text{H20-O20-C19}}(21\%) + \beta_{\text{H(15a)-C15-C16}}(16\%)$
59	1195.96	1149.8	
			$\beta_{\text{V18-C19}}(13.\%)$ $\beta_{\text{V19-C19}}(10\%)$
57	1130.97	1087 31	(120') + (120') + (100')
57	1150.97	1007.51	$V_{C17-C18}(13\%) + V_{C22-C21}(10\%)$
			$p_{H22-C22-C21}(10\%) + p_{H18-C18-C17}(17\%)$
54	1064 48	1023 39	$p_{H17-C17-C16}(1070)$
0.	100	1020103	$(C_{13}-C_{15})$ $(C_{13}-C_$
49	955.64	918.75	
			$\beta_{\mu(15_0)} C_{15} C_{15} (10\%)$
47	931.92	895.95	$\frac{\beta_{\rm H}(13a) - C13 - C10(10707)}{\beta_{\rm H}(12a) - \beta_{\rm H}(12a)} = \frac{\beta_{\rm H}(12a)}{\beta_{\rm H}(12a)} + \frac{\beta_{\rm H}(12a)}{\beta_{\rm H}(12$
	007.00	0/0/0	$p_{O12-C11-N10}(12\%) + p_{N8-C9-N10}(22\%)$
46	897.69	863.04	$\beta_{N5-C4-N3}(26\%)$

45	873.21	839.5	$v_{C13-C15}(10\%)$
			$\tau_{H(14a)-N14-C13-C15}(18\%) + \tau_{H(14b)-N14-C13-C15}(18\%)$
			_{C15} (14%)
42	839.5	807.1	$\tau_{\rm H18-C18-C19-C21}(29\%) + \tau_{\rm H17-C17-C16-}$
			_{C15} (25%)
39	791.42	760.87	$v_{O20-C19}(12\%) + v_{C15-C16}(12\%)$
			$\beta_{C16-C22-C21}(11\%)$
38	762.91	733.46	OUT _{012 C13 N10 C11} (32%)
35	691.82	665.12	$v_{C11-C13}(17\%)$
			OUT _{N7 C1 N5 C6} (12%)
32	656.45	631.11	$\tau_{H9-C9-N8-C1}(10\%) + \tau_{C1-N8-C9-N10}(42\%)$
20	359.94	346.05	$\tau_{\rm H20-O20-C19-C18}(90\%)$
17	319.53	307.2	β _{C15-C16-C22} (10%)
			$\tau_{\rm H(14b)-N14-C13-C15}(14\%)$
16	313.08	300.1	$\tau_{H(14a)-N14-C13-C15}(14\%) + \tau_{H(14b)-N14-C13-C15}(14\%)$
			_{C15} (13%)
			$\tau_{C6-N5-C4-N3}(12\%) + \tau_{C2-C1-N8-C9}(17\%)$
			OUT _{N3 N10 C1 C2} (11%)
14	285.74		β _{N7-C6-N5} (32%)
13	251.19	241.49	$\beta_{C15-C16-C22}(11\%) + \beta_{C11-C13-C15}(12\%)$
			$\tau_{H(7a)-N7-C6-C1}(12\%) + \tau_{H(7b)-N7-C6-}$
			_{C1} (14%)
12	249.4	239.77	$ au_{ m H(7b)-N7-C6-C1}(20\%) + au_{ m C4-N3-C2-}$
			_{N10} (14%)
11	218.48	210.05	$\beta_{N14-C13-C11}(16\%) + \beta_{N10-C11-C13}(24\%)$
10	215.88	207.55	$\tau_{H(7a)-N7-C6-C1}(13\%) + \tau_{C4-N3-C2-}$
			_{N10} (29%)
			$OUT_{N3 N10 C1 C2}(10\%)$

3.3. ¹³C and ¹H NMR Analysis

NMR spectroscopy is the key to reveal the conformational analysis of organic molecule. Good quality geometries must be taken into consideration for the quantum calculation of the absolute isotropic magnetic shielding tensors to yield more reliable results. There are many reports on NMR isotropic magnetic shielding tensor calculations employing the GIAO [10]. The GIAO ¹H NMR and ¹³C NMR chemical shift calculations of the stable conformer is made in CDCl3 [scrf= (solvent=chloroform)] by using B3LYP / 6 – 31G (d,p) basis set. The computed chemical shift values ¹H and ¹³C NMR [11] are tabulated Table.3.

Table 3: Computational ¹H and ¹³C NMR spectral analysis of the molecule TYADE in CDCl3 phase by DFT method

Proton	Calculated chemical Shifts (ppm)	Carbon	Calculated chemical shift (ppm)
H4	8.68	C1	124.8
N-H(7a)	5.19	C2	156.6

N-H(7b)	5.55	C4	163.6
H9	9.14	C6	160.9
H13	4.04	C9	147.3
N-H(14a)	1.62	C11	179.4
N-H(14b)	1.65	C13	67.3
H(15a)	2.74	C15	46.2
H(15b)	3.74	C16	136
H17	7.53	C17	135.8
H18	7.2	C18	118.9
O-H20	4.9	C19	162.9
H21	6.89	C21	117.6
H22	7.83	C22	138

3.4. Hyperpolarizability

The calculated values of the dipole moment (μ), the polarizability (α) and first hyperpolarizability (β_{tot}) are given in Table.4. The highest value of dipole moment is observed for the component μ_y [12]. The molecule TYADE is found to be polar molecule having non-zero dipole moment components. The calculated polarizabilities α_{ij} have non-zero values and are conquered by the diagonal components. The β_{tot} value of the molecule TYADE is found to be 553.33 x 10⁻³³ esu. Delocalization of charges in particular directions is indicated by large values of those particular components of polarizability and hyperpolarizability. First order hyperpolarizability is dominated by β_{xxx} value. Thus, the delocalization of the charges in the presence of external field is recognized in those directions. The calculated values of α_{ij} and β_{ijk} are converted into electrostatic units from atomic units. (α : 1 a.u = 0.1482 x 10⁻²⁴ esu; β : 1 a.u = 8.6393 x 10⁻³³ esu) The first hyperpolarizability (β_{tot}) of the molecule is 1.5 times greater than that of urea (0.3728 *10⁻³⁰), hence this molecule can have considerable NLO activity.

$\mu = (\mu_x^2 + \mu_y^2 + \mu_z^2)^{1/2}$	(1)
$<\alpha>=1/3 (\alpha_{xx} + \alpha_{yy} + \alpha zz)$	(2)
$\beta_{\text{tot}} = \left[\left(\beta_{xxx} + \beta_{xyy} + \beta_{xzz} \right)^2 + \left(\beta_{yyy} + \beta_{yzz} + \beta_{yxx} \right)^2 + \left(\beta_{zzz} + \beta_{zxx} + \beta_{zyy} \right)^2 \right]^{\frac{1}{2}}$	(3)

Table 4 The electric dipole moment μ , the mean polarizability α (x 10 ⁻²⁴ esu) and the first hyperpolarizability β tot (x 10 ⁻³³ esu) of the molecule by DFT method

Parameter	Value	Parameter	value
μx	0.23	βxxx	330.38
μ _y	0.89	βxxy	111.33
μz	-0.60	βхуу	22.83
μ	1.098	βууу	116.93
αχχ	204.24	βxxz	100.61
αχγ	12.52	βxyz	4.60
αуу	192.85	βyyz	58.63
αχΖ	3.41	βxzz	87.99
αyz	-23.25	βyzz	44.11
αzz	158.59	βzzz	33.97
(α)	185.23	βtot	553.33

 α :1 a.u = 0.1482 x 10⁻²⁴ esu β : 1 a.u = 8.6393 x 10⁻³³ esu

3.5. NBO analysis

The natural bond orbital (NBO) analysis of the molecule is performed at B3LYP / 6 - 31G (d,p) basis set [13]. The donor bonding orbitals (BD), the acceptor antibonding orbitals (BD*), the donor lone pair atoms (LP) are given in Table 5 along with the E (2) values which estimates the interaction between the donor (filled) and acceptor (vacant) orbitals. The E (2) energy is the lowering energy that occurs during the hyper conjugative electron transfer process and hence E (2) can be referred to as stabilization energy. Larger the E (2) values, greater is the stability of the molecule. In the NBO analysis, the E (2) values are greater for the delocalization of the electrons between the bonds (C6-N5 to C4-N3) present in the phenyl ring is 37.76 kcal/mol. The E (2) values for the delocalization of electrons from C16-C22 to C17-C18, C17-C18 to C21-C19 and C21-C22 to C16-C22 are 22.62 kcal/mol, 21.89 kcal/mol and 22.41 kcal/mol respectively. Meanwhile the delocalization energy of electron density from C1-C2 to C6-C5, C6-C5 to C4-C3 and C4-C3 to C1-C2 are 30.39kcal/mol, 37.76 kcal/mol and 30.37 kcal/mol respectively. There is also interaction between the lone pair of electrons in the O12, O20, N7 and N10 atoms and the nearest antibonding orbitals. The delocalization of lone pair of electrons from O12-C13-C11 and C11-N10 are 20.39 kcal/mol and 30.69 kcal/mol respectively. The delocalization of lone pair of electrons from O20 to C21-C19 is 28.98 kcal/mol. Similarly, the delocalization of lone pair of electrons from N10 to C11-O12, C9-N8, C1-C2 are 40.22 kcal/mol, 38.31 kcal/mol and 34.07 kcal/mol. The highest energy E (20.53 kcal/mol is observed for the delocalization of lone pair of electrons from N7 to C6-N5. This indicates the presence of strong electrostatic interactions N7 lone pair with C6-C5 bond in the molecule.

Donor NBO (i)	Occupancy	Acceptor NBO(j) BD*	Occupancy	E(2) in kcal/mol
(BD) C16-C22	3.64	C17-C18	0.35	22.62
(BD) C17-C18	3.68	C21-C19	0.42	21.89
(BD) C21-C19	3.63	C16-C22	0.38	22.41
(BD) C1-C2	3.62	C6-N5	0.48	30.39
(BD) C6-N5	3.68	C4-N3	0.40	37.76
(BD) C4-N3	3.73	C1-C2	0.47	30.37
(LP) O12	1.98	C13-C11	0.07	20.39
(LP) O12	1.86	C11-N10	0.09	30.69
(LP) O20	3.85	C21-C19	0.42	28.98
(LP) N7	1.75	C6-N5	0.48	53.00
(LP) N10	1.57	C11-O12	0.17	40.22
(LP) N10	1.57	C9-N8	0.27	38.31
(LP) N10	1.57	C1-C2	0.47	34.07

Table 5: Second order perturbation theory analysis of fock matrix in NBO basis for TYADE

BD- Bonding orbital, LP – Lone pair, BD* - Anti bonding orbital.

3.6. Electrochemical analysis of TYADE

The anionic form of the molecule TYADE is optimized at B3LYP/6-31 G ++ (d,p) level. In the anionic form of the molecule, the bond length of C6-C7, C11-O12 and C13-C11 are noticeable varied that C6-C7, C11-O12 and C13-C11 bond length in the neutral molecule. The bond C11-O12 is more elongated in anionic form of the molecule. The bond C6-C7 is also lengthened in anionic form of the molecule. The lengthening of C11-O12 bond in anion may be due to the conversion of C11-O12 double bond to single bond (keto-Enol tautomerism). The elongation of C11-O12 bond is well explained by the NBO analysis of the anionic form of the molecule B. The NBO's of the neutral molecule and anion of the molecule are analysed. The hybridizations underwent by the atoms involved in the formation of the vital bonds in the neutral and anionic form of the C6, C7, C13, C11, C15, N14, C16, C19 and O20 in the formation of C6-C7, C13-C11, C13-C15,N14-C13, C15-C16 and C19-O20 are appear to be composed in the anionic form of the molecule. Hence there is no change in the bond length and bond order. In the carbonyl

group of the molecule, during the formation of the anion the p – character increases with increase in the bond length and decrease in the bond order of the C11 – O12 bond. The C11 – O12 bond is found to possess a partial single bond character during the formation of anion. The π – bond in the carbonyl group of the neutral molecule formed by the overlap of p orbitals of C11 and O12 is vanished in the anionic form and that p – orbitals are supposed to be involved in the hybridisation which increases the p – character of the C11 – O12 bond in anion. The p – character decreases with the decrease in bond length and increase in bond order of the C11-N10 bond. Hence C11-N10 bond attains a partial double bond character during the formation of the anion.

Bond	Bond length		
	Neutral	Anion	
C6-C7	1.355	1.383	
C11-N10	1.417	1.417	
C11-O12	1.21	1.263	
C13-C11	1.541	1.517	
C13-C15	1.547	1.554	
N14-C13	1.471	1.488	
C15-C16	1.515	1.514	
C19-O20	1.367	1.384	

|--|

Bond	Bonded atoms		Neutral form				Anionic form				
		Ну	bridisation	n	Bond length (Å)	Bond order	Hybridisation		Bond length (Å)	Bond order	
C6-C7	C6		SP ^{2.27}		1.355	0.98		SP ^{2.27}		1.383	0.5
	C7		SP ^{1.59}					SP ^{1.63}			
C11- N10	C11		SP ^{2.32}		1.417	0.95	SP ^{2.34}		S ⁰ P ¹	1.417	0.69
	N10		SP ^{1.85}				SP ^{1.80}		S ⁰ P ¹		
C11- 012	C11	SP ^{2.09}		S ⁰ P ¹	1.209	1.9		SP ^{2.03}		1.263	0.5
	012	SP ^{1.33}		S ⁰ P ¹				SP ^{1.34}			
C13- C11	C13		SP ^{3.14}		1.541	0.95		SP ^{3.10}		1.517	0.51
	C11		SP ^{1.66}					SP ^{1.69}			
C13- C15	C13		SP ^{2.45}		1.547	0.97		SP ^{2.51}		1.554	0.5
	C15		SP ^{2.86}					SP ^{2.84}			
N14- C13	N14		SP ^{2.15}		1.471	0.98		SP ^{2.13}		1.488	0.51
	C13		SP ^{3.33}					SP ^{3.21}			
C15- C16	C15		SP ^{2.56}		1.515	0.98		SP ^{2.64}		1.514	0.5
	C16		SP ^{2.16}					SP ^{2.08}			
C19- O20	C19		SP ^{3.03}		1.367	0.99		SP ^{3.02}		1.384	0.5
	O20		SP ^{1.88}					SP ^{1.89}			

Table 7: Natural bond hybridization calculated for vital bond (NBO analysis) with bond order

3.7. AIM Analysis

The title molecule is subjected to AIM analysis and it exposed 41 bond critical points with a (3, -1) topology between the covalently bonded atoms and 6 ring critical point (RCP) with a (3, +1)topology within the ring and it is pictured out in Figure.5 using a multifunctional Wavefunction analyser 'Multiwfn'. The values of electron densities (pBCP), Laplacian of electron density $(\nabla^2 \rho BCP)$, bond ellipticity (ϵ), the three eigen values ($\lambda 1$, $\lambda 2$, $\lambda 3$), the relationship between the largest curvature of the charge density perpendicular and parallel to the bond path ($|\lambda 1|/\lambda 3$), the potential energy density (V), the kinetic energy density (G), the kinetic energy density per charge unit (G/pBCP) values and delocalization index (DI) for the bond critical points (BCP) and ring critical point (RCP) present in the molecule are tabulated in Table 8. The AIM analysis depicts the presence of six ring Critical points (RCP) and presence of two weak intramolecular hydrogen bonding in the molecule. As proposed by Koch and Popelier [14] the presence of hydrogen bonding in the molecule is evidenced by lower electron densities (ρ BCP), higher bond ellipticity (E), positive value for Laplacian of Rho ($\nabla 2\rho$) and lower Electron Delocalization Index (DI) for two BCPs O12- N3 and O12_ _ H22. This indicates the presence of weak intramolecular hydrogen bonding between the atoms forming those significant BCPs. In Figure 6, the ring critical points observed in the positive region of the contour plot of Laplacian of Rho ($\nabla^2 \rho$) indicates the presence of intramolecular hydrogen bonding. The BCPs involving hydrogen bonds in the molecule have $G/\rho BCP$ values slightly lesser than 1 or closer to 1 indicating closed shell interaction like hydrogen bond between the bonded atoms. The other significant BCPs presented in Table 8 have $G/\rho BCP$ values very much lesser than 1. In the two BCPs O12-N3and O12 _H22 in the molecule, the DI is less than 1 indicating the confinement of electrons to one of the interacting atoms. Hence there are two intramolecular hydrogen bonding in the molecule. Among the predicted two intramolecular hydrogen bonding O12_ __H22 is found to be the weakest intramolecular interaction with lower ρ , $\nabla^2 \rho$, DI and higher E, G/ ρ BCP values than the other intramolecular interaction O12-N3. This is confirmed by the NBO analysis too.



Figure 5. BCPs and RCPs in TYADE [violet bubble – Nuclear attractor critical points; orange bubble – Bond Critical points; Yellow bubble – Ring Critical points]



Figure.6. Contour map depicting $\nabla 2\rho$ [green – positive region; red – negative region]

ВСР	ρ	$\nabla^2 \rho$	3	$ \lambda_1 /\lambda_3$	DI	V	G	G/рвср
C1C2	0.322	-0.889	0.276	1.991	1.2	-0.437	0.106	0.329
C1C6	0.308	-0.852	0.224	1.891	1.149	-0.396	0.091	0.295
N3C2	0.355	-1.258	0.159	3.489	1.241	-0.757	0.221	0.622
N3C4	0.345	-1.095	0.162	2.306	1.241	-0.847	0.286	0.828
C4N5	0.342	-1.075	0.142	2.238	1.218	-0.835	0.283	0.827
C5C6	0.348	-1.236	0.129	3.403	1.209	-0.726	0.208	0.597
C6-N7	0.328	-1.029	0.128	2.058	1.039	-0.784	0.263	0.801
N8C1	0.314	-0.997	0.107	2.637	1.128	-0.606	0.178	0.567
C9N8	0.376	-1.055	0.324	1.771	1.41	-1.029	0.382	1.015
N10C2	0.292	-0.836	0.112	2.048	0.953	-0.635	0.213	0.729
N10C9	0.293	-0.832	0.138	2.066	0.965	-0.66	0.226	0.771
C11N10	0.289	-0.91	0.056	2.182	0.884	-0.559	0.166	0.574
O12N3	0.01	0.036	2.865	0.152	0.049	-0.007	0.008	0.8
O12C11	0.414	0.230	0.114	0.475	1.317	-1.475	0.767	1.852
C13C11	0.251	-0.603	0.038	1.343	0.863	-0.261	0.055	0.219
N14H(9a)	0.012	0.04	0.154	0.169	0.039	-0.007	0.008	0.666
N14C13	0.265	-0.721	0.046	1.648	0.978	-0.392	0.106	0.4
C15C13	0.241	-0.536	0.033	1.273	0.931	-0.245	0.055	0.228
C15C16	0.252	-0.587	0.038	1.358	0.993	-0.263	0.058	0.23
C16C17	0.308	-0.821	0.218	1.876	1.346	-0.402	0.098	0.318
C16C28	0.309	-0.829	0.22	1.894	1.358	-0.405	0.099	0.32
C17C18	0.313	-0.85	0.235	1.97	1.412	-0.416	0.102	0.325
C18C19	0.314	-0.88	0.247	2.018	1.294	-0.418	0.099	0.315

C19O20	0.286	-0.343	0.006	0.713	0.919	-0.785	0.35	1.223
C21C19	0.314	-0.864	0.255	1.994	1.315	-0.417	0.101	0.321
Н (22)-О12	0.008	0.031	0.294	0.159	0.026	-0.005	0.006	0.75
C22C21	0.311	-0.842	0.226	1.943	1.395	-0.411	0.1	0.321
RCP	ρ	$\nabla^2 \rho$	3	$ \lambda_1 /\lambda_3$	DI	V	G	G/рвср
C1C2N3C4N5C6	0.024	0.187	-	0.165	-	-0.028	0.037	1.542
N10C9N8C1C2	0.05	0.402	-	0.237	-	-0.076	0.088	1.76
C11012N3C2N10	0.01	0.04	-	0.155	-	-0.007	0.008	0.8
C13C15C16 C22H22O12C11	0.007	0.028	-	0.087	-	-0.004	0.005	0.769
N14C13 C11N10C9H9	0.009	0.05	-	0.024	-	-0.007	0.01	1.111
C16C17 C18C19C21C22	0.019	0.159	-	0.15	-	-0.022	0.03	1.578

3.8. Electrophilicity index

The determination of various global and local reactivity descriptors in the context of chemical reactivity is also performed and the electrophilicity at the site of carbonyl carbon is revealed. The local reactivity descriptors like fukui functions and dual descriptor are calculated employing Mulliken population (MCA), Natural population (NCA) and Hirshfeld population (HCA) and independent single point energy calculations have been made on N – 1, N and N + 1 electronic systems with same molecular geometry at B3LYP/6 – 31G+(d,p) level [15]. The Mulliken charge, Natural charge and Hirshfeld charge on the atoms are tabulated Table 9 from the DFT analysis of the molecule and its N + 1 and N^t – 1 electronic form and are used to determine the and *fk* ⁺ and *fk* values. The *fk* ⁺ and *fk* ⁻ values are determined for all the atomic sites based on mulliken charges (MCA), natural charges (NCA) and Hirshfeld charges (HCA). The dual descriptor (Δf) is calculated for atoms forming the sites for attack from the and *fk* ⁺ and *fk* values. The *fk* ⁺, *fk qk* ^{N+} ¹, *qk* ^{N-1}, *q* ^N and Δf values for the vital atomic sites are given in Table 9. The values in Table 9 point out that the MCA and NCA scheme provide negative *fk* ⁺ fukui function and HCA scheme provide positive *fk* ⁺ fukui function [16].

The MCA scheme provides a negative Δf value for C11 atomic site which clearly predicts that MCA scheme is not able to effectively reproduce the change in the electron density around the reactive atom in these type of carbonyl compounds. The HCA schemes provide a negative Δf value for C13 atomic site indicating that the carbonyl carbon C13 site is favourable for electrophilic attack and a positive Δf value for N3 atomic site indicating that the N3 atomic site is favourable for Nucleophilic attack.

Atomic site	q k ^N	q_k^{N+1}	q_k^{N-1}	$\mathbf{f_k}^+$	f _k -	Δf			
Mulliken charge-based analysis (MCA)									
C1	0.175436	0.133385	0.387264	-0.04205	-0.21183	0.169777			
C2	0.538738	0.165308	0.14255	-0.37343	0.396188	-0.76962			
N3	-0.48132	-0.26903	-0.20506	0.212287	-0.27626	0.488542			
C4	0.328083	0.266125	0.408886	-0.06196	-0.0808	0.018845			
N5	-0.51433	-0.43906	-0.32317	0.075275	-0.19116	0.266434			
C6	0.489137	0.225309	0.047376	-0.26383	0.441761	-0.70559			
N7	-0.0704	-0.00579	0.210999	0.064617	-0.2814	0.34602			
N8	-0.53176	-0.44037	-0.31608	0.091388	-0.21568	0.307065			

Table 9: Calculated mulliken charges, natural charges and hirshfeld charges q_k^N , q_k^{N+1} , q_k^{N-1} , condensed fukui functions f_k^+ , f_k^- dual descriptor (Δf), at significant atomic sites at DFT level.

C9	0.458905	0.520776	0.618272	0.061871	-0.15937	0.221238			
N10	-0.59019	-0.16475	-0.12943	0.425438	-0.46076	0.886195			
C11	0.620045	-0.32618	-0.15105	-0.94622	0.771099	-1.71732			
012	-0.43016	-0.49428	-0.33386	-0.06412	-0.09629	0.032171			
C13	0.077108	-0.29167	-0.07561	-0.36878	0.152721	-0.5215			
N14	-0.09345	0.121115	0.055633	0.214563	-0.14908	0.363644			
C15	-0.03512	-0.17453	-0.0744	-0.13941	0.039285	-0.1787			
C16	0.099584	0.793588	0.765396	0.694004	-0.66581	1.359816			
C17	-0.05518	-0.43456	-0.32502	-0.37938	0.269836	-0.64922			
C18	-0.00464	0.356231	0.523916	0.360868	-0.52855	0.889421			
C19	0.325883	-0.27151	-0.24494	-0.59739	0.570826	-1.16822			
O20	-0.24118	-0.19398	-0.06338	0.047201	-0.17779	0.224995			
C21	-0.05394	0.262771	0.347956	0.316706	-0.40189	0.718597			
C22	-0.01126	-0.33891	-0.26622	-0.32764	0.254957	-0.5826			
Natural charge-ba	ased analysis (NCA)							
C1	-0.00207	-0.0256	0.05785	-0.02353	-0.05992	0.03639			
C2	0.3807	0.33839	0.38467	-0.04231	-0.00397	-0.03834			
N3	-0.5051	-0.48708	-0.43574	0.01802	-0.06936	0.08738			
C4	0.25108	0.16937	0.26927	-0.08171	-0.01819	-0.06352			
N5	-0.54731	-0.58611	-0.50549	-0.0388	-0.04182	0.00302			
C6	0.42907	0.39265	0.42428	-0.03642	0.00479	-0.04121			
N7	-0.81907	-0.86674	-0.72677	-0.04767	-0.0923	0.04463			
N8	-0.47167	-0.54363	-0.43577	-0.07196	-0.0359	-0.03606			
С9	0.22899	0.1388	0.27493	-0.09019	-0.04594	-0.04425			
N10	-0.46557	-0.44762	-0.47505	0.01795	0.00948	0.00847			
C11	0.73425	0.55611	0.72771	-0.17814	0.00654	-0.18468			
O12	-0.53136	-0.67294	-0.51304	-0.14158	-0.01832	-0.12326			
C13	-0.13994	-0.20693	-0.16454	-0.06699	0.0246	-0.09159			
N14	-0.9101	-0.93665	-0.8916	-0.02655	-0.0185	-0.00805			
C15	-0.49096	-0.49172	-0.50908	-0.00076	0.01812	-0.01888			
C16	-0.0809	-0.0624	0.01251	0.0185	-0.09341	0.11191			
C17	-0.22056	-0.23374	-0.21563	-0.01318	-0.00493	-0.00825			
C18	-0.28517	-0.29794	-0.23852	-0.01277	-0.04665	0.03388			
C19	0.32638	0.29284	0.36189	-0.03354	-0.03551	0.00197			
O20	-0.69189	-0.72334	-0.63083	-0.03145	-0.06106	0.02961			
C21	-0.31212	-0.32223	-0.27963	-0.01011	-0.03249	0.02238			
C22	-0.20858	-0.20015	-0.1959	0.00843	-0.01268	0.02111			
Hirshfeld charge analysis (HCA)									
C1	-0.02359	-0.04871	0.019511	-0.02513	-0.0431	0.017971			
C2	0.076102	0.053632	0.095329	-0.02247	-0.01923	-0.00324			
N3	-0.18474	-0.19609	0.137833	-0.01136	-0.32257	0.311211			

C4	0.070061	0.010769	0.108523	-0.05929	-0.03846	-0.02083
N5	-0.19859	-0.23913	-0.16333	-0.04054	-0.03526	-0.00528
C6	0.103639	0.076359	0.13146	-0.02728	-0.02782	0.000541
N7	-0.13374	-0.15216	-0.05225	-0.01842	-0.08149	0.063069
N8	-0.18946	-0.25476	-0.15361	-0.0653	-0.03585	-0.02945
С9	0.059908	-0.0062	0.099993	-0.06611	-0.04009	-0.02602
N10	-0.00554	-0.01095	0.004102	-0.00541	-0.00965	0.004237
C11	0.191774	0.083577	0.194961	-0.1082	-0.00319	-0.10501
O12	-0.21635	-0.33814	-0.19908	-0.12179	-0.01727	-0.10451
C13	0.016559	0.001299	0.024662	-0.01526	-0.0081	-0.00716
N14	-0.19314	-0.19934	-0.16169	-0.0062	-0.03145	0.025251
C15	-0.0564	-0.06294	-0.04517	-0.00653	-0.01123	0.0047
C16	-0.01923	-0.00593	0.031268	0.013294	-0.0505	0.06379
C17	-0.04745	-0.05149	-0.01791	-0.00404	-0.02955	0.025505
C18	-0.06212	-0.07581	-0.01796	-0.0137	-0.04416	0.030465
C19	0.069079	0.05228	0.113307	-0.0168	-0.04423	0.027429
O20	-0.1866	-0.1986	-0.11757	-0.012	-0.06903	0.057026
C21	-0.07069	-0.07891	-0.03335	-0.00823	-0.03733	0.029107
C22	-0.04072	-0.03456	-0.01076	0.006156	-0.02996	0.036115

3.9. HOMO-LUMO

Highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) are playing an important role in the study of absorption in organic compounds. HOMO tends to donate the electrons and LUMO which contains unoccupied orbitals accepted the electrons. LUMO is the next highest energy orbital which is empty and HOMO is the lowest energy place to put or excite an electron. The energy difference between the HOMO and LUMO is generally the lowest energy electronic excitation that is possible in a molecule. Hence smaller the HOMO-LUMO gap correspond to better stability. In the present study, the HOMO LUMO energies and the band gap are calculated are B3LYP/6-31G (d,p) level of computation [17] . The HOMO energy, LUMO energy and the band gap of the title molecule are -5.87975 eV, -1.34177 eV and 4.537978 eV respectively. In the molecule, the pz orbitals of C9, C2, C1, C4 and C6 do not participate in the formation of HOMO. The participation of pz orbitals of C11 and N10 in the formation of HOMO orbital is very less. Similarly, the pz orbitals of C15, C16, C17, C18, C19, C21 and C22 do not participate in the formation of LUMO orbitals.



Figure 7. HOMO-LUMO pictures of TYADE

3.10. Molecular electrostatic potential (MEP) surfaces

Molecular electrostatic potential surface gives information about the charge distribution of a molecule because of the properties of the nucleus and nature of electrostatic potential energy. It visualized three dimensionally, the reactive behaviour of the molecule and helps in predicting the sites for nucleophilic and electrophilic attack in the molecule. The MEP surface is a superimposition of the electrostatic potential on the isoelectronic density surface [18]. The MEP surface has been plotted for TYADE Figure. 8 Region of negative charge is pictured out in red colour and it is found around C2-N10 bond of pyrrole ring of adenine in the molecule TYADE. The red colour region is for electrophilic attack. The blue colour region represents strong positive section and is likely to to nucleophilic attack. The green colour zone links to a potential half way between the two extremes red and blue region.



Figure 8. MEP plot of TYADE

4. Conclusion

TYADE molecule is constructed and optimized with Guassian03 software. The sable conformer is justified with the heat of formation values. Among two conformer A and B, the conformer B is the most stable conformer. The theoretical IR frequencies of the molecule are analysed by means of Potential energy Distribution (PED %) calculation using Vibrational Energy Distribution Analysis (VEDA 4) program. The theoretical values of NMR obtained by DFT method for ¹H and ¹³C NMR values are observed. The molecule is subjected to NBO analysis and the stability of the molecule is examined. NBO analysis predicts the presence of two weak intra molecular hydrogen bonding between O12- N3 and O12_ _ H22. This electrochemical study is complemented by the computational study on the hybridisation of the vital bonds in the neutral and anionic form of the molecule. The Fukui functions, dual descriptors and the local electrophilicity of crucial atomic sites in the molecule have been analysed on the basis of Mulliken charges, natural charges and Hirshfeld charges. Hirshfeld population analysis is found to be reliable as it gives only positive Fukui functions. The first hyperpolarizability of UA (ßtot) is 1.5 times greater than that of urea and hence this molecule can have considerable NLO activity. The topological analysis (AIM) of the molecule predicts the presence of two weak intramolecular interactions (hydrogen bonding) in the molecule and six bond critical points.

Acknowledgments

None.

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