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Tautomerism of 2-Azido-1, 3, 4-Thiadiazole Studied by Theoretical Methods in Gas Phase and Solution

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Abstract: The tautomeric equilibrium of 2-azido-1, 3,4-thiadiazole and [1,3,4]thiadiazolo[3,2-e]tetrazole derivatives (5-H, 5-F, 5-Cl, 5-CH_3, 5-CH_2CH_3, 5-NO_2, 5-CN) has been investigated using HF, B3LYP and MP2 level of calculation with the 6-311G (d,p) in the gas phase and solution with full geometry optimization. The calculation results demonstrate 2-azido-1, 3, 4-thiadiazole derivatives are more stable. In addition variation of dipole moments, charges on atoms, HOMO, LUMO and the interfrontier molecular orbital energy gap are studied.

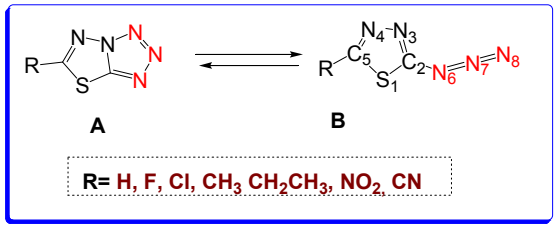
Keywords: 2-Azido-1, 3, 4-Thiadiazole, [1, 3, 4]Thiadiazolo[3,2-E]Tetrazole, Tautomerism, Polarizable Continuum Model (PCM), Tautomerism, Density Functional Theory (DFT)

1. Introduction

The [1, 3, 4]thiadiazoles heterocyclic core is a widespread subunit in numerous natural products (such as B6-vitamins pyridoxine, pyridoxamine, pyrodoxal and codecarbaxylase contain a thiadiazole nucleus) and synthetic compounds. The [1,3,4]thiadiazoles have recived the attention of medicinal chemists due to which include their broad spectrum of pharmacological actions such as anti-fungal, anti-inflammatory, analgesic, anti-anxiety, anti-viral, anti-depressant, anti-tubercular, analgesic and antibacterial activities. [1-5]

Tetrazoles are an important class of heterocycles in a wide range of applications, such as, organ catalysis and transition metal catalysis, propellants, explosives, and perhaps most commonly, as non-classical isosteres of carboxylic acids in medicinal chemistry.[6,7] [1,3,4]thiadiazoles azides are known for transformation to [1,3,4]thiadiazolo[3,2-e]tetrazole. Undoubtedly, This product can highly enhance biological activity of [1, 3, 4]thiadiazoles and Tetrazoles.

Tautomerism of five-membered heterocycles of importance for pharmacy (substituted diazoles and tetrazoles) was a subject of several theoretical and experimental papers. So, The aim of this study is systematic investigation of substituent effect and its influence on tautomerism of the C5-substituted [1,3,4]thiadiazoles azides and [1,3,4]thiadiazolo[3,2-e]tetrazole (Scheme 1).



Scheme 1. *Tautomeric forms of [1,3,4]thiadiazoles azides and [1,3,4]thiadiazolo[3,2-e]tetrazole derivatives .*

2. Computational Details

Quantum chemical calculations were performed with the use of the Gaussian 03 set of programs. [8] All structures were fully optimized with Hartree-Fock (RHF) and density functional theory (DFT) using Becke's three parameter hybrid method [9] and correlation functional of Lee-Yang-Parr (B3LYP) [10] in conjunction at the level of 6-31++G** [11] basis sets. Atomic charges of the stationary points were obtained by using the natural bond orbital (NBO) approach. [12] The solvent effects have been considered by B3LYP/6-31G single point calculations over the gas phase optimized structures using a self-consistent reaction field [13] (SCRF)

based on the PCM method of the Tomasi's group. [14, 15]

3. Results and Discussion

[1,3,4]thiadiazolo[3,2-e]tetrazole and 2-azido-1,3,4-thiadiazole derivatives are depicted in Scheme 1 and the results of calculated total energies in the different methods and using many basis sets presented in Table 1. The results of our calculations suggest that in the gas phase, B form is more stable. For example, based on the B3LYP/6–311+ +G (d,p) calculations, the stability of B form over A form was found to be -5.83 kcal/mol (1 cal = 4.184 J). Consideration of the electron correlation effects did not change the stability order, and calculations at the MP2/6–311++G (d,p) level showed B form favored by -0.094 kcal/mol over A form.

Table 1. *Calculated relative instabilities of A form over B form in the gas phase.*

		A	B	ΔE(B-A)
HF	6–311G(d)	-746.0386482	-746.0432189	-2.89
	6–311+G(d)	-746.0475718	7-746.0520187	-2.79
	6-311++(d,p)	-746.0493644	-746.0538495	-2.81
DFT	6–311G(d)	-748.7522259	-748.7619111	-6.08
	6–311+G(d)	-748.7627467	-748.7719908	-5.80
	6-311++(d,p)	-748.764434	-748.7737262	-5.83
MP2	6–311G(d)	-746.0256874	-746.0257692	-0.051
	6–311+G(d)	-746.0339809	-746.0341500	-0.106
	6-311++(d,p)	-746.0358793	-746.0360288	-0.094

The results of energy comparisons of two tautomers in the gas phase and different solvents are given in Table 2. It is easily seen that in the gas phase all (B) forms are more stable than (A) forms. The major difference between (B) and (A) form in gas phase was found for 5-NO_2 2-azido-1, 3, 4-thiadiazole with -9.54 kcal mol^{-1}. By glancing at the table, we can notice that the stability of (B) tautomer relates to the nature of substituents.

Obviously, the solvent molecules play an important role in tautomer stability, Here, the solvent effects were calculated by PCM/B3LYP calculations (which is widely used for investigation of the solute-solvent interactions) to analyze the solvent effects on tautomerism of [1,3,4]thiadiazolo[3,2-e]tetrazole and 2-azido-1,3,4-thiadiazole derivatives. The data presented in Table 1 show that polar solvents increase the stability of derivatives of two forms in compare to gas phase.

Table 2. *Calculated total energies[a] at B3LYP/6-311++G** and relative stability[b] in the gas phase and solvents.*

R		Gas	Benzene	THF	Ethanol	Dmso	Water
	A	-788.1008843	-788.1086744	-788.113921	-788.1157318	-788.1161062	-788.1162782
CH_3	B	-788.1080242	-788.1125702	-788.1155352	-788.1165443	-788.1167523	-788.1168477
	ΔE(B-A)	-4.48	-2.44	-1.01	-0.51	-0.40	-0.36
	A	-827.4253493	-827.4329168	-827.4379859	-827.4397281	-827.4400886	-827.4402542
CH_2CH_3	B	-827.4322643	-827.4366759	-827.4395399	-827.4405127	-827.4407128	-827.440805
	ΔE(B-A)	-4.34	-2.36	-0.97	-0.49	-0.39	-0.34
H	A	-748.76443	-748.7722345	-748.7774966	-748.7793131	-748.7796883	-748.7798612
	B	-748.7737262	-748.7783719	-748.781384	-748.7824046	-748.7826148	-748.782711
	ΔE(B-A)	-5.83	-3.85	-2.44	-1.94	-1.84	-1.79
F	A	-848.0235647	-848.030326	-848.0348274	-848.036372	-848.0366905	-848.0368371
	B	-848.0338839	-848.0379412	-848.0405625	-848.0414517	-848.0416344	-848.0417181
	ΔE(B-A)	-6.47	-4.78	-3.60	-3.19	-3.10	-3.06
Cl	A	-1208.3792004	-1208.3857656	-1208.3901442	-1208.3916476	-1208.3919588	-1208.3921014
	B	-1208.3898749	-1208.3937667	-1208.3962814	-1208.397133	-1208.3973087	-1208.397389
	ΔE(B-A)	-6.70	-5.02	-3.85	-3.44	-3.36	-3.32
	A	-953.3045945	-953.3127692	-953.3180451	-953.319824	-953.3201889	-953.3203562
NO_2	B	-953.3198031	-953.3262439	-953.3303823	-953.3317793	-953.3320664	-953.332198
	ΔE(B-A)	-9.54	-8.45	-7.74	-7.50	-7.45	-7.43
	A	-841.0148361	-841.0227068	-841.0279177	-841.0296984	-841.0300659	-841.0302335
CN	B	-841.0298493	-841.0355616	-841.0392779	-841.0405388	-841.040798	-841.040917
	ΔE(B-A)	-9.42	-8.07	-7.13	-6.80	-6.73	-6.70

a Hartree.

b Relative stabilities in kcal mol_1.

The plots of relative stability of two tautomers separately are depicted in Fig. 1. The electron donating and electron withdrawing groups show a regular decrease of in the difference between two forms from gas phase to most polar solvents (water).

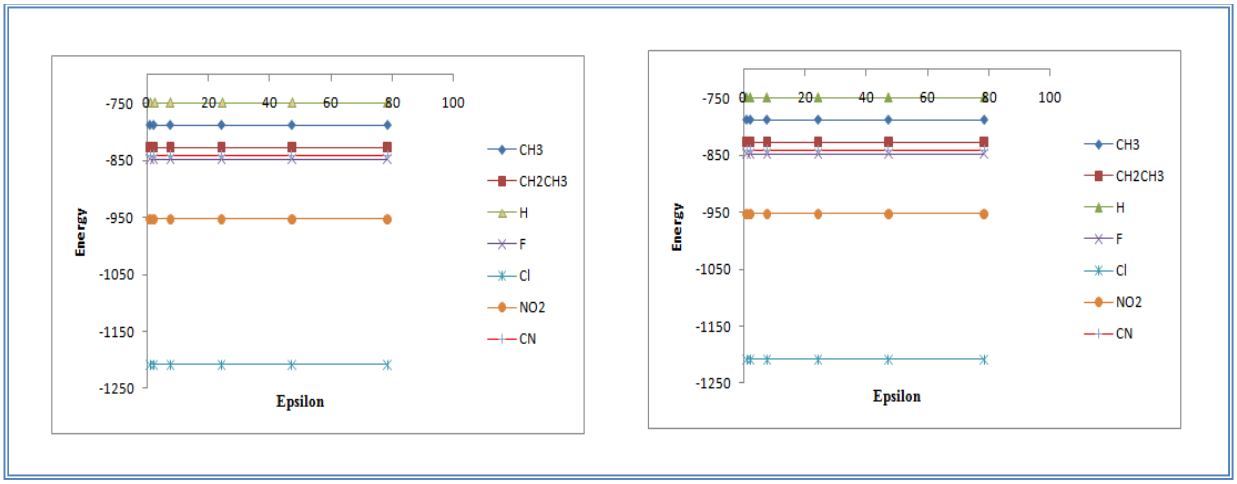


Fig. 1. *Relative stability of [1,3,4]thiadiazolo[3,2-e]tetrazole tautomers (left) and 2-azido-1,3,4-thiadiazole tautomers (right) of tetrazole derivatives.*

The thermodynamics parameters, *E*, *H* and *G*, of each tautomer were calculated at B3LYP/6-311G (d,p) level according to the formulas [16]

$$H = E + RT \quad (1)$$

$$G = H - TS \quad (2)$$

E is the thermal energy

H is the enthalpy

G is the Gibbs free energy

For comparison, the relative values, ΔE, ΔH and ΔG are collected and shown with *E*, *H* and *G* in Table 3. The calculation results confirm that form B is more stable than form A.

Table3. *The thermodynamics parameters, E, H and G, of each tautomer were calculated by DFT/6-311G** level.*

		E_0	H	G	ΔE	ΔH	ΔG
A	Gas	-748.711359	-748.710415	-748.746553	-6.32	-6.32	-8.09
	Water	-748.726465	-748.725521	-748.761530	-2.48	-2.48	-4.35
B	Gas	-748.721428	-748.720484	-748.759448	0	0	0
	Water	-748.730412	-748.729468	-748.768461	0	0	0

Equilibrium constants [17] between the tautomeric forms A and B were calculated in gas phase and in water from Gibbs free energies using

$$\Delta G = -RT \ln K_{eq.} \quad (3)$$

The R value is equal to 1.987 cal $K^{-1}mol^{-1}$, ΔG the Gibbs free energy difference between the A and B tautomers and T is 298.15K. The result of the calculated equilibrium constant for the B→A conversions in the gas phase and with water as the solvent is tabulated in Table 4. As seen in the table, from gas phase to the water solvent phase, the equilibrium constants decreased.

Table 4. *Calculated equilibrium constants in the gas phase and water solvent phase using DFT methods using 6–311++G (d,p) basis function.*

B→A	DFT
Gas	1.15
Water	0.932

The calculated dipole moments of two tautomeric are presented in Table 5. It is notable that dipolemoments significantly relate to the nature of substituents at the 5th position. In the A tautomers, electron withdrawing derivatives have smaller dipole moments than electron releasing ones; however in B forms electron donating derivatives have lower dipole moments values than electron withdrawing substituents.

Table 5. *Calculated dipole moments of optimized tautomers of tetrazoles (Debye).*

R	Tautomer	Gas	Benzene	THF	Ethanol	Dmso	Water
CH_3	A	7.11	8.29	9.14	9.44	9.50	9.53
	B	3.30	3.93	4.41	4.59	4.62	4.64
CH_2CH_3	A	7.35	8.51	9.34	9.63	9.69	9.72
	B	3.39	4.01	4.49	4.66	4.69	4.71
H	A	6.13	7.23	8.02	8.30	8.36	8.38
	B	2.95	3.54	3.98	4.14	4.18	4.19
F	A	4.79	5.71	6.39	6.63	6.68	6.70
	B	2.85	3.42	3.85	4.00	4.02	4.03

R	Tautomer	Gas	Benzene	THF	Ethanol	Dmso	Water
Cl	A	5.35	6.34	7.06	7.32	7.38	7.40
	B	2.67	3.23	3.66	3.81	3.84	3.86
NO_2	A	2.63	3.27	3.77	3.95	3.99	4.00
	B	4.46	5.29	5.91	6.13	6.18	6.20
CN	A	2.95	3.64	4.16	4.35	4.39	4.40
	B	4.24	4.98	5.53	5.71	5.75	5.77

For example for methyl and Cl derivatives difference between dipole moment of A and B is 3.81 and 2.68 D but for NO2 and CN the values are -1.83 and -1.29, respectively. The results of calculations show that dipole moments of the A and B forms is affected by variation of polarity of the medium, and in all tautomers a regular increase in the dipole moment when using more polar solvents was observed. Plot of dipole moment of tetrazole derivatives vs. dielectric constants are given in Fig. 2.

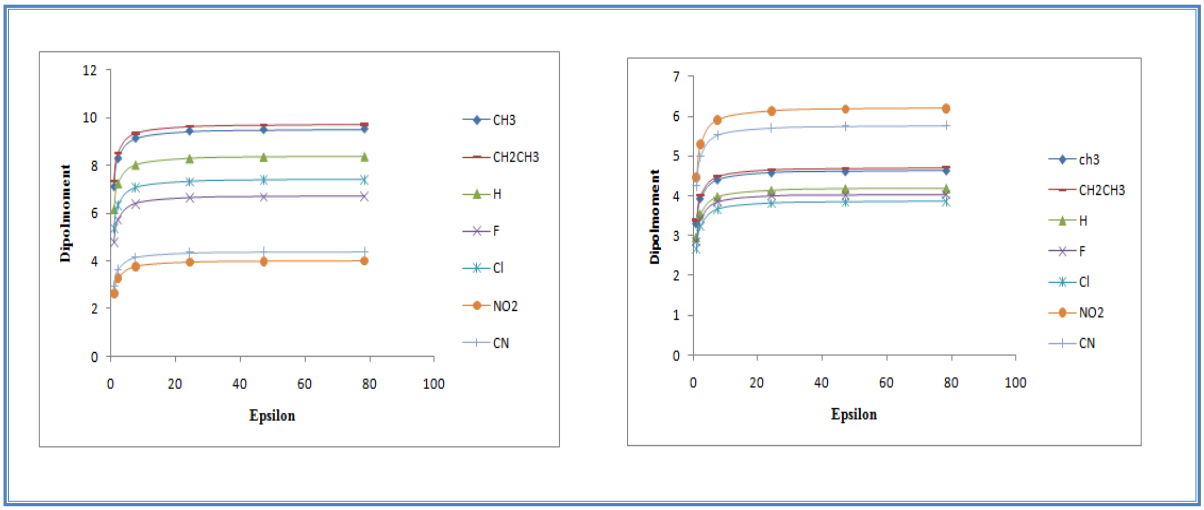


Fig. 2. *Dielectric constant dependence of the dipole moments of [1,3,4]thiadiazolo[3,2-e]tetrazole (left) and 2-azido-1,3,4-thiadiazole (right).*

The atomic charges for all the atoms of the title compound calculated by DFT method in gas phase and solutions are listed in Table 6. As seen from this table, Nitrogens atoms of the tautomer A carry negative charge and the sulfur atom S has positive atomic charge with values as 0.397, 0.395, 0.413, 0.398, 0.444, 0.495 and 0.475 units for CH_3, CH_2CH_3, H, F, Cl, $NO_2$and CN respectively. Negative charge was found for C2 atom in A forms when substituent are CH_3, CH_2CH_3, Cl and NO_2. However as it can be seen from Table 3 S1, C2, C5, N7 and N8 in the derivatives of B forms have positive charge values but N3, N4 and N6 have negative charge. From Table 3, it is clear that substituents have some influence on charge in two tautomers. The charge at the S1, C2, N3, N4, C5, N6, N7, and N8 atoms differs a little from that in unsubstituted forms solely for electron donating or electron withdrawing groups. Unexpectedly, the substituents, which have lone electron pair(s), generate increase of charge at the C2 atom. This phenomenon can be related to electron flow from the substituent to the p-electron systems of the five-membered system. The charge at this atom of the substituent is also quite negative for electron drawing group CN.

The charge distributions of dipolar compounds are often altered significantly in the presence of a solvent reaction field. [18] We have examined the charge distribution of tautomers in the solvent as well as gas phase by using calculated NBO charges. The charge distribution in solvents with increase of polarity differently varies for any atoms. For example, a regular increase of positive charge was found for S1 atom in A and B forms when passing from gas phase to more polar solvent water, In N3, N6, N7 and N8 position the negative charge of A isomers from gas phase to polar solvents increased drastically. When passing from gas phase to polar solvents a regular increase of negative charge in the C5 position in A and B tautomers was found. In C2 position in B tautomers with increase of polarity an increase of negative charge was observed.

Table 6. *Calculated NBO charges on ring atoms of [1, 3, 4]thiadiazolo[3,2-e]tetrazole and 2-azido-1,3,4-thiadiazole derivatives.*

	Form	A						B					
	ε	(1.0)	(2.2)	(7.6)	(24.3)	(47.2)	(78.4)	(1.0)	(2.2)	(7.6)	(24.3)	(47.2)	(78.4)
	Atom												
CH_3	S1	0.397	0.423	0.443	0.450	0.452	0.453	0.367	0.386	0.402	0.408	0.409	0.409
	C2	0.107	0.121	0.129	0.133	0.134	0.134	0.063	0.071	0.077	0.078	0.078	0.079
	N3	-0.250	-0.264	-0.272	-0.276	-0.277	-0.277	-0.277	-0.299	-0.315	-0.320	-0.321	-0.322

	Form	A						B					
	ε	(1.0)	(2.2)	(7.6)	(24.3)	(47.2)	(78.4)	(1.0)	(2.2)	(7.6)	(24.3)	(47.2)	(78.4)
	Atom												
CH_2CH_3	N4	-0.075	-0.067	-0.062	-0.060	-0.060	-0.060	-0.323	-0.340	-0.353	-0.357	-0.358	-0.359
	C5	0.167	0.173	0.175	0.176	0.176	0.176	0.191	0.193	0.195	0.195	0.195	0.195
	N6	-0.322	-0.337	-0.347	-0.351	-0.352	-0.352	-0.365	-0.365	-0.363	-0.363	-0.362	-0.362
	N7	-0.056	-0.077	-0.093	-0.098	-0.099	-0.100	0.257	0.263	0.266	0.267	0.267	0.267
	N8	-0.052	-0.066	-0.076	-0.080	-0.081	-0.081	0.022	0.017	0.013	0.012	0.011	0.011
	S1	0.395	0.420	0.441	0.448	0.449	0.450	0.366	0.385	0.400	0.406	0.407	0.407
	C2	0.118	0.131	0.138	0.141	0.142	0.142	0.072	0.080	0.084	0.085	0.086	0.086
	N3	-0.250	-0.263	-0.271	-0.274	-0.274	-0.275	-0.276	-0.297	-0.312	-0.317	-0.318	-0.319
H	N4	-0.075	-0.067	-0.062	-0.061	-0.060	-0.060	-0.324	-0.341	-0.353	-0.357	-0.358	-0.359
	C5	0.166	0.172	0.175	0.176	0.176	0.176	0.189	0.192	0.193	0.194	0.194	0.194
	N6	-0.323	-0.338	-0.348	-0.351	-0.352	-0.352	-0.365	-0.365	-0.363	-0.363	-0.363	-0.363
	N7	-0.057	-0.077	-0.092	-0.098	-0.099	-0.099	0.257	0.263	0.266	0.267	0.267	0.267
	N8	-0.053	-0.067	-0.077	-0.080	-0.081	-0.081	0.021	0.016	0.013	0.011	0.011	0.011
	S1	0.413	0.440	0.461	0.469	0.471	0.471	0.380	0.400	0.416	0.422	0.424	0.424
	C2	-0.089	-0.075	-0.066	-0.062	-0.062	-0.061	-0.132	-0.126	-0.122	-0.120	-0.120	-0.120
	N3	-0.217	-0.233	-0.244	-0.274	-0.248	-0.248	-0.252	-0.275	-0.291	-0.297	-0.298	-0.299
F	N4	-0.079	-0.071	-0.066	-0.064	-0.064	-0.064	-0.324	-0.341	-0.353	-0.357	-0.358	-0.358
	C5	0.163	0.169	0.172	0.173	0.173	0.174	0.187	0.190	0.192	0.192	0.192	0.192
	N6	-0.319	-0.334	-0.344	-0.347	-0.348	-0.348	-0.365	-0.364	-0.363	-0.362	-0.362	-0.362
	N7	-0.050	-0.071	-0.087	-0.092	-0.093	-0.094	0.257	0.263	0.266	0.267	0.267	0.268
	N8	-0.050	-0.064	-0.074	-0.078	-0.079	-0.079	0.029	0.024	0.020	0.019	0.018	0.018
	S1	0.398	0.430	0.453	0.461	0.463	0.464	0.357	0.382	0.402	0.408	0.409	0.410
	C2	0.480	0.489	0.495	0.497	0.495	0.498	0.448	0.451	0.450	0.451	0.451	0.451
	N3	-0.275	-0.287	-0.295	-0.298	-0.296	-0.298	-0.707	-0.326	-0.338	-0.343	-0.344	-0.344
Cl	N4	-0.076	-0.067	-0.062	-0.060	-0.059	-0.059	-0.317	-0.332	-0.343	-0.347	-0.348	-0.348
	C5	0.171	0.178	0.182	0.184	0.184	0.184	0.200	0.205	0.208	0.209	0.209	0.209
	N6	-0.314	-0.328	-0.336	-0.340	-0.340	-0.340	-0.368	-0367	-0.365	-0.364	-0.363	-0.363
	N7	-0.049	-0.070	-0.084	-0.089	-0.090	-0.091	0.257	0.263	0.267	0.268	0.268	0.269
	N8	-0.042	-0.055	-0.065	-0.068	-0.069	-0.069	0.037	0.033	0.029	0.028	0.028	0.028
	S1	0.444	0.472	0.493	0.501	0.503	0.503	0.411	0.433	0.450	0.456	0.458	0.458
	C2	-0.007	-0.000	0.004	0.005	0.005	0.005	-0.033	-0.031	-0.030	-0.030	-0.030	-0.030
	N3	-0.251	-0.263	-0.272	-0.274	-0.275	-0.275	-0.280	-0.299	-0.313	-0.318	-0.319	-0.320
NO_2	N4	-0.074	-0.065	-0.060	-0.058	-0.058	-0.058	-0.315	-0.330	-0.340	-0.344	-0.345	-0.345
	C5	0.167	0.175	0.179	0.180	0.180	0.180	0.195	0.200	0.203	0.204	0.205	0.205
	N6	-0.316	-0.329	-0.339	-0.342	-0.343	-0.343	-0.366	-0.365	-0.363	-0.362	-0.361	-0.361
	N7	-0.048	-0.068	-0.082	-0.087	-0.088	-0.089	0.257	0.263	0.267	0.268	0.268	0.269
	N8	-0.044	-0.057	-0.066	-0.069	-0.070	-0.071	0.037	0.033	0.030	0.029	0.029	0.028
	S1	0.495	0.524	0.546	0.554	0.556	0.556	0.437	0.494	0.510	0.516	0.517	0.518
	C2	0.159	0.168	0.174	0.176	0.176	0.176	0.121	0.124	0.124	0.124	0.124	0.124
	N3	-0.178	-0.185	-0.190	-0.192	-0.192	-0.192	-0.203	-0.216	-0.225	-0.228	-0.229	-0.229
CN	N4	-0.074	-0.064	-0.058	-0.057	-0.056	-0.056	-0.314	-0.323	-0.328	-0.330	-0.331	-0.331
	C5	0.167	0.178	0.184	0.187	0.186	0.187	0.198	0.207	0.213	0.215	0.215	0.215
	N6	-0.309	-0.322	-0.330	-0.332	-0.333	-0.333	-0.361	-0.358	-0.355	-0.353	-0.353	-0.353
	N7	-0.031	-0.049	-0.062	-0.066	-0.067	-0.067	0.257	0.264	0.269	0.270	0.271	0.271
	N8	-0.036	-0.047	-0.054	-0.057	-0.058	-0.058	0.062	0.061	0.061	0.061	0.061	0.061
	S1	0.475	0.510	0.536	0.546	0.547	0.548	0.450	0.478	0.449	0.506	0.508	0.509
	C2	-0.037	-0.033	-0.031	-0.030	-0.030	-0.030	-0.085	-0.090	-0.094	-0.095	-0.095	-0.095
	N3	-0.165	-0.172	-0.178	-0.179	-0.180	-0.180	-0.193	-0.270	-0.218	-0.221	-0.222	-0.222
	N4	-0.072	-0.063	-0.057	-0.056	-0.055	-0.055	-0.311	-0.322	-0.330	-0.332	-0.333	-0.333
	C5	0.166	0.174	0.179	0.180	0.181	0.181	0.196	0.202	0.206	0.207	0.208	0.208
	N6	-0.311	-0.324	-0.332	-0.336	-0.336	-0.336	-0.362	-0.360	-0.357	-0.356	-0.356	-0.356
	N7	-0.035	-0.054	-0.067	-0.072	-0.073	-0.073	0.257	0.264	0.268	0.270	0.270	0.270
	N8	-0.040	-0.052	-0.060	-0.063	-0.064	-0.064	0.055	0.052	0.050	0.049	0.049	0.049

The optimized structural parameters (bond lengths, bond angles and dihedral angles) of the titled compound have been obtained at the B3LYP level of theory with a 6-311G (d,p) basis set are listed in table 8, To the best of our knowledge, there is no experimental report on the geometry of the titled compound isomers in the literature for comparison.

The calculated dihedral angles demonstrate that both tautomers are planar. From the table 7 the bond lengths S1-C2 and C2-N3 are in A-isomer 1.776, 1.290 and 1.74, 1.294 in B-isomer respectively.

Table 7. *Calculated geometrical parameters of [1,3,4]thiadiazolo[3,2-e]tetrazole and 2-azido-1,3,4-thiadiazole in the gas phase and solution using the DFT/6–311++G(d,p) level of theory.*

		R	S1-C2	C2-N3	N3-N4	N4-C5	C5-R	C2-N6-N7	R-C5-N4	S1-C5-R	N3-C2-N6-N7
A	Gas	CH_3	1.738	1.355	1.359	1.293	1.491	104.191	123.227	120.943	0.00453
	benzen		1.735	1.353	1.343	1.294	1.489	104.34407	123.22790	120.91698	0.01734
	thf		1.733	1.352	1.359	1.296	1.488	104.390	123.290	120.876	-0.00655
	dmso		1.733	1.3513	1.3594	1.2967	1.4882	104.47061	123.27351	120.86751	-0.02671
	ethanol		1.733	1.351	1.359	1.297	1.488	104.441	123.313	120.860	0.00286
	water		1.733	1.351	1.359	1.297	1.488	104.454	123.294	120.868	-0.00282
B	Gas		1.747	1.298	1.368	1.296	1.493	116.09685	123.97798	122.81229	-0.01015
	benzen		1.745	1.390	1.3700	1.2980	1.493	116.24493	124.12734	122.74003	-0.01113
	thf		1.744	1.390	1.371	1.299	1.492	116.323	124.218	122.665	0.01920
	dmso		1.743	1.300	1.372	1.299	1.492	116.372	124.283	122.624	-0.01739
	ethanol		1.743	1.300	1.372	1.300	1.492	116.356	124.276	122.619	0.02234
	water		1.743	1.301	1.372	1.300	1.492	116.365	124.272	122.627	-0.00513
A	Gas	CH_2CH_3	1.737	1.355	1.359	1.293	1.496	104.205	123.138	121.146	0.03122
	benzen		1.735	1.298	1.359	1.295	1.495	104.372	123.155	121.112	0.05461
	thf		1.733	1.352	1.359	1.296	1.495	104.415	123.208	121.063	0.01394
	dmso		1.732	1.351	1.359	1.297	1.494	104.426	123.229	121.0428	-0.04244
	ethanol		1.732	1.351	1.372	1.297	1.494	104.399	123.260	121.032	-0.01876
	water		1.732	1.351	1.359	1.297	1.494	104.452	123.225	121.047	0.01189
B	Gas		1.747	1.299	1.367	1.297	1.498	123.931	116.090	122.976	0.01999
	benzen		1.745	1.299	1.369	1.298	1.498	116.208	124.045	122.923	0.03985
	thf		1.743	1.300	1.371	1.300	1.497	116.300	124.109	122.872	0.06273
	dmso		1.743	1.301	1.372	1.300	1.497	116.326	124.137	122.866	0.04077
	ethanol		1.743	1.309	1.372	1.300	1.497	116.317	124.140	122.864	0.05577
	water		1.742	1.301	1.372	1.300	1.497	116.324	124.151	122.854	0.05277
A	Gas	H	1.739	1.358	1.357	1.290	1.081	104.196	122.027	120.535	-0.00156
	benzen		1.737	1.356	1.358	1.291	1.081	104.381	122.041	120.431	-0.06582
	thf		1.735	1.354	1.358	1.293	1.080	104.399	122.169	120.266	0.02190
	dmso		1.734	1.354	1.358	1.293	1.080	104.472	122.173	120.208	0.04728
	ethanol		1.734	1.354	1.358	1.293	1.080	104.448	122.201	120.201	0.00101
	water		1.734	1.356	1.358	1.293	1.080	104.458	122.211	120.187	0.00081
B	Gas		1.748	1.3018	1.367	1.294	1.081	-116.077	123.431	121.869	0.00497
	benzen		1.746	1.302	1.369	1.295	1.0801	116.202	123.543	121.814	-0.00588
	thf		1.744	1.303	1.370	1.296	1.081	116.275	123.630	121.713	0.00637
	dmso		1.744	1.304	1.371	1.297	1.081	-116.307	123.707	121.647	-0.00456
	ethanol		1.744	1.304	1.3701	1.297	1.081	116.302	123.698	121.652	0.02220
	water		1.744	1.304	1.371	1.297	1.080	116.307	123.707	121.646	-0.00458
A	Gas	F	1.748	1.356	1.362	1.779	1.311	104.022	122.225	119.865	0.00248
	benzen		1.745	1.354	1.361	1.282	1.310	104.161	121.859	118.669	-0.01742
	thf		1.744	1.303	1.370	1.296	1.081	116.275	123.630	121.713	0.00637
	dmso		1.742	1.352	1.360	1.284	1.308	104.278	121.517	121.517	-0.03902
	ethanol		1.742	1.352	1.360	1.284	1.308	104.273	121.533	118.952	-0.00484
	water		1.742	1.352	1.360	1.284	1.308	104.301	121.516	118.948	-0.00663
B	Gas		1.758	1.297	1.374	1.279	1.320	116.053	123.391	119.865	-0.01658
	benzen		1.756	1.299	1.375	1.280	1.321	116.191	123.027	120.148	-0.00311
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.754	1.300	1.377	1.281	1.321	116.315	122.642	120.468	-0.00460
	ethanol		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00794
	water		1.754	1.300	1.377	1.281	1.321	116.315	122.642	120.468	-0.00460
A	Gas	Cl	1.742	1.357	1.358	1.288	1.711	104.090	122.448	119.804	0.05013
	benzen		1.740	1.355	1.358	1.290	1.709	104.235	122.227	119.964	-0.00195
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.738	1.353	1.357	1.292	1.706	104.322	122.024	120.181	0.00066
	ethanol		1.737	1.353	1.357	1.292	1.706	104.270	122.0347	120.142	-0.01491
	water		1.737	1.353	1.357	1.292	1.706	104.322	122.024	120.181	-0.00270
B	Gas		1.751	1.300	1.368	1.288	1.720	116.058	123.449	121.2552	-0.01221
	benzen		1.750	1.301	1.370	1.289	1.720	116.203	123.245	121.440	-0.00467
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.748	1.303	1.371	1.291	1.720	116.341	123.038	121.604	-0.00273
	ethanol		1.748	1.303	1.371	1.291	1.720	116.332	123.052	121.586	-0.03502
	water		1.748	1.303	1.371	1.291	1.720	116.341	123.038	121.604	-0.00270
A	Gas	NO_2	1.744	1.365	1.345	1.286	1.475	104.147	121.692	118.971	0.03754
	benzen		1.741	1.363	1.351	1.287	1.472	104.233	121.294	119.204	-0.01982

		R	S1-C2	C2-N3	N3-N4	N4-C5	C5-R	C2-N6-N7	R-C5-N4	S1-C5-R	N3-C2-N6-N7
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.739	1.362	1.344	1.288	1.471	104.296	120.833	119.547	0.00311
	ethanol		1.739	1.362	1.344	1.288	1.471	104.311	120.879	119.505	-0.00620
	water		1.739	1.362	1.344	1.288	1.471	104.296	120.833	119.547	0.00308
B	Gas		1.745	1.313	1.354	1.288	1.466	116.066	123.248	120.389	-0.00261
	benzen		1.744	1.316	1.351	1.291	1.460	116.210	122.849	120.809	0.01141
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.743	1.319	1.350	1.293	1.4557	116.389	122.412	121.212	-0.00620
	ethanol		1.743	1.319	1.350	1.293	1.456	116.380	122.452	121.191	0.01334
	water		1.742	1.319	1.350	1.293	1.455	116.393	122.411	121.228	0.01542
A	Gas	CN	1.736	1.363	1.345	1.299	1.419	108.763	122.732	120.234	0.00307
	benzen		1.734	1.361	1.344	1.300	1.420	104.295	122.1778	120.576	-0.00365
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.731	1.359	1.343	1.301	1.421	104.361	121.580	120.976	-0.00042
	ethanol		1.732	1.359	1.343	1.302	1.421	104.352	121.602	120.980	-0.01304
	water		1.731	1.359	1.343	1.302	1.421	104.326	121.553	121.004	0.04256
B	Gas		1.743	1.308	1.350	1.306	1.419	116.032	123.828	121.871	-0.00180
	benzen		1.742	1.311	1.3496	1.307	1.419	116.186	123.291	122.311	0.00237
	thf		1.754	1.300	1.377	1.281	1.321	116.311	122.663	120.453	-0.00801
	dmso		1.740	1.313	1.349	1.309	1.419	116.367	122.707	122.790	0.02259
	ethanol		1.740	1.309	1.349	1.309	1.419	116.36477	122.743	122.765	0.00122
	water		1.740	1.313	1.349	1.309	1.419	116.371	122.707	122.789	-0.00270

Table 8 shows the HOMO, LUMO, and the interfrontier molecular orbital energy gap (Δε) values of two men-tioned isomers calculated at HF and DFT method using 6–311++G(d,p) basis set. Three dimensional pictures of HOMO and LUMO of the studied molecules calculated at B3LYP/6–311++G (d,p) level are shown in Fig. 3. Substituents Fand NO2 of Tautomers A and B are characterized with the lowest and highest lying HOMO energy values, respectively. The HOMO–LUMO energy separation has been used as a simple indicator of kinetic stability. The HOMO–LUMO gaps were found to be 150 and 158 kcal/mol for Substituents F of Tautomers A and B and 158 and 169 kcal/mol for Substituents F of tautomers A and B for DFT and HF methods, respectively. A large HOMO–LUMO gap implies high kinetic stability and low chemical reactivity, because it is energetically unfavorable to add an electron to a high-lying LUMO or to extract electrons from a low-lying HOMO.

Table 8. *The HOMO and LUMO energies (eV) and interfrontier energy gaps (Δε) of the structures considered.*

R		HF			DFT		
		HOMO	LUMO	Δε	HOMO	LUMO	Δε
CH_3	A	-0.146	-0.294	0.149	-0.151	-0.293	0.142
	B	-0.135	-0.300	0.164	-0.141	-0.297	0.142
CH_2CH_3	A	-0.148	-0.295	0.147	-0.153	-0.293	0.140
	B	-0.137	-0.299	0.162	-0.142	-0.297	0.154
H	A	-0.149	-0.300	0.149	-0.153	-0. 296	0.143
	B	-0.136	-0.300	0.163	-0.141	-0.297	0.156
F	A	-0.135	-0.294	0.158	-0.142	-0.292	0.150
	B	-0.131	-0.300	0.169	-0.139	-0.297	0.158
Cl	A	-0.144	-0.295	0.151	-0.149	-0.293	0.144
	B	-0.134	-0.300	0.166	-0.141	-0.297	0.157
NO_2	A	-0.183	-0.299	0.115	-0.189	-0.297	0.108
	B	-0.179	-0.300	0.120	-0.186	-0.297	0.111
CN	A	-0.182	-0.298	0.116	-0.187	-0.296	0.109
	B	-0.174	-0.299	0.125	-0.179	-0.296	0.117

Figure 3. *The HOMO and LUMO patterns of two tautomers.*

4. Conclusion

Molecular orbital calculations to study of tautomerism of 2-azido-1, 3,4-thiadiazole and [1,3,4]thiadiazolo[3,2-e]tetrazole derivatives were performed using different calculation levels. In the gas phase, all calculations predict that 2-azido-1, 3,4-thiadiazole is more stable. The charge on all atoms in the two tautomers was calculated using an NBO method in the gas phase and in solution. The charge distribution in solvents with increase of polarity differently varies for any atoms.The dipole moments of the compounds

were calculated in the gas phase and the solvent case and it was observed that they are affected by the solvent. The HOMO–LUMO energy separation indicates kinetic stability of the title compound. A large HOMO–LUMO gap implies high kinetic stability and low chemical reactivity

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References

[1] H. Kaur, S. Kumar, I. Singh, K.K. Saxena, A. Kumar, Dig J Nanomater Bios. 5(1) (2010) 67-76.

[2] C. Franchini, M. Muraglia, F. Corbo, M.A. Florio, A.D. Mola, A. Rosato, R. Matucci, M. Nesi, F.V. Bambeke, C. Vitali, Arch. Pharm. Chem. Life Sci. 342 (2009) 605-613.

[3] V.R. Solomon, H. Changkun, L. Hoyun, Life Sci. 8(3) (2011) 257-265]

[4] K.G. Desai a, J.P. Ravalb and K.R. Desaic, J Iran Chem Soc. 3(3), (2006*)* 233-241

[5] S.K. Sonwane, S.D. Srivastava. Proc. Nat. Acnd. Sci. India. 78A (II) (2008) 129-136.

[6] L. A. Flippin, Tetrahedron Lett. 32 (1991) 6857-6860; b) A.J.A. Cobb, D.M. Shaw, S.V. Ley, Synlett. 3 (2004) 558-560; c) M.B. Talawar, A.P. Agrawal, M. Anniyappan, D.S. Wani, M.K. Bansode, G.M. Gore, J. Hazard. Mater. 137 B (2006) 1074-1078.

[7] a) H. *Singh, A.S. Chawla, V.K. Kapoor, D. Paul, R.K. Malhotra, Prog. Med. Chem. 17(1980) 151-183; b) R.J. Herr, Bioorg. Med. Chem, 10 (2002) 3379-3393.*

[8] M.J. Frisch, G.W. Trucks, H.B. Schlegel, G.E. Scuseria, M.A. Robb, J.R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G.A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H.P. Hratchian, A.F. Izmaylov, J. Bloino, G. Zheng, J.L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J.A. Montgomery, Jr., J.E. Peralta, F. Ogliaro, M. Bearpark, J.J. Heyd, E. Brothers, K.N. Kudin, V. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J.C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J.M. Millam, M. Klene, J.E. Knox, J.B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R.E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J.W. Ochterski, R.L. Martin, K. Morokuma, V.G. Zakrzewski, G.A. Voth, P. Salvador, J.J. Dannenberg, S. Dapprich, A. . Daniels, O. Farkas, J. B. Foresman, J.V. Ortiz, J. Cioslowski, and D.J. Fox, Gaussian, Inc., Wallingford CT, 2009.

[9] W. Kohn, L. J. Sham, Phys. Rev. 140 (1965)A1133–A1138,

[10] R. G.Parr,W. Yang, Oxford University Press, London, UK, 1989.

[11] D. C.Young, Wiley-Interscience, NY, USA, 2001.

[12] A.E. Reed, L.A. Curtiss, F. Wienhold, Chem. Rev. 88 (1988) 899.

[13] J. Tomasi, M. Persico, Chem. Rev. 94 (7) (1994) 2027–2094.

[14] E. Cancès, B. Mennucci, and J. Tomasi. Citation: J. Chem. Phys. 107 (1997) 3032-3042

[15] V. Barone, M. Cossi, J. Tomasi, J. Comput. Chem. 19 (4) (1998) 404-417.

[16] A. Assoma, Benjamine, Bede A.Lucie, Kone M, NGussan,Y. Thomas, *Europen journal of scientific research*, , 44(2) (2010) 337-354.

[17] C. Peng, P.Y Ayala, H.B Schlegel, M. J Frisch, *J. Comp. Chem*, , 17 (1996) 49-56.

[18] M.W. Wong, K.B. Wiberg, M.J. Frisch, J. Am. Chem. Soc. 114 (1992) 1645.