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DFT, AIM, AND NBO ANALYSES OF 1-METHYL-2-THIOXOIMIDAZOLIDIN-4-ONE TAUTOMERS AND THEIR COMPLEXES WITH IODINE

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Thioimidazoline derivatives can be used to treat hyperthyroidism due to their ability to make complexes with iodine. In this research designed to find new structures with the same ability, 1-methyl-2-thioxoimidazolidin-4-one (MTIO) and the structures of MTIO tautomers (5 tautomers), their isomers (total 9 isomers) and their complexes with iodine are optimized using the B3LYP method with two different basis sets to obtain their molecular parameters, relative energies, and vibrational frequencies. The relative energies show that in all tautomers and complexes, ketone and thione forms are more stable than enol and thienol forms, and also Z isomers are more stable than E isomers. Moreover, the NBO calculation is carried out for tautomers and complexes to obtain atomic charges and acceptor-donor interactions. These results confirm the ability of MTIO tautomers to form complexes and show that the planar complexes have more effective interaction than the perpendicular complexes. The essence and important complexation properties are also calculated and confirmed using the AIM analysis.

K e y w o r d s: tautomers, thioimidazoline, iodine complex, DFT, NBO, AIM.

INTRODUCTION

Interaction of organic molecules with iodine has been widely observed in biological systems [1], especially in a human thyroid gland [2—4]. This phenomenon has also been studied computationally in pervious researches [5, 6]. In this category, imidazoline [7] and related compounds like thioimidazoline derivatives [8, 9] are known as iodine absorbent in a human body [10]. Methimazole, as the most famous member of this group, can make an efficient complex with iodine. This complex can prevent the first step of biosynthesis of thyroid hormones to prevent hyperthyroidism [11—16]. As a result, each compound with a powerful complex with iodine can be considered as a new drug in this category. For example, carbimazoles and propylthiouracils are prevalent drugs for hyperthyroidism [17]. Generally, treatment of hyperthyroidism is achieved by two different mechanisms. One mechanism is the coordination to iodine and the prevention of electrophilic substitution of iodine on thyrosine [18] and another is the coordination to a metal ionic center of thyrosine peroxide and its deactivation [19]. The first mechanism was considered in this study. Therefore, we decided to design new molecules with high ability to complex with iodine, which can be used as a new drug for hyperthyroiddism.

To reach to this purpose, 1-methyl-2-thioxoimidazolidin-4-one was chosen to study its structure and complexation properties to iodine in this research. Another important aspect of this molecule is its diversity in tautomerism [20, 21]. This molecule has different tautomers, and each tautomer can have different properties in the interaction with iodine (Figs. 1, 2). A study of tautomerism, especially in

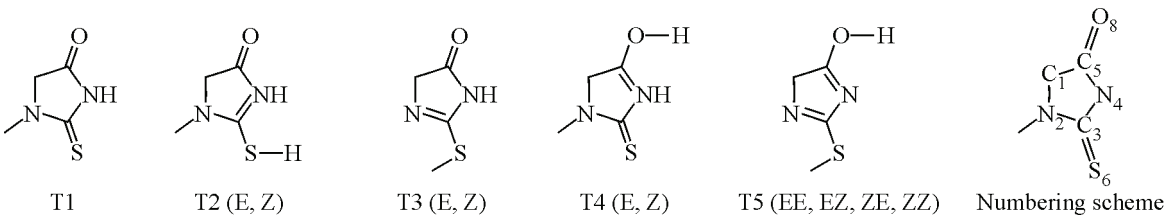

Fig. 1. Possible tautomers and numbering scheme for METO

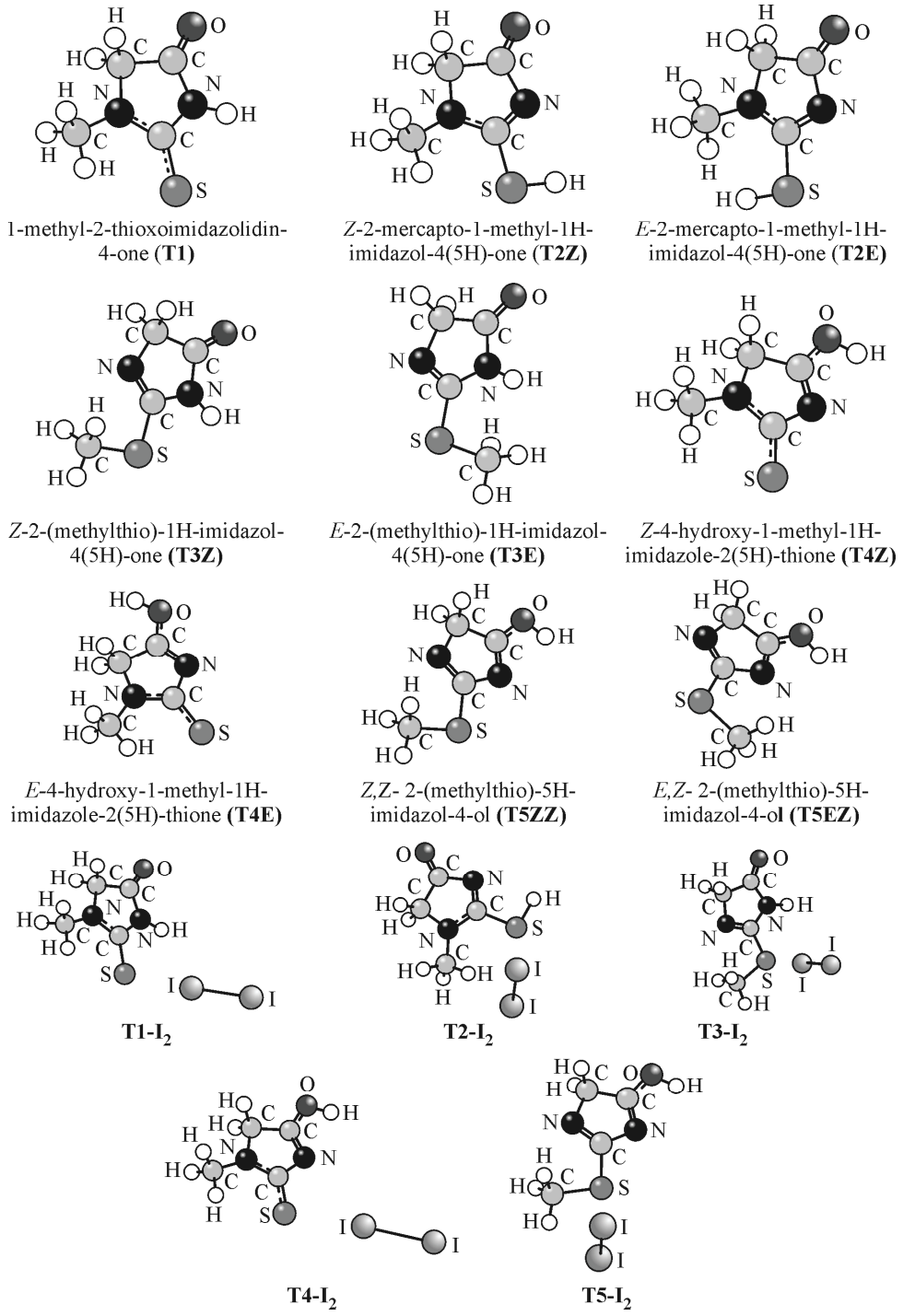

Fig. 2. Optimized structures of the tautomers and complexes

Table 1

Important molecular parameters for the complexes and the most stable isomer of each tautomer (*bond lengths are reported in angstroms and angles are reported in degrees*)

Molecules	T1	T2Z	T3Z	T4Z	T5Z
C3—S	1.66	1.77	1.76	1.66	1.75
C3—N2	1.36	1.36	1.28	1.37	1.29
C3—N4	1.40	1.31	1.40	1.42	1.42
C—O	1.21	1.21	1.21	1.33	1.33
N2—C3—N4	106.3	117.2	115.3	108.8	118.1
S—C3—N4	124.4	122.3	118.0	124.1	115.7
C1—N2—C3	112.3	106.8	106.0	110.8	104.1
C5—N4—C3	113.9	106.1	109.0	106.9	102.5
N2—C1—C5—N4	0.0	–0.3	0.0	0.1	0.0
Complexes	T1—I2	T2Z—I2	T3Z—I2	T4Z—I2	T5Z—I2
C3—S	1.68	1.77	1.77	1.67	1.76
C3—N2	1.35	1.36	1.28	1.37	1.29
C3—N4	1.39	1.31	1.40	1.41	1.42
C—O	1.21	1.21	1.21	1.33	1.33
S—I	3.15	3.36	3.19	3.05	3.17
I—I	2.78	2.74	2.76	2.79	2.77
N2—C3—N4	107.4	117.9	115.8	110.0	118.8
S—C3—N4	123.9	122.0	118.3	123.7	115.6
C1—N2—C3	111.8	106.2	105.8	110.1	103.8
C5—N4—C3	113.3	105.7	108.6	106.6	102.3
I—I—S—C3	–9.5	–32.5	60.7	–175.3	80.2
I—S—C3—N4	108.7	–102.7	81.0	–2.1	82.1
N2—C1—C5—N4	0.0	2.9	0.2	–0.4	0.2

biologically active molecules, has been one of the most interesting in computational researches because tautomerism plays an important role in the determination of compound application [22—34], and different tautomers of each molecule behave differently in both chemical and biological systems. Thus, since the biological, chemical, and complexation properties of MTIO are different in different tautomers, we have attempted a thorough analysis of this molecule in both the tautomery scheme and complexation properties in our study.

In this research, molecular parameters (Table 1), relative energies (Table 2), and vibrational frequencies (Table 3) of MTIO tautomers were calculated using B3LYP/6-311++G** and B3LYP/6-31+G** levels of theory to study its tautomery scheme and the properties of all tautomers. In addition, NBO calculations were made to obtain natural atomic charges (Table 4), occupation numbers (Table 5), and acceptor-donor interactions (Tables 6, 7) of all tautomers and complexes using the B3LYP/6-311++G** level of theory. Then, AIM analyses (Table 8) of the complexes were performed to determine the complexation properties of different tautomers in the interaction with iodine. Computation details and the results obtained in this work are presented below.

METHODS

Density functional theory (DFT) has been widely applied by chemists to study the electronic structure of molecules in the past years [35, 36]. In this work, all calculations were carried out using Becke′s three-parameter density functional [37] and the Lee, Yang, and Parr functional [38] to describe gradient-corrected correlation effects, which leads to the well-known B3LYP method. The

B3LYP method has been validated to give results similar to those of the more computationally expensive MP2 theory for molecular geometry and frequency calculations [39—41].

The geometry optimizations and frequency calculations were performed for all tautomers by the B3LYP method with 6-31+G** and 6-31++G** basis sets, and the NBO analysis [42] was carried out at the B3LYP/6-31++G** level of theory. All optimizations, frequency calculations, and NBO analyses were carried out using the Gaussian 98 program package [43]. The absence of imaginary frequencies verified that all structures were true minima at their respective levels of theory. All results of frequency calculations have been corrected with an appropriate scaling factor [44]. AIM analyses were performed using the AIM200 program [45]. This method has presented useful information about intermolecular interactions and the characterization of bonds through the analysis of the electron density [46].

RESULTS AND DISCUSSION

1-methyl-2-thioxoimidazolidin-4-one (METO) can be presented by 5 different tautomers and total 11 geometric isomers. In Fig. 1, the general structures of different METO tautomers and the numbering scheme of all structures are shown. It seems that **T1** can be considered as the most stable tautomer because of two C=O and C=S strong bonds.

In the first part of our study, the structures of all isomers were optimized using the B3LYP/6-31+G** and B3LYP/6-31++G** levels of theory. To reduce the calculations of tautomer T5, only Z geometric isomers were considered for the OH group and two geometric isomers (E, Z) were only considered for the SMe group. In addition, for the most stable isomer of each tautomer, its complex with an iodine molecule was designed and optimized at the above levels of theory to find the most stable structure for each complex.

The structures of the optimized isomers and complexes are shown in Fig. 2, and important optimized parameters for the complexes and tautomers are listed in Table 1. As shown in Fig. 2, the structures of all isomers are planar and SH and OH groups are in the plane of the molecule ring. In complexes T1 and T4, iodine is in the plane of the molecule, while in T1, T2, and T5, the iodine molecule is perpendicular to the molecule plane. It is remarkable that, when we have a C=S double bond in the molecule, it makes a planar complex with iodine, while in molecules with SH or SMe groups, their complexes with iodine are perpendicular. The spatial interaction of SH and SMe with iodine in the planar complexes are responsible for a higher stability of the perpendicular complexes in those molecules.

By observing Table 1, important aspects of the molecular structure can be followed. The C_3—S bond lengths are listed in the first row. The value of this bond length in T1 and T4 (that consist of the C=S double bond) is 1.66 Å and 1.67—1.68 Å in their complexes. In other tautomers or complexes that consist of the C—S single bond, its value lies between 1.75—1.77 Å. This shows that complexation with iodine has no important effect on the C—S bond, and this length is equal in the tautomers and complexes. In other words, bonding electrons of the C—S bond have not been donated to iodine. The next rows present C3—N2, C3—N4, and C—O bond lengths. The values of these bond lengths are dependent on their order (single bond or double bond) and all of these values are in agreement with their order. In next rows, S—I and I—I bond lengths of the complexes are listed. The S—I bond is slightly shorter in the planar complexes than that in the perpendicular complexes, but any important difference does not exist between different complexes in I—I bond lengths.

Next 4 rows of Table 1 consist of bond angles. Observing bond angle variations, we can follow hybridization changes in the central atom of each angle. For example, when the central atom is sp^2, its angle is near 120 degree (as C3 in all tautomers and N4 in T2, T4, and T5). But for C3, the endocyclic angle (N2—C3—N4) is smaller than the exocyclic angle (S—C3—N4) because of a higher mobility of the external sulfur atom.

Dihedral angles are listed in the last columns of Table 1. The value of the N2—C1—C5—N4 dihedral angle can show the degree of planarity of the molecules. This value is near zero in all tautomers and complexes, so that these values confirm the planarity of all structures. Moreover, the

Table 2

Relative enthalpies and Gibbs free energies of all tautomers and complexes versus the most stable structure (*all in* kcal/mol)

Tautomers	B3LYP/6-31+G**			B3LYP/6-31++G**			Complexes	B3LYP/6-31+G**			B3LYP/6-31++G**		
	ΔZPE	ΔH	ΔG	ΔZPE	ΔH	ΔG		ΔZPE	ΔH	ΔG	ΔZPE	ΔH	ΔG
T1	0.00	0.00	0.00	0.00	0.00	0.00	T1—I2	0.00	0.00	0.00	0.00	0.00	0.00
T2Z	–2.63	18.34	17.97	–2.70	17.89	17.26	T2—I2	–2.53	23.06	24.61	–2.45	22.84	24.07
T2E	–2.52	21.63	22.13	–2.61	20.25	20.86	T3—I2	–1.46	14.35	15.40	–1.47	13.97	15.06
T3Z	–1.42	10.56	11.02	–1.53	10.15	10.62	T4—I2	–0.29	18.12	19.43	–0.28	17.91	19.19
T3E	–1.50	14.17	15.19	–1.63	13.80	14.63	T5—I2	–1.38	28.00	28.66	–1.32	25.63	26.06
T4Z	–0.32	18.36	18.35	–0.29	26.22	26.32							
T4E	–0.69	24.76	25.00	–0.66	32.60	32.95							
T5Z	–1.30	23.17	23.10	–1.28	31.03	31.08							
T5E	–1.45	25.16	25.60	–1.39	33.15	33.59							

I—I—S—C3 and I—S—C3—N4 dihedral angles determine the situation of the iodine molecule versus tautomers.

Energies. The relative zero point energies, enthalpies, and Gibbs free energies for the most stable tautomer and complex are collected in Table 2. In the first section of this table, energy entries for 9 isomers are listed. Among these isomers, T1 has the lowest enthalpy and Gibbs free energy at both levels of theory. T1 has both C=S and C=O strong double bonds, so these strong bonds can be responsible for the most stability of this tautomer. The same observation about the relative stability of cyclic tautomers was observed in various pyrimidine and purine bases [47—49]. The relative stability (enthalpy and Gibbs free energy) of other tautomers and geometric isomers obtained at the B3LYP/6-31++G** level of theory is found to be as follows: T3Z > T3E > T2Z > T2E > T4Z > T5Z > T4E > > T5E. Moreover, the relative stability of the complexes is found to be as follows: T1—I2 > T3—I2 > > T4—I2 > T2—I2 > T5—I2. These results show that although isomers T4 are less stable than isomers T2, complex T4—I2 is more stable than complex T2—I2. This observation is derived from the higher ability of thione tautomers (in T4) to form complexes with iodine. The stability order of isomers shows that the C=O double bond (in T3 and T2) is more energetically favorable than the C=S double bond, or C=O is stronger than C=S. The bond dissociation energies reported confirm this observation. The least stable tautomer is T5 that has neither C=O nor C=S double bond. Moreover, in all tautomers, the Z isomer is more stable than the E isomer. A consideration of the structures of these isomers shows that Z is eclipsed and E is a staggered (or bisected) conformer. In the literature, it is clearly described [50] that because of the reduction of the repulsive interaction between the substituent and $\pi_{C—C}$ orbitals, the eclipsed conformer is more stable than the bisected conformer.

Frequencies. Important vibrational modes of the tautomers and complexes are listed in Table 3. The amount of each frequency can show the bond strength or band order. For example, the C3—S

Table 3

Most important vibrational modes (*in* cm^{-1}) *for the tautomers and complexes*

	T1	T2Z	T3Z	T4Z	T5Z	T1—I2	T2Z—I2	T3Z—I2	T4Z—I2	T5Z—I2
C3—S	496	449	451	482	433	490	445	448	484	428
N2—C3	1506	1515	1589	1481	1523	1516	1518	1597	1387	1530
N4—C3	1380	1426	1368	1187	1120	1410	1428	1371	1198	1674
NH, SH or OH	3543	2623	3538	3651	3642	3407	2627	3536	3621	3640
S—I	—	—	—	—	—	83	68	76	86	82
I—I	—	—	—	—	—	178	200	192	176	187

Table 4

Natural atomic charges (*in atomic units*, a.u. *or e*[a]) *extracted from NBO calculations*

Molecules	C3	N2	N4	O8	H11	S6	CH3	C5
T1	0.25	–0.47	–0.65	–0.58	0.47	–0.17	0.27	0.68
T2Z	0.24	–0.53	–0.68	–0.59	0.45	0.28	0.25	0.68
T2E	0.24	–0.51	–0.68	–0.59	0.45	0.32	0.25	0.68
T3Z	0.32	–0.49	–0.61	–0.57	0.18	0.07	0.26	0.66
T3E	0.30	–0.49	–0.59	–0.57	0.12	0.14	0.25	0.65
T4Z	0.21	–0.48	–0.53	–0.67	0.53	–0.12	0.26	0.60
T4E	0.21	–0.48	–0.49	–0.65	0.51	–0.12	0.27	0.59
T5Z	0.20	–0.53	–0.57	–0.68	0.52	0.32	0.28	0.60
T5E	0.21	–0.51	–0.59	–0.68	0.52	0.31	0.27	0.60
Complexes	C3	N2	N4	O8	H11	S6	I15	I16
T1—I2	0.27	–0.43	–0.65	–0.46	0.46	–0.11	–0.02	–0.16
T2—I2	0.28	–0.46	–0.57	–0.48	0.19	0.07	–0.02	–0.05
T3—I2	0.22	–0.48	–0.68	–0.50	0.44	0.34	–0.03	–0.09
T4—I2	0.22	–0.44	–0.52	–0.59	0.50	–0.07	–0.17	–0.01
T5—I2	0.17	–0.48	–0.54	–0.60	0.49	0.39	–0.11	–0.02

[a] Each a.u. (or *e*) is 1.60×10^{-19} coulombs (in SI units).

bond in T1 and T4 is a double bond and its frequency is about 50 cm^{-1} higher than that of the other tautomers (in tautomers and complexes). The same observations were obtained for N2—C3 (for T3 and T5) and N4—C3 (in T2). In addition, the C3—S frequency of each complex is lower than its value in the related tautomer. This confirms that in all cases, complexation of a sulfur atom to iodine affect the strength of the C—S bond. Other important frequencies are SH, NH or OH frequencies. It is noticeable that although the values of NH and OH frequencies are less in the complexes than those in the tautomers, the SH frequency of the complex (in T2) is slightly higher than that in the tautomer because complexation of sulfur to iodine molecule can affect the strength of the SH bond. The last frequencies are S—I and I—I frequencies of complexes. The S—I frequency is higher in T1 and T4 than that in the other complexes because of the more effective interaction between the tautomer and iodine in these planar complexes. This observation also shows that the π bond in C=S increases the donor property of the sulfur atom to iodine. According to this observation, the I—I frequency is higher in T1 and T4 complexes than that in the other tautomers.

NBO analysis. NBO population analyses were made to obtain natural atomic charges and the other important complexation properties. Table 4 presents the natural atomic charges of atoms in all isomers and complexes. The numbering scheme of this table is the same as the scheme presented in Fig. 1. In tautomers (T1 to T5), all nitrogen and oxygen atoms have negative charges and carbon and hydrogen atoms have positive charges. These charges are usual, however, interesting charges were observed in the sulfur atom. In T1 and T4 and their related complexes, sulfur has a negative charge, while in the other tautomers and complexes it has a positive charge because in T1 and T4, the sulfur atom is bound only to C3 with a double bond while in the others, sulfur is bound to two atoms by single bonds. Other atomic charges of the atoms in tautomers have usual values with a little variation between the tautomers. In the complexes, the sum of net charges of all atoms is larger in the tautomer than that in simple tautomers, because negative charges are placed on the iodine atoms. These charges provide another proof for the existence of a real complex between the tautomers and iodine. Also, in the planar complexes (complexes of T1 and T4 with iodine), the absolute values of charges placed on

Table 5

Most important occupancies of NBOs in atomic units (LP: *lone pair*)

	T1	T2Z	T2E	T3Z	T3E	T4Z	T4E	T5Z	T5E	T1—I2	T2Z—I2	T3Z—I2	T4Z—I2	T5—I2
$\sigma_{C3—S6}$	1.98	1.98	1.98	1.98	1.98	1.99	1.98	1.98	1.98	1.99	1.99	1.98	1.99	1.98
$\pi_{C3—S6}$	1.98					1.97	1.96			1.99			1.98	
$LP1_{N2}$	1.65	1.99	1.91	1.66	1.69	1.66	1.66	1.92	1.92	1.62	1.65	1.91	1.63	1.91
$LP1_{N4}$	1.63	1.66	1.67	1.91	1.91	1.91	1.91	1.92	1.92	1.61	1.90	1.65	1.90	1.91
$LP1_{S6}$	1.99	1.98	1.98	1.99	1.98	1.98	1.99	1.98	1.98	1.99	1.99	1.98	1.99	1.98
$LP2_{S6}$	1.83	1.83	1.84	1.85	1.84	1.87	1.87	1.81	1.83	1.70	1.82	1.77	1.73	1.73
$LP1_{O8}$	1.98	1.98	1.98	1.98	1.98	1.97	1.97	1.97	1.97	1.98	1.98	1.98	1.97	1.97
$LP2_{O8}$	1.85	1.85	1.85	1.85	1.86	1.82	1.82	1.82	1.82	1.82	1.83	1.82	1.77	1.79
$\sigma^*_{C5—O8}$ [a]	0.01	0.01	0.01	0.01	0.01	0.04	0.04	0.04	0.04	2.00	2.00	2.00	2.00	2.00
$\pi^*_{C5—O8}$ [b]	0.25	0.25	0.24	0.24	0.24	—	—	—	—	1.99	2.00	1.99	2.00	1.99
$\sigma^*_{C3—S6}$ [c]	0.01	0.05	0.05	0.04	0.04	0.01	0.01	0.05	0.04	1.97	1.99	1.99	2.00	1.99
$\pi^*_{C3—S6}$ [d]	0.46	—	—	—	—	0.42	0.42	—	—	0.20	0.07	0.11	0.17	0.13

[a] In complexes: $LP1_{I15}$, [b] In complexes: $LP2_{I15}$, [c] In complexes: $LP3_{I15}$, [d] In complexes: $\sigma^*_{I15—I16}$.

the iodine atoms are larger than those in the other complexes. This shows that a more effective interaction (between the tautomer and iodine) seems to exist in the planar complexes.

One of the important results obtained from NBO calculations is orbital occupancies and another is acceptor-donor interactions. In Table 5, selected occupation numbers for all tautomers and complexes are listed. The occupancies given show that most bonding orbitals and lone pairs consist of more than 1.9 electrons, but some lone pairs have occupation numbers between 1.61 and 1.77. These occupancies display that important donor properties can exist on these lone pairs. Also, a significant change in the occupancies of the σ or π bond between the tautomers and related complexes has not been observed. This observation confirms that the σ or π bond do not contribute in electron donation to iodine. On behalf, a significant decrease was observed in the occupation number of lone pair 2 of sulfur in the complexes versus tautomers, which shows that this lone pair is donated to the iodine atom. In addition, while the occupation number of σ* bonds is very low (lower than 0.05), these numbers are significant in π* bonds. The occupation number of $\pi^*_{C5—O8}$ is between 0.24 and 0.25 in the tautomers because of the resonance between the N4 lone pair and the C5=O8 double bond. Otherwise, the N4 lone pair has resonance with $\pi^*_{C5—O8}$. The same results were observed in the $\pi^*_{C3—S6}$ occupation number in T1 and T4 (only these two tautomers have the C=S double bond). Because of a higher capacity of the sulfur atom in electron acceptance, these occupancies are higher in the tautomers than those in the previous example, and its value lies between 0.42 and 0.46.

The list of important donor-acceptor interactions is given in Table 6. As shown in this table, the lone pairs of N2, N4, and S6 are important donors, and C—N, C—S and C—O bonds are the main acceptors. The most powerful interactions are $LP1_{N2}$ to $\pi^*_{C3—S6}$ and $LP1_{N4}$ to $\sigma^*_{C4—O8}$, and powerful resonance exists between the nitrogen lone pair and the C=S or C=O double bond. Another important interaction is electron donation by $LP2_{S6}$ to the $\sigma^*_{C3—N4}$. This interaction has not been observed in most complexes because of the donation of this lone pair to iodine. It is obvious that in T2, the C3=N4 double bond exists, so that this interaction is replaced by $LP2_{S6}$ donation to $\pi^*_{C3—N4}$. In addition, special donor-acceptor interactions were listed only for the complexes in Table 7. The table data listed shows that although both sulfur lone pairs have been involved in electron donation to iodine, however, one of them (LP2) is more effective. Moreover, in the planar complexes (T1 and T2 with iodine) the

Table 6

Acceptor-donor interaction energies (*in* kcal/mol) *in the tautomers and complexes*

Donor	Acceptor	T1	T2Z	T2E	T3Z	T3E	T4Z	T4E	T5Z	T5E	T1—I2	T2Z—I2	T3Z—I2	T4Z—I2	T5—I2
$LP1_{N2}$	$\sigma^*_{C3—S6}$	—	—	1.0	—	—	—	—	0.9	0.8	1.0	—	1.6	—	0.9
$LP1_{N2}$	$\pi^*_{C3—S6}$	81.6	1.0	—	—	—	73.8	74.9	—	—	—	—	—	89.9	—
$LP1_{N4}$	$\sigma^*_{C3—S6}$	—	—	—	0.8	0.9	—	—	—	0.6	84.1	1.7	—	0.6	0.7
$LP1_{N4}$	$\pi^*_{C4—O8}$	42.6	52.4	51.4	1.1	11.1	3.3	4.3	2.7	—	54.7	54.3	2.3	5.3	3.9
$LP1_{S6}$	$\sigma^*_{C3—N4}$	3.6	—	5.2	4.7	—	3.9	3.7	—	5.2	3.4	2.6	—	3.2	—
$LP2_{S6}$	$\sigma^*_{N2—C3}$	4.4	6.0	—	—	—	—	13.2	—	—	12.5	—	—	13.6	—
$LP1_{S6}$	$\sigma^*_{N2—C3}$	—	—	—	—	4.6	4.0	3.8	6.2	—	1.1	—	3.5	0.9	4.0
$LP2_{S6}$	$\pi^*_{N2—C3}$	—	28.2	26.0	—	—	13.0	—	30.7	28.0	—	—	24.0	—	27.7
$LP2_{S6}$	$\sigma^*_{C3—N4}$	12.8	—	—	25.3	25.1	12.7	12.5	—	—	—	22.2	—	—	—

Table 7

Special acceptor-donor interaction energies (*in* kcal/mol) *in the complexes*

Donor	Acceptor	T1—I2	T2Z—I2	T3Z—I2	T4Z—I2	T5—I2
$LP1_{S6}$	$\sigma^*_{I—I}$	2.3	0.8	1.5	2.3	2.05
$LP2_{S6}$	$\sigma^*_{I—I}$	29.0	7.6	13.4	26.1	16.7

acceptor-donor energy is significantly higher than that in the perpendicular complexes in both interacttions (LP1 and LP2 to $\sigma^*_{I—I}$). This observation confirms our previous estimate about higher efficiency of the planar complex versus the perpendicular complex.

AIM results. In the final part of our study, AIM analyses were perfrmed for the complexes to obtain important complexation properties, and the results are listed in Table 8. In the first column, energy densities for our favorable interaction are mentioned with values between 32.0—54.7 kcal/mol. The energy densities are larger when SMe is linked to the iodine (complexes of T3 and T5) than the others (53.2 and 54.7 cal/mol respectively for T3 and T5). Moreover, when we have the C=S double bond (in T1 and T4), the lowest energy densities were obtained. The next part of this table (columns 2—7) consists of S—I interaction data. In this part, ρ (electron density) and its Laplacian may be very useful parameters to estimate the strengths of the S—I interaction. The values calculated for the charge density ρ at the S—I intermolecular bond critical points lie between 0.15 and 0.26. These low values re-

Table 8

Calculated critical point properties of the complexes

Complex	En. Den.[a]	*r*, Å	ρ(*r*), au	▼2ρ(*r*), au	cp-A, Å	cp-B, Å	ε	*r*, Å	ρ(*r*), au	▼2ρ(*r*), au	cp-A, Å	cp-B, Å	ε
		S—I interactions						C—S interaction					
T1—I2	32.0	3.065	0.026	0.058	1.574	1.484	0.008	1.680	0.200	–1.842	1.066	0.614	0.175
T2—I2	39.2	3.364	0.015	0.038	3.248	3.108	0.165	1.773	0.195	–0.411	1.648	1.703	0.003
T3—I2	53.2	3.190	0.020	0.050	3.093	2.930	0.003	1.770	0.196	–0.417	1.664	1.681	0.192
T4—I2	33.9	3.055	0.025	0.058	2.976	2.797	0.010	1.670	0.206	0.467	2.001	1.155	0.165
T5—I2	54.7	3.110	0.023	1.671	3.023	2.855	0.005	1.752	0.203	–0.418	1.493	1.981	0.004

[a] This column refers to energy densities at the critical point in kcl/mol.

flect the weak character of this bond in our complexes. It is noticeable that the planar complexes have the largest values of the electron density, confirming the higher efficiency of the planar complexes. In supporting this argument, $r_{S—I}$ is less in T1 and T4 than that in the other tautomers. The charge density values for the S—I bond critical point is relatively low and the Laplacian of the electron density is positive, indicating that the interaction is dominated by the contraction of charge away from the interatomic surface towards each nuclei. Therefore, the S—I interaction is characterized as a closed shell interaction. The ε values are the criterion of the π bond character and lies between 0.003 and 0.010. As the other parameters, the values of T1 and T4 (planar complexes) are more than those of the perpendicular complexes. In last part of Table 8 (columns 8—13) the negative values for the Laplacian of the C—S bond show the covalent bond.

CONCLUSIONS

In this report, 1-methyl-2-thioxoimidazolidin-4-one (MTIO) and their tautomers (5 tautomers) and isomers (total 9 isomers) have been studied to find new structures with the effective ability to make a complex with iodine (for treatment of hyperthyroidism). All structures and their complexes with iodine have been optimized using the B3LYP method with 6-311++G** and 6-31+G** basis sets to obtain their molecular parameters, relative energies, and vibrational frequencies. The optimized structures show that T1 and T4 (thione) tautomers make planar complexes with iodine while the other tautomers make perpendicular complexes. The relative energies show that in all tautomers and complexes, ketone and thione forms are more stable than enol and thienol forms, and also Z isomers are more stable than E isomers. In other words, the relative stability of the tautomers found to be: T1 > T3Z > T3E > T2Z > T2E > T4Z > T5Z > T4E > T5E. The relative stability of the complexes is found to be: T1—I2 > T3—I2 > T4—I2 > T2—I2 > T5—I2. Then, NBO calculations were performed for the tautomers and complexes to obtain atomic charges, occupation numbers, and acceptor-donor interactions. These results confirm the ability of MTIO tautomers to form complexes and show that the planar complexes have more effective interaction than the perpendicular complexes. Finally, the AIM analyses were performed on the complexes to prove them and obtain complexation properties. These calculations show that the interaction between the sulfur atom and iodine has low electron density and π bond character. The interaction of the tautomers with iodine is more powerful in the planar complexes versus the perpendicular complexes.

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