



# Ring-Chain Tautomerism of the Condensation Products of 2-Mercaptobenzohydrazide with Aliphatic and Aromatic Aldehydes: Influence of Electronic and Steric Factors

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## Abstract

It has been shown by <sup>1</sup>H and <sup>13</sup>C NMR spectroscopy that 2-mercaptobenzoylhydrazones of aliphatic and aromatic aldehydes exist in solution as tautomeric mixtures of linear and cyclic benzo-1,3,4-thiadiazepine forms. The linear hydrazone form is represented by (*E,E*)- and (*E,Z*)-conformational isomers, differing in the disposition relative to the amide C–N bond. Growing bulk of the alkyl substituent at the C=N bond of the aliphatic aldehydes derivatives decreases the fraction of the cyclic tautomer; therewith the logarithms of the constants of the chain-ring tautomeric equilibrium correlate with the *E<sub>s</sub>* steric constants of the alkyl substituents. In the series of the aromatic aldehydes 2-mercaptobenzoylhydrazones the linear tautomer prevails, and the logarithms of the tautomeric equilibrium constants *K<sub>T</sub>* correlate with the  $\sigma$ -constants of the substituents in the aromatic nucleus.

## Subject Areas

Organic Chemistry

## Keywords

Hammett and Taft Equations, Ring-Chain Tautomerism 2-Mercaptobenzoylhydrazones, Benzo-1,3,4-Thiadiazepines

## 1. Introduction

The tendency of functionally-substituted hydrazones to undergo intramolecular

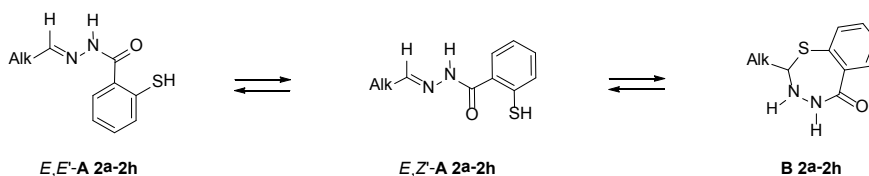
cyclization at the polar C=N bond of the hydrazone fragment is commonly used in the synthesis of five- and six-membered heterocycles [1] [2] [3]. This reaction is sometimes reversible, which leads to the coexistence of the hydrazone and cyclic forms as their tautomeric mixture in solution [4] [5] [6]. Thus, the 2-mercaptobenzoylhydrazone of acetone transforms in solution to the alternative 1,3,4-benzothiadiazepine form [7]. We note that the hydrazones obtained using the hydrazides of 2-hydroxy- and 2-aminobenzoic acids have linear structure. The possible cyclization at the C=N bond by attack of the available OH or NH functions does not occur [8] [9].

The aim of the present work, being a continuation of the previous investigations, was to study the structure of the products of condensation of 2-mercaptobenzoic acid hydrazone (2-HSC<sub>6</sub>H<sub>4</sub>CONHNH<sub>2</sub>) **1** with a series of aliphatic and aromatic aldehydes, and also the effect of the steric or electronic properties of a substituent in the aldehyde component on the position of the tautomeric equilibrium (**Figure 1** and **Figure 2**).

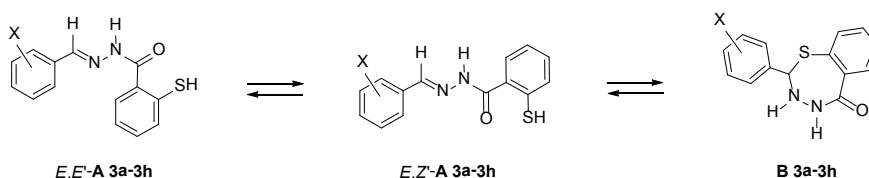
## 2. Results and Discussion

Compounds **2a-2h** and **3a-3h** were obtained in 55% - 90% yield after briefly maintaining equimolar quantities of 2-mercaptobenzoic acid hydrazone **1** and the appropriate aldehyde during 10 - 15 min in methanol solution at room temperature (**Experimental part**). In all experiments, the <sup>1</sup>H- and <sup>13</sup>C-NMR spectra were recorded at definite time intervals starting from the moment of dissolution until the end of transformations. In addition, the structure of the compounds under study in the crystalline state was confirmed by solid-phase high-resolution <sup>13</sup>C-NMR spectroscopy (CPMAS).

The variation in time of the <sup>1</sup>H-NMR spectra of compounds **2a-2h** suggests that they exist in the crystalline state in the cyclic benzo-1,3,4-thiadiazepine form **B**. For instance, in the freshly prepared solution of compound **2a** in DMSO-*d*<sub>6</sub> a single set of peaks is observed corresponding just to **B** form in <sup>1</sup>H-



**Figure 1.** Tautomerism of 2-mercaptobenzoylhydrazones of aliphatic aldehydes **2a-2h**. Alk = H (**2a**), Me (**2b**), Et (**2c**), Bu (**2d**), *i*-Pr (**2e**), *i*-Bu (**2f**), *s*-Bu (**2g**), *t*-Bu (**2h**).



**Figure 2.** Tautomerism of 2-mercaptobenzoylhydrazones of aromatic aldehydes **3a-3h**. X = 4-NO<sub>2</sub> (**3a**), 3-NO<sub>2</sub> (**3b**), 4-Br (**3c**), 4-Cl (**3d**), H (**3e**), 4-Me (**3f**), 4-MeO (**3g**), 4-Me<sub>2</sub>N (**3h**).

NMR spectrum. It is indicated by two signals of NH protons at 5.69 and 9.44 ppm and by a doublet at 4.29 ppm (H-2), and the  $^{13}\text{C}$ -NMR spectrum of this form is characterized by the signal of  $\text{sp}^3$ -hybridized atom C-2 at 58.49 ppm. Gradually in the  $^1\text{H}$ -NMR spectrum of compound **2a** in  $\text{DMSO-d}_6$  signals appear corresponding to the stereoisomer of the linear acylhydrazone form **A**: one signal of azomethine protons at 7.43 ppm and also broadened signal of NH protons in the region 11.89 ppm. After some time the spectrum of compound **2a** stopped to change indicating that the ring-chain equilibrium was attained where alongside the cyclic thiadiazepine form **B** existed one stereoisomeric modification of the linear form **A**. A similar situation exists for the solutions in  $\text{DMSO-d}_6$  of other condensation products of aliphatic aldehydes with 2-mercaptobenzoic acid hydrazide **2b-2h** (Table 1). Transition from compounds **2b-2d** having an alkyl substituent with normal structure to compounds **2f-2h** containing bulky isobutyl, *sec*-butyl, and *tert*-butyl groups leads to the appearance in the equilibrium of the second linear isomer and to the considerable decrease in the content of cyclic tautomer **B** in the solution.

The observed doubling of the signals of the linear form **A** in the  $^1\text{H}$ -NMR spectra of compounds **2f-2h** must be linked with the presence of conformational *E,Z*-isomers, differing in the disposition of substituents relative to the amide C–N bond. The existence of an *E,Z*-configuration of isomer relative to the C=N bond was not considered by us since aldoacylhydrazones exist primarily or completely in the *E*-configuration relative to this bond [10] [11] [12] [13]. Assignment of the signals of the *E,E*- and *E,Z*-isomers of the linear form **A** was based on the known difference in position of the signals of the azomethine protons of the conformational *E,Z*-isomers in the  $^1\text{H}$ -NMR spectra [14]. The signals of the *Z*-isomer of this group are disposed at lower field than the analogous signals of the *E*-isomer. An opposite value of both signals in the  $^1\text{H}$ -NMR spectra is observed for the protons of the NHCO groups of these conformers. Taking into consideration the above-indicated it may be confirmed that the main isomer has the *E,Z*-structure, and the minor isomer the *E,E*-spatial disposition.

**Table 1.** Tautomeric composition of the aliphatic aldehydes 2-mercaptobenzoyl-hydrazones **2a-2h** in  $\text{DMSO-d}_6$ .

Compound	Tautomeric composition in $\text{DMSO-d}_6$ , % (48 h after dissolution)			$\lg K_T^*$
	<i>E,E</i> - <b>A</b>	<i>E,Z</i> - <b>A</b>	<b>B</b>	
<b>2a</b>	–	0.5	99.5	2.299
<b>2b</b>	–	2	98	1.690
<b>2c</b>	–	4	96	1.380
<b>2d</b>	–	7	93	1.123
<b>2e</b>	–	10	90	0.954
<b>2f</b>	1	10	89	0.908
<b>2g</b>	6	38	56	0.105
<b>2h</b>	12	61	27	–0.432

\*Tautomeric equilibrium constant  $K_T = [\mathbf{B}]/[E,E - \mathbf{A}] + [E,Z - \mathbf{A}]$ .

The position of the equilibrium  $\mathbf{A} \rightleftharpoons \mathbf{B}$  depends on the length and branching of the alkyl substituent: the introduction of bulky groups into the aliphatic aldehyde component leads to a displacement of the ring-chain equilibrium to the side of the 2-mercaptobenzoylhydrazone form **A** (Table 1). A linear correlation is then observed between the logarithms of the tautomeric equilibrium constants  $K_T$  and the Taft  $E_s$  constant [15], [16], [17]. The use of the Palm steric constants  $E_s^\circ$  [18] improves the correlation (Table 2 and Figure 1).

By an example of compound **2h** we explored the effect of solvent on the tautomeric equilibrium (Table 3). In crystalline state compound exist as benzo-1,3,4-thiadiazepine **B**. This proves to be true because in its solid-phase  $^{13}\text{C}$ -NMR spectrum  $\text{sp}^3$ -hybridized atom C-2 at 84.56 ppm is present (Experimental part). In low-polar  $\text{CDCl}_3$  about 70% of cyclic benzo-1,3,4-thiadiazepine form was detected. In going to basic dipolar solvents such as  $\text{DMSO-}d_6$  and  $\text{DMF-}d_7$  the domination of the linear form **A** was favored.

Thus the condensation products of aliphatic aldehydes with 2-mercaptobenzoic acid hydrazide **2a-2h** in the crystalline state possess the structure benzo-1,3,4-thiadiazepine, and in solution of polar solvents they partially transform into the open-chain form **A**; consequently, it is only tentatively possible to use the name “mercaptobenzoylhydrazone” for such compounds.

In the series of aromatic aldehydes 2-mercaptobenzoylhydrazones **3a-3h** the ring-chain tautomeric equilibrium should shift to the open-chain form **A** for the latter is stabilized by involving the aromatic ring in the system of  $\pi$ -p- $\pi$ -conjugation of the acylhydrazone fragment [10] [12]. This assumption was completely confirmed by the study of  $^1\text{H}$ - and  $^{13}\text{C}$ -NMR spectra of compounds **3a-3h** (Figure 2).

**Table 2.** Correlation of the logarithms of the tautomeric equilibrium constants  $K_T$  of compounds **2a-2h** with substituent constants of Taft  $E_s$  and Palm  $E_s^\circ$  according to the equation:  $\lg K_T = a + \rho \cdot X$ ; ( $n = 8$ ).

$X$	$a$	$\rho$	$r$	$s_D$
$E_s$	$1.398 \pm 0.116$	$0.960 \pm 0.129$	0.949	0.292
$E_s^\circ$	$1.852 \pm 0.084$	$1.068 \pm 0.077$	0.985	0.161

**Table 3.** Tautomeric composition of trimethylacetic aldehyde 2-mercaptobenzoylhydrazone **2h** in different solvents.

Solvent	Tautomeric composition, %, (48 h after dissolution)		
	Form $E,E$ - <b>A</b>	Form $E,Z$ - <b>A</b>	Form <b>B</b>
Solid phase	–	–	100
$\text{CDCl}_3$	–	30	70
$\text{Pyridine-}d_5$	6	37	57
$\text{DMF-}d_7$	10	46	44
$\text{DMSO-}d_6$	12	61	27

In the  $^1\text{H-NMR}$  spectra of solutions in  $\text{DMSO}d_6$  of all the synthesized compounds **3a-3h** there were signals corresponding both to the linear **A** and to the cyclic benzo-1,3,4-thiadiazepine **B** tautomeric forms. The signals of the linear 2-mercaptobenzoylhydrazone tautomer **A** were doubled in the spectra (**Table 4**). The observed doubling of the signals of the linear form **A** in the  $^1\text{H-NMR}$  spectra of compounds **3a-3h** must be linked with the presence of conformational  $E,Z$ -isomers, differing in the disposition of substituents relative to the amide C–N bond. An  $E, Z$ -structure must therefore be attributed to the main isomer whereas  $E,E$ -structural disposition to the minor isomer.

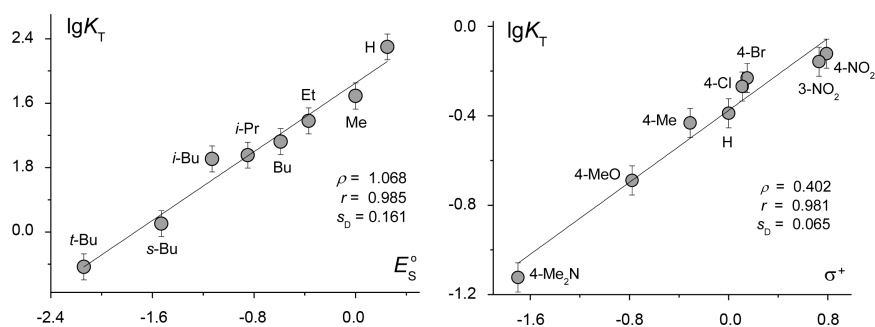
The existence of an  $E,Z$ -configuration of isomer relative to the C=N bond was not considered by us since aldoacylhydrazones exist primarily or completely in the  $E$ -configuration relative to this bond [10], [12]. The assignment of signals belonging to  $E,E$ - and  $E,Z$ -isomers of linear form **A** was based on the known difference in the chemical shifts of the carbon atoms in the C=N and C=O bonds in the  $^{13}\text{C-NMR}$  spectra of conformational isomers of monocarbonyl compounds acylhydrazones; the  $E$ -isomer signals of these groups were located in the region of 145 and 170 ppm, whereas those of  $Z$ -isomer, at 150 and 160 ppm respectively [3] [12] [13]. In view of the above the major isomer of compounds **3a-3h** had  $E,Z$ -configuration, and the structural arrangement of the minor isomer was  $E,E$ -configuration. The existence of the cyclic form **B** in solution may be judged in the  $^1\text{H-NMR}$  spectra by the doublet signals of the H-2 and NHCO protons at 5.76 and 9.62 ppm respectively and also by the doublet-doublet signals of the NH group proton at 6.25 ppm, which is caused by a spin-spin interaction with the protons in positions 2 and 4 of the benzo-1,3,4-thiadiazepine cycle (**Experimental part**).

The introduction of an electron-withdrawing substituent into the aromatic ring of the aldehyde component leads to a displacement of the ring-chain equilibrium  $\mathbf{A} \rightleftharpoons \mathbf{B}$  to the side of the cyclic benzo-1,3,4-thiadiazepine form **B**, and a linear correlation is then observed between the logarithms of the tautomeric equilibrium constants  $K_T$  and the Hammett  $\sigma$ -constant [16] [19]. The use of the  $\sigma^+$ -constant of Brown [20] improves the correlation (**Table 5** and **Figure 3**). The

**Table 4.** Tautomeric composition of the aromatic aldehydes 2-mercaptobenzoyl-hydrazones **3a-3h** in  $\text{DMSO}d_6$ .

Compound	Tautomeric composition in $\text{DMSO}d_6$ , %, (48 h after dissolution)			$\lg K_T^*$
	$E,E$ - <b>A</b>	$E,Z$ - <b>A</b>	<b>B</b>	
<b>3a</b>	6	51	43	-0.122
<b>3b</b>	6	53	41	-0.158
<b>3c</b>	9	54	37	-0.231
<b>3d</b>	9	56	35	-0.269
<b>3e</b>	10	61	29	-0.389
<b>3f</b>	10	63	27	-0.432
<b>3g</b>	11	72	17	-0.689
<b>3h</b>	13	80	7	-1.123

\*Tautomeric equilibrium constant  $K_T = [\mathbf{B}]/[E,E-\mathbf{A}] + [E,Z-\mathbf{A}]$ .



**Figure 3.** Plots of the tautomeric equilibrium  $K_T$  logarithms correlation of compounds **2a-2h** and **3a-3h** respectively with substituent constants: of Palm  $E_S^o$  alkyl substituent constants (*left*), of Brown  $\sigma^+$  substituent constants (*right*).

**Table 5.** Correlation of the logarithms of the tautomeric equilibrium constants  $K_T$  of compounds **3a-3h** with substituent constants of Hammett  $\sigma$  and Brown  $\sigma^+$  according to the equation:  $\lg K_T = a + \rho \cdot X$ ; ( $n = 8$ ).

$X$	$a$	$\rho$	$r$	$s_D$
$\sigma$	$-0.477 \pm 0.045$	$0.595 \pm 0.090$	0.938	0.125
$\sigma^+$	$-0.376 \pm 0.025$	$0.402 \pm 0.033$	0.981	0.065

same regularity is explained by the fact that the electron-withdrawing substituents strengthen the electrophilicity of the carbon atom of the C=N bond, addition of the SH function to which leads to the formation of benzo-1,3,4-thiadiazepine tautomer **B**. The conformational equilibria within the linear tautomer are sensitive to a lesser extent to the nature of the substituent in the aromatic ring. Probably in both linear forms  $E,E$ -**A** and  $E,Z$ -**A** identical systems of conjugation occur, reacting in the same way to the change of electronic parameters of the substituent (**Table 4**).

In a much greater extent the position of the tautomeric equilibrium is dependent on the nature of solvent used. This was demonstrated by the example of 4-chlorobenzoic aldehyde 2-mercaptobenzoylhydrazone **3d** (**Table 6**). The open-chain structure  $E,Z$ -**A** of compound **3d** in crystalline state was confirmed by its solid-phase  $^{13}\text{C}$ -NMR spectrum: 150.74 (C=N), 166.55 (C=O) ppm (**Experimental part**). The same form was detected under the study of the spectrum of compound **3d** taking of in  $\text{CDCl}_3$ . In going to basic dipolar solvents such as  $\text{DMSO}d_6$  and  $\text{DMF}d_7$  the domination of the benzo-1,3,4-thiadiazepine form **B** was favored. Perhaps, its stabilization is due to the possibility of hydrogen bonds formation between the NH groups of the benzo-1,3,4-thiadiazepine ring and the polar solvent molecules.

### 3. Conclusions

Therefore, in contrast to the products of the condensation of aldehydes with the hydrazides of 2-hydroxy- and 2-aminobenzoic acids reported in the literature [8] [9], 2-mercaptobenzoylhydrazones of aliphatic and aromatic aldehydes display a tendency to cyclize to give the seven-membered 1,3,4-benzothiadiazepine

**Table 6.** Tautomeric composition of 4-chlorobenzoic aldehyde 2-mercaptobenzoyl-hydrazone **3d** in different solvents.

Solvent	Tautomeric composition, %, (48 h after dissolution)		
	Form <i>E,E</i> - <b>A</b>	Form <i>E,Z</i> - <b>A</b>	Form <b>B</b>
Solid phase	–	100	–
CDCl <sub>3</sub>	–	100	–
Pyridine- <i>d</i> <sub>5</sub>	16	71	13
DMF- <i>d</i> <sub>7</sub>	8	58	34
DMSO- <i>d</i> <sub>6</sub>	9	56	35

ring. This naturally reflects the greater nucleophilicity of the sulfur atom of the SH function, which participates in intramolecular cyclization, in comparison with the nucleophilicity of the oxygen and nitrogen atoms in the OH and NH functions in the hydrazones obtained using 2-hydroxy- and 2-aminobenzoic acid hydrazides. In this regard, 2-mercaptobenzoylhydrazones are similar to the products of the condensation of carbonyl compounds with thiobenzoic and thioglycolic acid hydrazides, for which intramolecular attack by the sulfur atom at the C=N bond of the hydrazone fragment leads to formation of 1,3,4-thiadiazoline [21] and 1,3,4-thiadiazine rings [7] [12], respectively. The determination of the conformational state of the seven-membered 1,3,4-benzothiadiazepine ring requires further study.

## 4. Experimental Part

### 4.1. General Methods

<sup>1</sup>H- and <sup>13</sup>C-NMR spectra were registered on a spectrometer Bruker AV-400 at operating frequencies 400 and 100 MHz respectively (internal reference hexamethyldisiloxane). The solid-phase <sup>13</sup>C-NMR spectra were obtained on a Bruker AM-500 spectrometer (125 MHz) using a standard procedure utilizing cross polarization and magic angle spinning (CPMAS) technique (frequency 4.5 kHz; internal reference hexamethylbenzene). The tautomeric composition of obtained compounds was estimated by the integration of the appropriate signals in the <sup>1</sup>H NMR spectra, and error of measurement was ±1%. Elemental analysis of previously unknown compounds was carried out on a CHN Analyzer Hewlett Packard 185B. The purity of prepared compounds was checked by TLC on Silufol UV-254 plates, eluent benzene-acetone, 4:1. 2-Mercaptobenzoic acid hydrazide **1** was obtained by method [22].

### 4.2. Synthesis of 2-Mercaptobenzoylhydrazones **2** and **3** (General Procedure)

To a solution of 2-mercaptobenzohydrazide **1** (1.68 g, 10 mmol) in methanol (25 ml) an appropriate aldehyde (11 mmol) was added (for compound **2a** 1.0 ml of 40% formaline was used), and the mixture was kept at room temperature for a

period of 10 - 15 min. The solvent was removed at a reduced pressure, and the residue was washed with ether (3 × 25 ml), filtered off, dried and recrystallized.

Physico-chemical and spectral characteristics of compounds **2b-2f** and **3a-3c**, **3e-3h** were described previously [23] [24].

### 4.3. Formic Aldehyde 2-Mercaptobenzoylhydrazone (2a)

Yield 54%, m.p. 201° - 203° (acetonitrile) (m.p. [22] 203° - 206°). <sup>1</sup>H-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form *E,Z*-**A** (0.5%): 11.89 (br.s, NHCO), 7.43 (br.s, HC=N); form **B** (99.5%): 4.29 (d, J = 7.8 Hz, H-2), 5.69 (dt, J<sub>1</sub> = 7.8 Hz, J<sub>2</sub> = 5.0 Hz, NH), 7.47 - 7.60 (Ar in *E,Z*-**A** and **B**), 9.44 (d, J = 5.0 Hz, NHCO) ppm. <sup>13</sup>C-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form **B**: 58.49 (C-2), 128.42 - 140.96 (Ar), 173.60 (C-5) ppm. Found, %: C 53.26; H, 4.53; N, 15.49. C<sub>8</sub>H<sub>8</sub>N<sub>2</sub>OS. Calculated, %: C 53.31, H 4.47, N 15.54.

### 4.4. 2-Methylbutyric Aldehyde 2-Mercaptobenzoylhydrazone (2g)

Yield 63%, m.p. 88°C - 91°C (benzene - hexane, 1:4). <sup>1</sup>H-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form *E,E*-**A** (6%): 0.86 (t, J = 7.4 Hz, CH<sub>3</sub>CH<sub>2</sub>), 0.97 (d, J = 6.5 Hz, CH<sub>3</sub>CH), 1.06 (m, CH<sub>3</sub>CH<sub>2</sub>), 1.40 (m, CH<sub>3</sub>CH), 7.44 (d, J = 4.2 Hz, HC=N), 11.98 (br.s, NHCO), form *E,Z*'-**A** (38%): 0.86 (t, J = 7.4 Hz, CH<sub>3</sub>CH<sub>2</sub>), 0.97 (d, J = 6.5 Hz, CH<sub>3</sub>CH), 1.21 (m, CH<sub>3</sub>CH<sub>2</sub>), 1.51 (m, CH<sub>3</sub>CH), 7.60 (d, J = 4.2 Hz, HC=N), 11.57 (br.s, NHCO), form **B** (56%): 0.84 (t, J = 7.2 Hz, CH<sub>3</sub>CH<sub>2</sub>), 0.90 (d, J = 6.4 Hz, CH<sub>3</sub>CH), 1.65 (m, CH<sub>3</sub>CH), 1.75 (m, CH<sub>3</sub>CH<sub>2</sub>), 4.43 (dd, J<sub>1</sub> = 7.5 Hz, J<sub>2</sub> = 5.5 Hz, H-2), 5.74 (dd, J<sub>1</sub> = 5.5 Hz, J<sub>2</sub> = 5.0 Hz, NH), 7.42 - 7.62 (Ar in **A** and **B**), 9.44 (d, J = 5.0 Hz, NHCO) ppm. <sup>13</sup>C-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form *E,E*-**A**: 11.43 (CH<sub>3</sub>), 17.14 (CH<sub>3</sub>), 26.97 (CH<sub>2</sub>), 166.89 (C=O), form *E,Z*-**A**: 11.54 (CH<sub>3</sub>), 16.19 (CH<sub>3</sub>), 25.59 (CH<sub>2</sub>), 37.85 (CH), 156.91 (C=N), 163.07 (C=O), form **B**: 10.95 (CH<sub>3</sub>), 15.32 (CH<sub>3</sub>), 26.17 (CH<sub>2</sub>), 38.59 (CH), 78.72 (C-2), 128.17 - 140.39 (Ar in **A** and **B**), 173.16 (C-5) ppm. Found, %: C 60.94; H 6.88; N 11.90. C<sub>12</sub>H<sub>16</sub>N<sub>2</sub>OS. Calculated, %: C 60.99; H 6.82; N 11.85.

### 4.5. Trimethylacetyl Aldehyde 2-Mercaptobenzoylhydrazone (2h)

Yield 57%, m.p. 132°C - 134°C (benzene - hexane, 1:4). <sup>13</sup>C-NMR spectrum (solid phase): δ = form **B** (100%): 27.12 ((CH<sub>3</sub>)<sub>3</sub>C), 35.07 ((CH<sub>3</sub>)<sub>3</sub>C), 84.56 (C-2), 126.84 - 142.21 (Ar), 174.79 (C-5) ppm. <sup>1</sup>H-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form *E,E*-**A** (12%): 0.95 (s, (CH<sub>3</sub>)<sub>3</sub>C), 7.60 (s, HC=N), 11.81 (br.s, NHCO), *E,Z*-**A** (61%): 1.11 (s, (CH<sub>3</sub>)<sub>3</sub>C), 7.65 (s, HC=N), 11.54 (br.s, NHCO), form **B** (27%): 0.97 (s, (CH<sub>3</sub>)<sub>3</sub>C), 4.40 (d, J = 9.5 Hz, H-2), 5.63 (dd, J<sub>1</sub> = 9.5 Hz, J<sub>2</sub> = 5.0 Hz, NH), 7.34 - 7.66 (Ar in **A** and **B**), 9.41 (d, J = 5.0 Hz, NHCO) ppm. <sup>13</sup>C-NMR spectrum (DMSO-*d*<sub>6</sub>): δ = form *E,E*-**A**: 27.06 ((CH<sub>3</sub>)<sub>3</sub>C), 36.80 ((CH<sub>3</sub>)<sub>3</sub>C), 147.86 (C=N), 163.04 (C=O), form *E,Z*-**A**: 27.06 ((CH<sub>3</sub>)<sub>3</sub>C), 36.80 ((CH<sub>3</sub>)<sub>3</sub>C), 150.43 (C=N), 159.88 (C=O), form **B**: 27.24 ((CH<sub>3</sub>)<sub>3</sub>C), 34.72 ((CH<sub>3</sub>)<sub>3</sub>C), 84.22 (C-2), 126.24 - 140.33 (Ar in **A** and **B**), 173.00 (C-5) ppm. Found, %: C 61.03; H 6.76; N 11.91. C<sub>12</sub>H<sub>16</sub>N<sub>2</sub>OS. Calculated, %: C 60.99; H 6.82; N 11.85.



#### 4.6. 4-Chlorobenzoic Aldehyde 2-Mercaptobenzoylhydrazone (3d)

Yield 76%, m.p. 181°C - 183°C (ethanol).  $^{13}\text{C}$ -NMR spectrum (solid phase):  $\delta$  = form *E,Z*-A (100%): 125.00 - 132.21 (Ar), 150.74 (C=N), 166.55 (C=O) ppm.  $^1\text{H}$ -NMR spectrum ( $\text{DMSO-}d_6$ ): form *E,E*-A (9%): 8.12 (s, HC=N), 12.13 (br.s, NHCO), form *E,Z*-A (56%): 8.40 (s, HC=N), 11.96 (br.s, NHCO), form B (35%): 5.76 (d,  $J = 6.9$  Hz, H-2), 6.25 (dd,  $J_1 = 6.9$  Hz,  $J_2 = 3.8$  Hz, NH), 7.38 - 7.76 (Ar in A and B), 9.62 (d,  $J = 3.8$  Hz, NHCO) ppm.  $^{13}\text{C}$ -NMR spectrum ( $\text{DMF-}d_7$ ):  $\delta$  = form *E,E*-A: 141.21 (C=N), 173.28 (C=O), form *E,Z*-A: 147.00 (C=N), 164.82 (C=O), form B: 73.95 (C-5), 173.90 (C-5), 124.79 - 139.10 (Ar in A and B) ppm. Found, %: C 57.78; H 3.77; N 9.79.  $\text{C}_{14}\text{H}_{11}\text{ClN}_2\text{OS}$ . Calculated, %: C 57.83; H 3.81; N 9.63.

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