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New Access to Pyrazole, Oxa(Thia)diazole and Oxadiazine Derivatives

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ABSTRACT: *1,4-Disubstituted thiosemicarbazides* **1b–f** *reacted with ethenetetracarbonitrile (***5***) in dimethylformamide with formation of 2-substituted 5-phenyl-1,3,4-thiadiazoles* **2a–f** *and 2-substituted 5-phenyl-1,3,4-oxadiazoles* **4a–f**. *Upon addition of* **5** *to* **1c–e** *in chlorobenzene, 3-amino-2-benzoyl-4,5,5-tricyano-2,5-dihydro-1*H*-pyrazole-1-[*N*-(4-tricyanovinyl)phenyl]carbothioamide (***12***), 5-benzylamino-, and 5-allylamino-4-benzoyl-2,3-dihydro-[1,3,4]thiadiazol-2,2-dicarbonitrile (***13a,b***) and 5-amino-1-benzoylpyrazole-3,4-dicarbonitrile (***14***) as well as 2-phenyl-4*H*-[1,3,4]-oxadiazine-5,6-dicarbonitrile (***15***) were formed. Rationales for the role of the solvent and the conversions observed are presented.* © 2005 Wiley Periodicals, Inc. Heteroatom Chem 16:12–19, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/hc.20071

INTRODUCTION

Cyclization of 1,4-disubstituted thiosemicarbazides may be achieved under various conditions [1–5]. For example, 4-substituted 1-phenylacetylthiosemicarbazides undergo cyclization to yield 3-benzyl-Δ^2-1,2,4-triazoline-5-thiones and 2-amino-5-benzyl-1,3,4-thiadiazoles, respectively, in the presence of either acid or alkali, and disubstituted thiosemicarbazides on reaction with acetone in an acidic medium afforded 1,2,4-triazolidine-3-thione derivatives [3]. 3-Alkylthio-4-phenyl-Δ^2-1,2,4-triazolin-5-ones have been obtained by S-alkylation of 1-aminocarbonyl-4-phenylthiosemicarbazides followed by acid catalyzed cyclization with liberation of ammonia [4]. Recently, the synthesis of some 1,3,4-oxa-(thia)diazole derivatives from the readily available 1-(4,6-diphenyl-2-pyrimidinylcabonyl)-4-phenylthiosemicarbazide (**1a**) has been reported [5] (Scheme 1). Brief heating of **1a** in concentrated sulfuric acid gave the corresponding 2-anilino-1,3,4-thiadiazole **2a**, whereas treatment of **1a** with KOH brought about the alternative C—N cyclization with formation of the triazolethione derivative **3**. Heating of **1a** in ethoxyethanol effected the formation of 1,3,4-oxadiazole **4a** with evolution of H_2S [5]. Some recent publications have reported mild cyclization methods [6–10] for this heterocyclic system.

In medicinal chemistry, there is interest in the aforementioned heterocycles. For example, 1,3,4-oxadiazol-2-ylmethyl and various 1,2,4-triazol-3-ylmethyl groups have been tested as replacements for aminocarbonylmethyl groups in a piperidino ether based human NK_1-antagonist [11].

As a part of our program aimed at the development of new simple and efficient procedures for the synthesis of some important heterocyclic systems from thiosemicarbazide derivatives, we have recently reported different successful approaches for synthesis of thiazole, thiazine, thiadiazole, thiadiazine, thiadiazepine, oxathiadiazole and indazole, as

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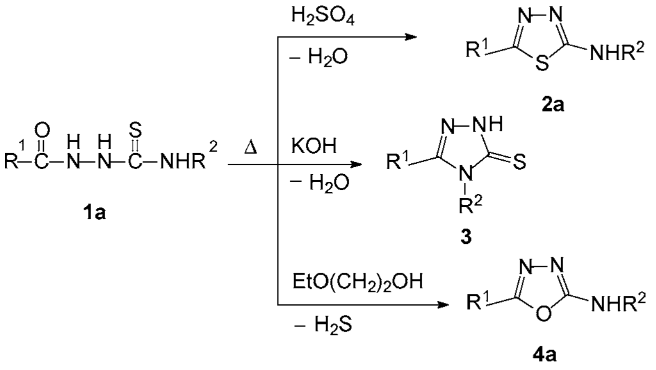
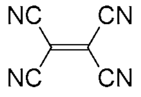


1a, **2a**, **3**, **4a** : R^1 = 4,6-diphenylpyrimidin-2-yl, R^2 = Ph

SCHEME 1

well as pyridazine derivatives [12–17]. As will be outlined in detail below, in this paper we report several heterocyclizations of 4-substituted 1-benzoylthiosemicarbazides (**1b–f**) using ethenetetracarbonitrile ("tetracycanoethylene", **5**) either as a reaction mediator or as a building block.



5

Ethenetetracarbonitrile (**5**) is the simplest of percyanoalkenes (cyanocarbons) [18]. The general chemistry of **5** had been reviewed with emphasis on molecular complexes, reactions with ketones and amines, tricyanovinylation reactions [18], additions [18] and cycloaddition reactions [19] as well as synthesis of heterocycles [18–23].

RESULTS AND DISCUSSION

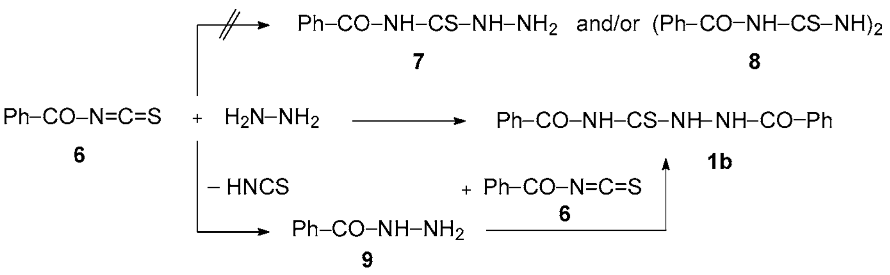
Preparation of Thiosemicarbazides **1b–f**

Mixing equimolar amounts of each hydrazine and benzoylisothiocyanate (**6**) in DMF at room temperature resulted in an excellent yield of 1,4-dibenzoylthiosemicarbazide (**1b**) rather than in the formation of compounds **7** or **8** (Scheme 2). Interaction of double molar amounts of hydrazine with **6** did not terminate at the monoaddition stage, but gave again the product **1b**. In this respect, the rapid addition of **6** to hydrazine may afford the formation of hydrazide **9** via substitution of thiocyanate anion followed by the addition of another molecule of **6** to **9**. On the other hand, heating equimolar amounts of hydrazide **9** and **6** in ethanol gave again **1b** [24]. The other 1-benzolylthiosemicarbazides **1c–f** were prepared according to literature procedures (see Experimental section for references).

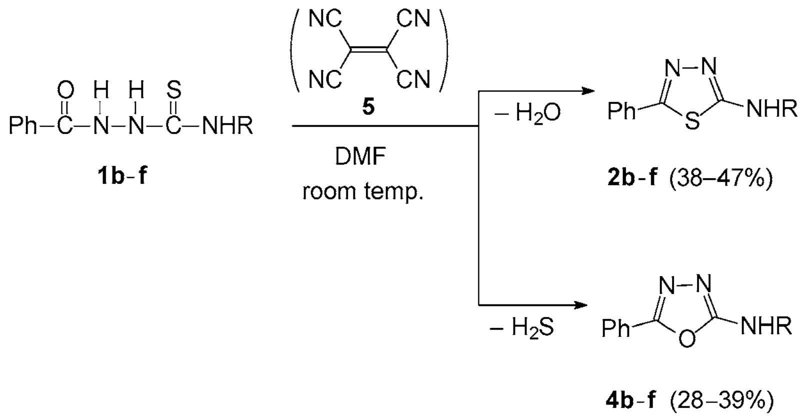
Reactions of Thiosemicarbazides **1b–f** *with Ethenetetracarbonitrile* (**5**) *in DMF*

Treatment of **1b–f** with two molar equivalents of **5** in DMF as solvent at room temperature resulted in a pink coloration of the solution that quickly turned into brown. Concentration of the preparative runs resulted in formation of colorless precipitates of oxadiazole derivatives **4b–f** (28–39%, Scheme 3). Of these, **4b–d,f** are known from the literature, while the structure of **4e** was derived by analogy taking into account the NH absorption at 3193 cm^{-1} and the characteristic absorption of the C—O—C fragment at 1086 cm^{-1} [25]. The 300 MHz ^1H NMR (in DMSO-d_6) displayed broadened signals at δ 4.10 (allyl C*H*$_2$—N) and 8.27 ppm (NH) as well as multiplets at 5,02–5.16 (allyl *H*$_2$C=) and 5.78–5.85 ppm (allyl —C*H*=). The elemental analysis supported the gross composition $C_{11}H_{11}N_3O$, and the mass spectrum revealed the expected molecular ion.

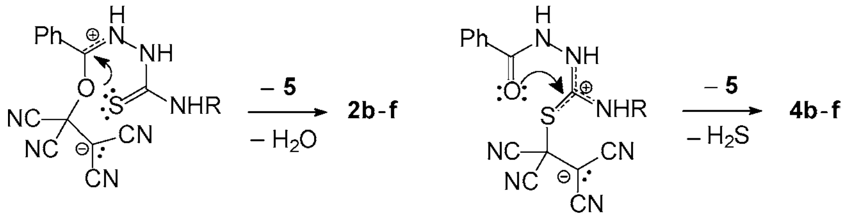
The filtrates were concentrated to dryness and the residue subjected to vacuum sublimation to remove any unreacted **5**. Chromatographic separation of the residue in each case gave only one significant zone containing the known thiadiazole derivatives **2b–f** in 38–47% yield (Scheme 3), which were also identified by means of their spectroscopic data and by comparison with the literature data and/or authentic samples.



SCHEME 2



1, 2, 4, 10, 11	b	c	d	e	f
R	PhCO	Ph	$PhCH_2$	$H_2C{=}CH{-}CH_2$	EtOOC



10 **11**

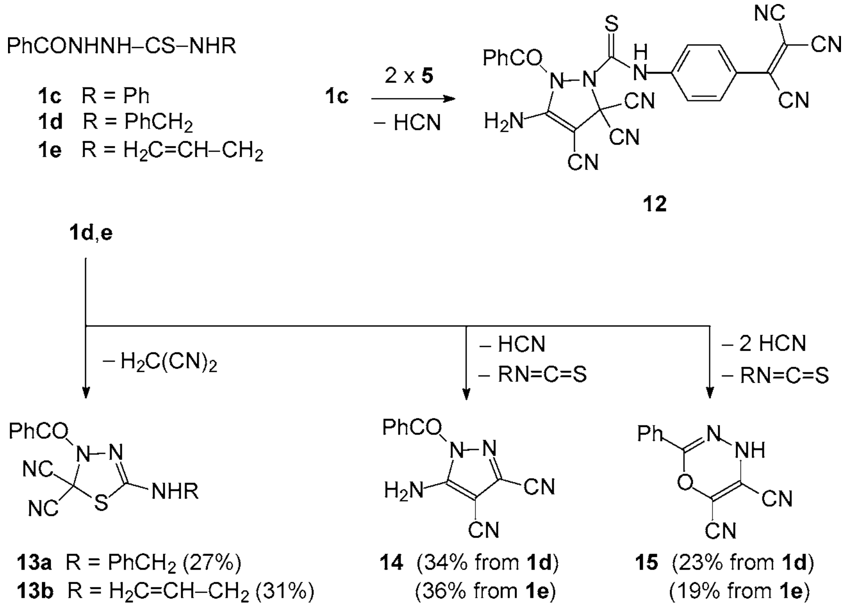
SCHEME 3

Since the aforementioned reactions do not take place when no **5** is added to the solution of **1b–f** in DMF, the presence of **5** is definitely required for the transformations observed. Charge-transfer complexes may (but not necessarily have to) play an intermediate role. Since the cyclizations involve intramolecular nucleophilic attacks on either a thiocarbonyl or a carbonyl group, it is conceivable that **5** accelerates the process in the sense of a proton or a Lewis acid, possibly through intermediates **10** and **11** (Scheme 3), activating the respective C=O/C=S bonds toward nucleophilic addition. This behavior may well be supported by the polar nature of the solvent stabilizing zwitterionic adducts.

After cyclization, **5** is released and the liberation of H_2O or H_2S ensues as usual. While **5** is not consumed in these cyclizations as such and is indeed recovered to a large extent (200–220 mg, 1.56–1.72 mmol, 78–86%), the only reason for losses of **5** may be seen in the reactions with water or hydrogen sulfide being released during the cyclization. Reducing the amount of **5** applied to 1.5 mmol resulted in incomplete transformation of the starting materials **1b–f**. "Catalytic" amounts of **5** have not been applied for this reason.

Reactions of Thiosemicarbazides **1c–e** *with Ethenetetracarbonitrile (***5***) in Chlorobenzene as Solvent*

While the reactions of **1b–f** in DMF and mediated by **5** were found to run relatively smoothly, the conversions of starting materials **1c–e** (**1b** was too sparingly soluble) in chlorobenzene as solvent went comparatively slowly. No products **2** and **4** were formed, instead compounds **12** (79% from **1c**) and **13a** (27%), **13b** (31%), **14** (34% from **1d**, 36% from **1e**), and **15** (23% from **1d**, 19% from **1e**) were obtained as products (Scheme 4). In these cases, **5** is "built in" completely or partially into the new structures. It may thus be concluded that the less polar solvent fails to stabilize bipolar intermediates as **10** and **11** sufficiently but allows for addition of the nucleophilic sites (N—H bonds or formally S—H) of the starting materials **1c–e** across the C=C double bond of **5**. These additions may generate the four primary



SCHEME 4

adducts **A–D** (Chart 1) or tautomers thereof, capable of releasing either HCN (which effects a net tricyanovinylation [18]) or malononitrile. On the other hand, any [$\pi^4 + \pi^2$]-cycloadditions of **5** to dehydrogenated **1** are not suggested to occur from the nature of the products formed, except perhaps in the formation of **15**. Thus, the structures of products **12–15** need to be derived from one or two suitable precursor(s) out of the options **A–D**.

3-Amino-2-benzoyl-4,5,5-tricyano-2,5-dihydro-1*H*-pyrazole-1-[*N*-(4-tricyanovinyl)-phenyl]carbothioamide (**12**) was obtained as a characteristically blue powder, the color being due to the *p*-tricyanovinyl-phenylamino moiety. Its molecular structure is supported by the following findings:

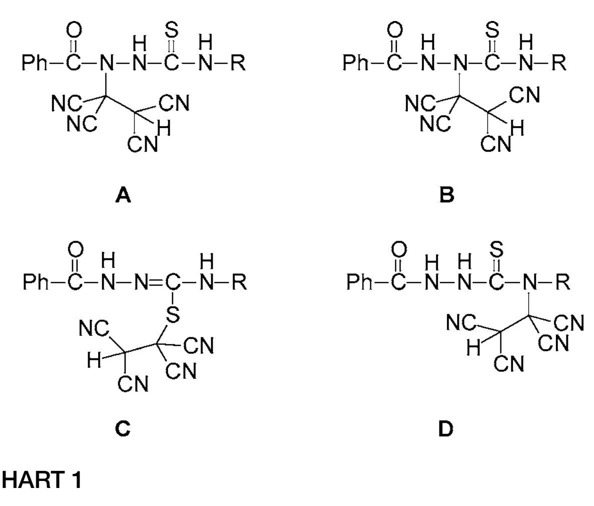
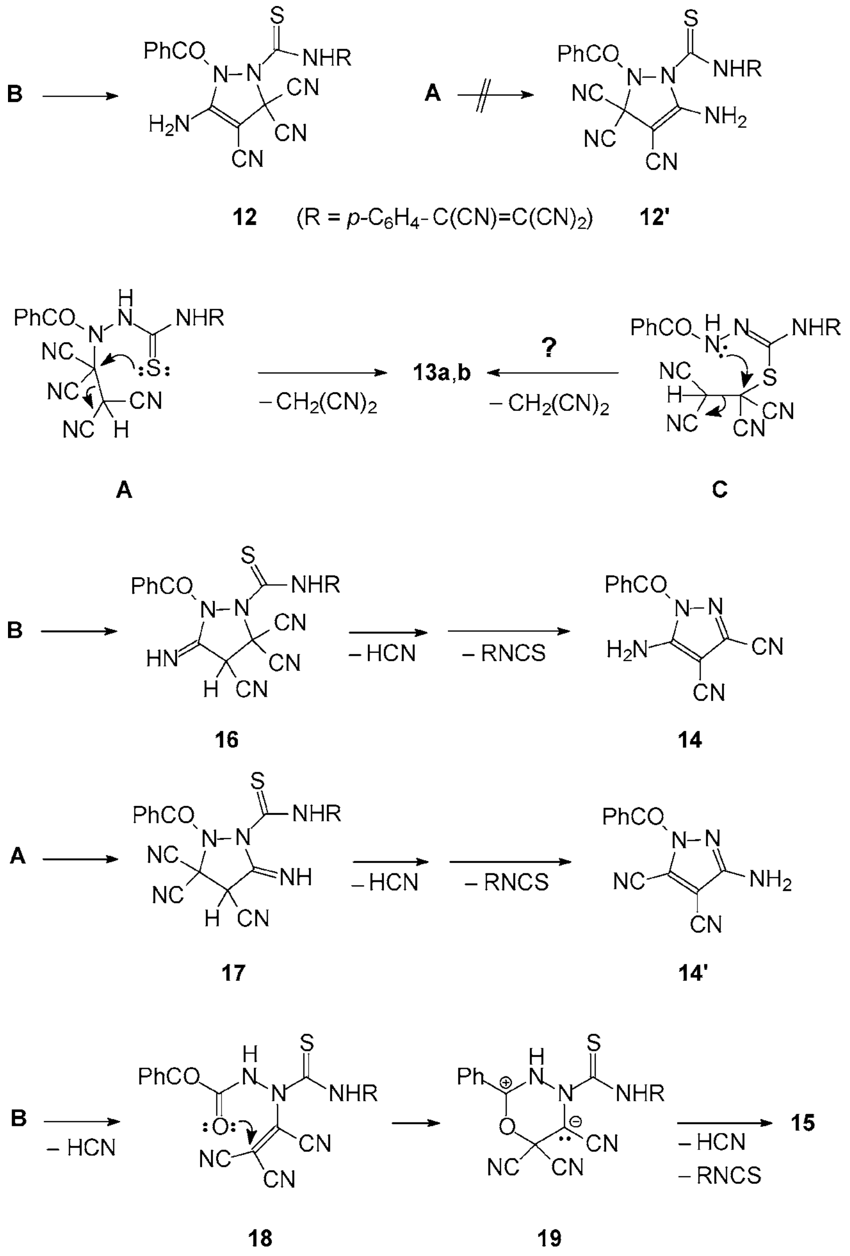


CHART 1

- The gross formula $C_{25}H_{12}N_{10}OS$ represents a product from one molecule of **1c** and two molecules of **5** with loss of one molecule of HCN (liberated in the *p*-tricyanovinylation of the thiocarbonylaminophenyl group, a reaction which can occur only with **1c** and is taking place independently of the cyclization forming the pyrazoline ring).
- The presence of both an amide ($\delta_{C=O} = 167.3$ ppm) and a thioamide function ($\delta_{C=S} = 186.6$ ppm) rules out any oxa- or thiacyclic structures.
- Both a NH_2 ($\delta_H = 7.14$ ppm) and a low-field NH group ($\delta_H = 9.61$ ppm) are present.
- The mass spectrum shows fragments at *m/z* 263 (representing the polysubstituted pyrazolinyl residue) and 237 (representing the *p*-tricyanovinylphenylaminothiocarbonyl residue) resulting from the cleavage of the N1—CS bond.
- The amide carbonyl stretch wavenumber (1706 cm^{-1}) points to some degree of electron withdrawal from N2, therefore structure **12** resulting from precursor **B** is given preference over **12**′ derived from precursor **A** (Scheme 5).

For compounds **13a,b**:

- The gross formulas (confirmed by MS) $C_{18}H_{13}N_5OS$ (**13a**) and $C_{14}H_{11}N_5OS$ (**13b**) clearly demonstrate the loss of a $C(CN)_2$ unit (probably in the form of $CH_2(CN)_2$).
- The absence of a ^{13}C C═S signal but the presence of an amide C═O signal (165.2 ppm) and only one CN

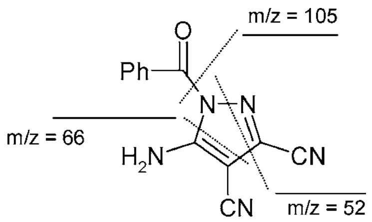


SCHEME 5

resonance (117.8 ppm) in the case of **13a** points to the 1,3,4-thiadiazole structure **13** as assigned. Thus **13a,b** could have emanated from either **A** or **C** (Scheme 5) but not from **B** or **D**.

Compound **14** does not contain sulfur but contains five N atoms, thus the molecular mass represents a gross composition $C_{12}H_7N_5O$ reached from **1d,e** and **5** after loss of HCN and R—N=C=S. A five-membered ring structure was thus accessible from both precursors **A** and **B** but not from **C** and **D**. While **B** would lead to **14** via **16**, the isomeric structure **14′** would be accessible from **A** via **17** (Scheme 5). The mass spectral fragmentation of the product (see Fig. 1), however, is well in agreement with structure **14** but not with structure **14′**.

Compound **15** ($C_{11}H_6N_4O$) is derived from starting materials **1d,e** and **5** by loss of RN=C=S and *two* molecules of HCN. This way of formation is not possible from precursors **A, C**, and **D**. From its IR and ^{13}C NMR this product does not contain a free benzoyl group any more, thus the oxadiazine structure **15** is suggested and rationalized by the sequence **B** → **18** → **19** → **15** (Scheme 5).



14

FIGURE 1 The mass spectrum fragments of compound **14**.

CONCLUSION

In this study two kinds of ring-forming reactions of 1-benzoylthiosemicarbazides **1** with ethenetetracarbonitrile (**5**) have been observed: (i) Cyclizations of **1** by intramolecular nucleophilic attack on either the carbonyl or thiocarbonyl C atom may be activated by ethenetetracarbonitrile (**5**) in the sense that **5** acts like a Lewis acid on the heteroatom of the C=X bond being involved. It is suggested that the highly polar aprotic solvent DMF stabilizes the resulting transient intermediates and thereby enhances the probability for intramolecular cyclizations. (ii) On the other hand, the tendency of **5** to effect tetracyanoethylation (with the option for subsequent tricyanovinylation) of secondary amino functions (where bipolar intermediates may be less important) is exercised in the less polar chlorobenzene as solvent. The four a priori possible types of tetracyanoethylation adducts (**A–D**) of **5** to **1** may in principle release either HCN or malononitrile but do so with different probabilities as can be concluded from the products observed. Thus, ethenetetracarbonitrile (**5**) may act either as a mediator or as a building block in heterocyclizations of thiosemicarbazides.

EXPERIMENTAL

Mps have been determined using open glass capillaries on a Gallenkamp melting point apparatus and are uncorrected. The IR spectra were recorded with a Shimadzu 408 or a Bruker Vector 22 FT-IR instrument using potassium bromide pellets. A Bruker WM 300 instrument has been used to determine ^{1}H NMR (300 MHz) and ^{13}C NMR (75 MHz) spectra, assignments of carbon resonances have been supported by DEPT experiments. Mass spectra have been obtained with an AMD 604 doubly focusing instrument using electron impact ionization (70 eV). Elemental analyses have been determined by the Microanalytical Centre, Cairo University. Preparative layer chromatography (plc) was made using 48 cm × 20 cm glass plates covered with slurry applied and air dried 1 mm thick layers of Merck silica gel PF_{254}. Zones were detected by indicator fluorescence quenching upon 254 nm excitation, removed from plates and extracted with cold acetone.

Starting materials

*Synthesis of 1,4-Dibenzoylthiosemicarbazide (***1b***).* To a stirred solution of hydrazine hydrate (5 g, 10 mmol) in 30 mL dimethylformamide, benzoylisothiocyanate (**6**, 16.3 g, 10 mmol) was added dropwise at room temperature. Stirring at room temperature was continued for 3 h, the mixture set aside overnight, then added to ice/water. A white precipitate was formed, recrystallized from ethanol to give colorless crystals (20.3 g, 68%), mp 172–174°C (lit. 173–176°C) [24]. IR (KBr) $\nu = 3213$ (NH), 1674 (CO), 1643, 1600 (Ar—C=C) and 1354 cm^{-1} (C=S) [27]. ^{1}H NMR (DMSO-d_6) δ 7.52–7.99 (m, 10H, Ar-H), 11.13 (s, br, 1H, N^2-H), 11.77 (s, br, 1H, N^1-H), 12.39 (s, br, 1H, N^4-H), ^{13}C NMR δ 126.90, 127.60, 127.91, 129.00, 129.60. 129.80, 130.05, 130.14, 132.02, 132.11, 132.22, 132.31 (Ar-C), 164.78 (CON^{1}H), 168.06 (CON^{4}H), and 180.83 (C=S); MS (70 eV) *m/z* (%) 299 (M$^+$, 3), 266 (6), 223 (8), 195 (8), 105 (100), 77 (72), 51 (18). $C_{15}H_{13}N_3O_2S$ (299.35); calcd C, 60.19; H, 4.38; N, 14.04; S, 10.71; found: C, 60.33; H, 4.26; N, 14.17; S, 10.58.

*1-Benzoyl-4-phenylthiosemicarbazide (***1c***)*: mp 170–172°C (lit. [28] 170–173°C).

*1-Benzoyl-4-benzylthiosemicarbazide (***1d***)*: mp 160–162°C (lit. [28] 159–160°C).

*4-Allyl-1-benzoylthiosemicarbazide (***1e***)*: mp 171–173°C (lit. [29] 171–173°C).

*N-(2-Benzoylhydrazinothiocarbonyl)carbamic acid ethyl ester (***1f***).* A solution of 10 mmol (1.36 g) of benzoyl hydrazine (**9**) and 10 mmol (1.31 g) of ethoxycarbonylisothiocyanate in ethanol was refluxed for 2 h, the white precipitate was recrystallized from ethanol (1.71 g, 64%), mp 178–180°C, IR $\nu = 3320$–3230 (NH), 1722, 1670 (CO), 1620 (Ar—C=C). ^{1}H NMR (DMSO-d_6) δ 1.22–1.27 (t, 3H, CH_3), 4.18–4.21 (q, 2H, CH_2), 7.47–7.58 (m, 3H, Ar-H), 7.87–7.90 (m, 2H, Ar-H), 10.93 (s, br, 1H, N^2-*H*), 11.31 (s, br, 1H, N^1-*H*), 11.38 (N4-*H*). MS (70 eV), *m/z* (%) 267 (M$^+$, 24), 134 (37), 105 (100), 77 (32), 60 (3), 51 (6). $C_{11}H_{13}N_3O_3S$ (267.31); calcd C, 49.43; H, 4.90; N, 15.72; S, 12.00; found: C, 49.31; H, 4.77; N, 15.88; S, 11.83.

Preparation of 1,3,4-thiadiazoles **2b–f** *and 1,3,4-oxadiazoles* **4b–f**. To 2 mmoles of **5** in dry dimethylformamide (10 mL), 1 mmol of **1b–f** in 15 mL of dry dimethylformamide was added with stirring within 2 h. The pink coloration of the solution quickly became brown, and the mixture was left standing for 48 h at room temperature, during which time a crystalline colorless product separated. The resulting solid material was filtered and the precipitate was washed with ethanol, dried, and recrystallized from suitable solvent to give 1,3,4-oxadiazoles **4b–f**. The filtrate was concentrated to dryness and the residue was sublimed at 80°C under vacuum to remove unreacted **5**, then subjected to PLC using cyclohexane/ethyl acetate (2:1) as eluent to give only one zone which was removed and extracted to give 1,3,4-thiadiazole derivatives **2b–f**.

*2-Benzoylamino-5-phenyl-1,3,4-oxadiazole (***4b***)*: Colorless crystals from methanol (103 mg, 39%), mp 200–202°C, (lit. [30] 198–200°C).

*2-Anilino-5-phenyl-1,3,4-oxadiazole (***4c***)*: Colorless crystals from ethanol (96 mg, 40%), mp 218–220°C (lit. [31,32] 219–221°C).

*2-Benzylamino-5-phenyl-1,3,4-oxadiazole (***4d***)*: Colorless crystals from ethanol (91 mg, 36%), mp 203–205°C (lit. [33,34] 203°C).

*2-Allylamino-5-phenyl-1,3,4-oxadiazole (***4e***)*: Colorless crystals from ethanol (63 mg, 31%), mp 126–128°C; IR(KBr), $\nu = 3193$ (NH), 1086 (C—O—C), 1620 (C=N), 1590 (C=C); ^{1}H NMR (DMSO-d$_6$) $\delta = 4.10$ (br, s, 2H, allyl-CH$_2$N), 5.02–5.16 (m, 2H, allyl-CH$_2$=), 5.78–5.85 (m, 1H, allyl-CH=), 7.46–7.93 (m, 5H, Ar-H), 8.27(NH). MS (70 eV), *m/z* (%) 201 (M$^+$, 13), 160 (6), 119 (13), 105 (100), 91 (8), 77 (69), 41 (30). $C_{11}H_{11}N_3O$ (201.23); calcd C, 65.66; H, 5.51; N, 20.88; found C, 65.47; H, 5.66; N, 20.71.

*Ethyl (5-phenyl-[1,3,4]oxadiazol-2-yl)carbamate (***4f***)*: Colorless crystals from ethanol (66 mg, 28%), mp 205–207°C (lit. [35] 205–207°C).

*2-Benzoylamino-5-phenyl-1,3,4-thiadiazole (***2b***)*: Colorless crystals from ethanol, (132 mg, 47%), mp 232–234°C, (lit. [36] 235°C).

*2-Anilino-5-phenyl-1,3,4-thiadiazole (***2c***)*: Colorless crystals from ethanol (109 mg, 43%), mp 200–202°C (lit. [32,37] 198–200°C).

*2-Benzylamino-5-phenyl-1,3,4-thiadiazole (***2d***)*: Colorless crystals from acetonitrile (117 mg, 44%), mp 183–185°C (lit. [38] 183–185°C).

*2-Allylamino-5-phenyl-1,3,4-thiadiazole (***2e***)*: Colorless crystals from ethanol (82 mg, 38%), mp 114–115°C (lit. [39] 114–115°C).

*Ethyl (5-phenyl-[1,3,4]thiadiazol-2yl)carbamate (***2f***)*: Colorless crystals from ethanol (95 mg, 41%), mp 197–199°C (lit. [40] 198–200°C).

Preparation of Thiadiazole, Pyrazole, and Oxadiazine Derivatives **12–15**

General Procedure. To a stirred solution of 256 mg (2.0 mmol) of **5** in 15 mL of chlorobenzene a solution of 1.0 mmol of **1c–e** was added dropwise, which caused a spontaneous change of color from yellow to blue (in the reaction of **1c** with **2**) or dark green (in the reaction of **1d,e** with **5)**, respectively. The mixture was stirred for 3 h and left standing for 48 h at room temperature. After concentration to dryness, the residues were sublimed at 80°C and then subjected to PLC using cyclohexane/ethyl acetate (3:1) as eluent. From the reaction of **1c** with **5**, only one zone (deep blue, $R_f = 0.35$) containing the pyrazole **12** was extracted. On the other hand, for the reaction of **1d,e** with **5**, chromatographic separation of the residue (after sublimation) gave numerous colored zones, three of which (with high intensity) were removed and extracted. The fastest moving zone ($R_f = 0.43$) contained the pyrazole derivative **14**, the second zone ($R_f = 0.39$, orange) contained the oxadiazine **15**, while the slowest moving zone ($R_f = 0.15$) contained the thiadiazole derivatives **13a,b**. Extraction of the zones with acetone and concentration gave residues, which were rechromatographed to improve the purification.

*3-Amino-2-benzoyl-4,5,5-tricyano-2,5-dihydro-1*H*-pyrazole-1-carbothio-*N*-[4-(tricyanovinyl)phenyl]-amide (***12***)*: Blue crystals (acetonitrile), mp 301–303°C (395 mg, 79%), IR (KBr) $\nu_{\max}$ 3311 (NH), 2224 (CN), 1706 (CO), 1608 (C=C) cm^{-1}. ^{1}H NMR (DMS-d$_6$) δ 7.14 (s, br, 2H, NH$_2$), 7.37–7.45, 7.64–7.67, 7.89 (m, 9H, Ar-H), 9.61 (s, br, 1H, NH). ^{13}C NMR (DMSO-d$_6$) 48.41 (C-5), 63.27 (C-4), 92.36 (tricyanovinyl β-C); 117.19, 117.21, 117.29, 119.30, (CN); 126.71, 127.98, 128.77, 129.41, 130.33, 131.53, 132.94, 133.50, 148.21 (Ar-C); 147.63 (tricyanovinyl α-C), 158.42 (C-3), 167.30 (CO), and 186.60 (C=S). MS (70 eV), *m/z* (%) 500 (M$^+$, 16), 263 (12), 237 (63), 194 (9), 145 (18), 119 (100), 105 (65), 93 (92), 77 (13), 65 (23), 51 (36), 44 (50). $C_{25}H_{12}N_{10}OS$ (500.50); calcd C, 60.0; H, 2.42; N, 27.99; S, 6.41; found: C, 59.83; H, 2.56; N, 28.17; S, 6.58.

*3-Benzoyl-5-benzylamino-2,3-dihydro-[1,3,4]-thiadiazol-2,2-dicarbonitrile (***13a***)*: Orange crystals (ethanol), mp 263–265°C, (80 mg, 27%). IR (KBr) $\nu_{\max}$ 3355 (NH), 2213 (CN), 1670 (CO) cm^{-1}. ^{1}H NMR (acetone-d$_6$) δ 4.60 (s, 2H, CH$_2$), 7.18–7.64 (m, 8H, Ar-H), 7.90–8.10 (m, 2H, Ar-H), 9.12 (s, br, 1H, NH). ^{13}C NMR (acetone-d$_6$) 43.20 (C-5), 46.80 (CH$_2$), 117.80 (CN); 127.82, 128.93, 129.22, 130.44, 131.21, 131.48, 133.72, 141.14 (Ar-C); 152.40 (C-2), 165.20 (CO). MS (70 eV), *m/z* (%) 347 (M$^+$, 11), 285 (4), 240 (18), 150 (6), 132 (12), 119 (75), 106 (71), 105 (100), 91 (41), 77 (91), 65 (11), 51 (29), 44 (15). $C_{18}H_{13}N_5OS$ (347.40); calcd C, 62.23; H, 3.77; N, 20.16; S, 9.23; found: C, 62.06; H,3.59; N, 20.33; S, 9.12.

*5-Allylamino-3-benzoyl-2,3-dihydro-[1,3,4]thiadiazol-2,2-dicarbonitrile (***13b***)*: Orange crystals (ethanol), mp 144–146°C (108 mg, 31%), IR (KBr): ν_{max} 3345 (NH), 2225 (CN), 1668 (CO), 1600 (C=C) cm^{-1}. ^{1}H NMR (DMSO-d_6) 4.67–4.11 (m, 2H, allyl-CH_2N), 5.05–5.15 (m, 2H, allyl-CH_2=), 5.77–5.86 (m, 1H, allyl-C*H*=), 7.45–7.56 (m, 3H, Ar-H), 7.89–7.92 (m, 2H, Ar-H), 8.28 (s, br, 1H, NH). MS (70 eV), *m/z* (%) 297 (M$^+$, 7), 198 (12), 178 (13), 121 (48), 105 (100), 77 (75), 56 (8). $C_{14}H_{11}N_5OS$ (297.34); calcd C, 56.55; H, 3.73; N, 23.55; S, 10.78, found: C, 56.38; H, 3.64; N, 23.64; S, 10.92.

*1-Benzoyl-5-aminopyrazole-3,4-dicarbonitrile (***14***)*: Colorless crystals (81 mg (34%) from the reaction of **1d**, 85 mg (36%) from the reaction of **1e**), mp 202–204°C (lit. [26] 200°C). IR (KBr) ν_{max} 3320–3170 (NH), 2220 (CN), 1710 (CO), 1640 (C=N), 1600 (C=C) cm^{-1}. ^{1}H NMR (DMSO-d_6) δ 7.55–7.71 (m, 3H, Ar-H), 7.86–7.89 (m, 2H, Ar-H), 8.49 (s, br, 2H, NH_2). MS (70 eV), *m/z* (%) 237 (M$^+$, 6), 171 (3), 105 (100), 77 (48), 66 (26), 52 (13). $C_{12}H_7N_5O$ (237.22); calcd C, 60.76; H, 2.97; N, 29.52; found: C, 60.89; H, 3.12; N, 29.68.

*2-Phenyl-4H-[1,3,4]oxadiazine-5,6-dicarbonitrile (***15***)*: Yellow crystals (acetonitrile), mp 187–189°C [48 mg (23%) from **1d**, 40 mg (19%) from **1e**]. IR (KBr) ν_{max} 3230 (NH), 2225 (CN), 1620 (C=N), 1600 (C=C) cm^{-1}. ^{1}H NMR (DMSO-d_6) δ 7.46–7.81 (m, 5H, Ar-H), 8.21 (s, br, 1H, NH). ^{13}C NMR (DMSO-d_6) 106.23 (C-5), 123.31 (C-6); 117. 82, 117.91 (CN); 126.94, 127.18, 128.36, 136.22 (Ar-C); 159.86 (C-2). MS (70 eV), *m/z* (%) 210 (M$^+$, 12), 184 (14), 119 (26), 105 (54), 92 (43), 77 (52), 66 (100), 44 (61). $C_{11}H_6N_4O$ (210.20); calcd C, 62.86; H, 2.88; N, 26.65; found: C, 63.02; H, 2.75; N, 26.84.

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