Studies on 4-Thiazolidinones: Scope of the Reactions of 3-Aryl-2-thioxo-1,3-thiazolidin-4-ones with Cyanide and Cyanate Ions

by **Mohamed T. Omar**, **Mohamed E. Shaban**, **Nadia K. El-Aasar***, and **Khaled F. Saied**

Department of Chemistry, Faculty of Science, Ain Shams University, Cairo, Egypt
(e-mail: nadia.alaasar@yahoo.com)

Treatment of 3-aryl-2-thioxo-1,3-thiazolidin-4-ones **1** with CN^- and NCO^- effected the ring cleavage providing [(cyanocarbonothioyl)amino]benzenes **4** and arylisothiocyanates **5**, respectively. Similar treatment of 5-(2-aryl-2-oxoethyl) derivatives **2** afforded 2,4-bis(2-aryl-2-oxoethylidene)cyclobutane-1,3-diones **6** along with each of the preceding products. Treatment of the respective (*E,Z*)-5-(2-aryl-2-oxoethylidene) analogues **3b** and **3c** with CN^- gave **4b** and **4c** and 2-(arylcarbonyl)-2-methoxy-4-oxopentanedinitriles **7b** and **7c**, in addition to 3,6-bis[2-(4-chlorophenyl)-1-methoxy-2-oxoethylidene]-1,4-dithiane-2,5-dione **8c**, which has been generated from **3c**. Reactions of **3c** or **3d** with NCO^- provided **5c** or **5d**, together with **8c** or **8d** as pure isomers. In the formation of the MeO products **7** and **8**, the solvent (MeOH) has participated. Structures of these products are based on microanalytical and spectroscopic data. Rationalizations for the above transformations are given.

1. Introduction. – In continuation of our previous work [1][2] on 1,3-thiazolidin-4-ones [3], we planned to use the ability of this ring system to cleave the 1,2- as well as the 3,4-bond with the aim of synthesizing [(cyanocarbonothioyl)amino]benzenes and cyanato analogues. These are believed to be useful intermediates in heterocyclic synthesis [4]. The reactions were carried out in hot dioxane/MeOH solution with 2.2 equiv. of cyanide and/or cyanate ions; they have not been studied until now.

2. Results and Discussion. – The starting 3-aryl-2-thioxo-1,3-thiazolidin-4-ones **1a**–**1d** and **2a** were prepared according to previously reported methods [5][6]. 3-Aryl-5-(2-aryl-2-oxoethyl)-2-thioxo-1,3-thiazolidin-4-ones **2b**–**2d** were synthesized from aroylacrylic acids and aryldithiocarbamates according to *Nagase* [7], whilst (*E,Z*)-3-aryl-5-(2-aryl-2-oxoethylidene)-2-thioxo-1,3-thiazolidin-4-ones **3a**–**3d** were obtained from the corresponding **2a**–**2d** on treatment with Br_2 in hot AcOH solution; a reaction first reported by *Nagase* [7], and extensively studied by *Omar et al.* [1].

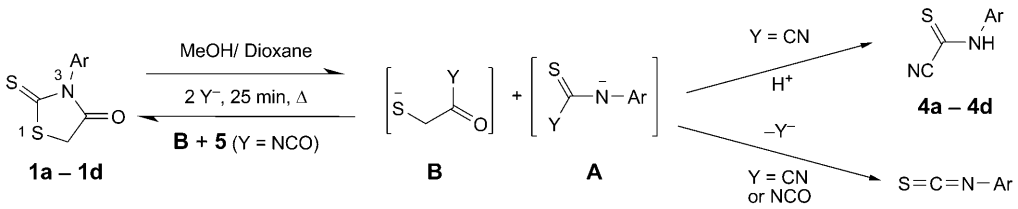
Structures of **2b**–**2d** and (*E,Z*)-**3a**–**3d** were confirmed by microanalytical and spectroscopic data. The ^{1}H-NMR spectra of compounds **2** exhibited the pattern consistent with the $-CH_A-CH_MH_X-$ moiety, which has collapsed into an olefinic *singlet* in the spectra of the respective compounds **3**.

The olefinic H-atom integration showed that **3a** and **3b** are pure isomers, whereas **3c** and **3d** are (*E*)/(*Z*)-mixtures in which the (*Z*)-isomer constitutes 92 and 90%, respectively. The configuration assignment of the (*Z*)-isomer is based on the assumption that the vinylic H-atoms in these isomers are more deshielded by the 4-

oxo group, as in azlactones [8] and 2-pyrazolin-5-ones [9], compared with the (*E*)-counterparts.

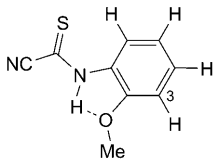
Treatment of **1a–d** with KCN (*Method i*) and KOCN (*Method i'*) effected heteroring cleavage, providing [(cyanocarbonothioyl)amino]benzenes **4a–d** and arylisothiocyanates **5a–d** [10–12], respectively (*Scheme 1*). Compound **4** was obtained in high yield, whereas **5** was obtained contaminated with *ca.* 20% of **1**. This could be rationalized in terms of the reaction reversibility, since the thiolate ion **B** could react with the produced **5** to reform **1**. This assumption is supported by the synthesis of 1,3-thiazolidine derivatives from isothiocyanates and mercaptoacetic acid or its esters [13].

Scheme 1. *Reactions of* **1a–1d** *with KCN and KOCN*



The structures of **4a** and **4c** were elucidated by comparison (m.p. and admixing m.p.) with authentic samples [14][15], whilst those of **4b** and **4d** were confirmed by microanalytical and spectroscopic data.

The ^{1}H-NMR spectrum of **4b** exhibited two *singlet*s for the MeO group at 3.39 and 3.97 ppm; likewise, two *doublet*s were displayed at 7.72 and 8.96 ppm for the aromatic H–C(3), indicating the existence of two forms. The shielded signals originated from the open form, whilst the deshielded signals are belonging to a form in which the N–H undergoes a H-bond with the O-atom of the MeO group (*Fig. 1*). This is supported by the highly deshielded δ value of H–C(3) in the H-bonded form. Moreover, the H-bond in *N*-aryl-2-methoxyaniline [16], as well as in 2-methoxyphenol [17], gives further support to this interpretation. Integration of the two MeO *singlet*s indicated that the H-bonded form constitutes 76% of the mixture. The IR spectrum displayed the stretching absorptions at 3280 and 2230 cm^{-1} for NH and CN groups, respectively. The EI-MS exhibits an abundant molecular ion peak and a base peak *m*/*z* 161 of the ion radical



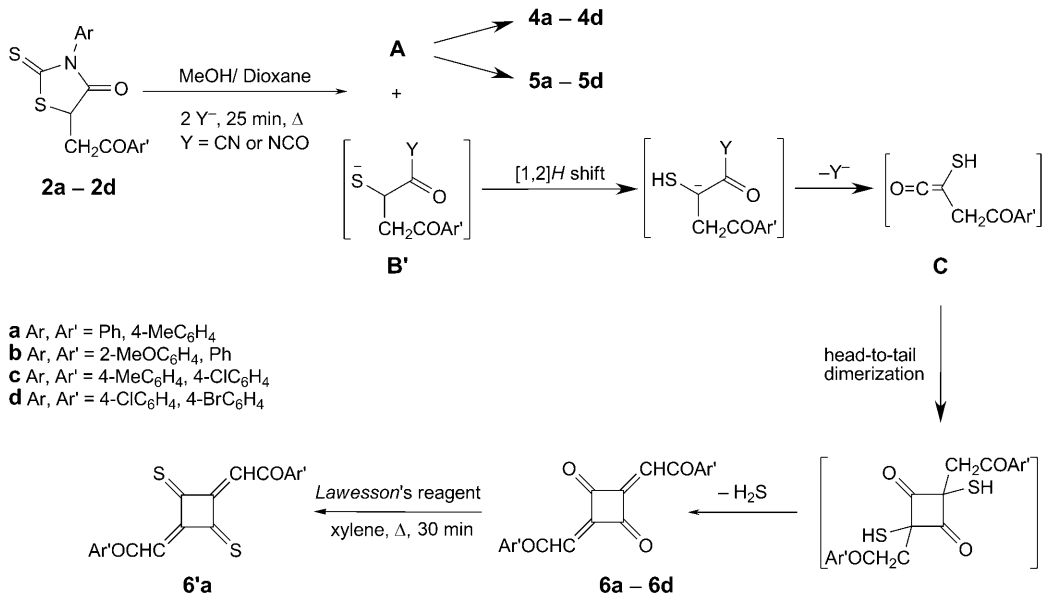
4b

Fig. 1. *H-Bonded form of* **4b** (76%; in $CDCl_3$)

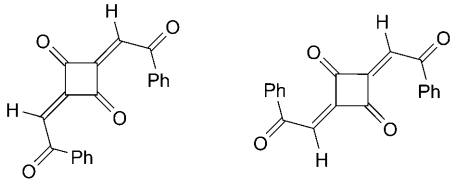
$[M - \mathrm{MeO}]^+$. The structures of compounds **5** were confirmed by matching m.p. with authentic samples [10–12].

Similar treatment of **2a–2d** with CN^- (*Method ii*) or NCO^- (*Method ii'*) provided in fair yield 2,4-bis(2-aryl-2-oxoethylidene)cyclobutane-1,3-diones **6a–6d**, along with high yields of **4a–4d** and/or **5a–5d**, respectively. Formation of **6** is believed to proceed *via* a [2+2] head-to-tail cycloaddition, similar to disubstituted ketenes [18] (*Scheme 2*). The structures of **6a–6d**, which do not contain N- or S-atoms, were confirmed by microanalytical and spectroscopic data. The IR spectra showed two $\tilde{\nu}$(C=O) absorptions consistent with the aroyl and highly conjugated cyclic ketone functions. In spite of the poor solubility of **6** in most of the solvents, the ^{1}H-NMR spectrum of **6b**, which is slightly soluble in (D_6)DMSO, is quite satisfactory for structure confirmation; the spectrum displayed the expected aromatic *multiplet*s and a broad *singlet* for the olefinic H-atom. These compounds exist, most likely, as (*E*)/(*Z*)-mixtures, but ratios of these isomers could not be measured, as the olefinic H-atoms of these isomers have the same chemical shift (*Fig. 2*). The EI-MS of **6a–6d** exhibited intense molecular ion peaks, along with less abundant peaks consistent with $[M - \mathrm{CO}]^+$ and $[M - 2\ \mathrm{CO}]^+$ fragments. Moreover, all spectra displayed aroyl fragments as base peaks, and low abundant peaks at exactly half of the *m*/*z* values that inferred with the possibility of the retro [2+2] reaction at high temperatures.

Scheme 2. *Reactions of* **2a–2d** *with KCN and KOCN*



Moreover, thiation of **6** was believed to afford soluble thione derivatives, which by measuring their ^{13}C-NMR spectra would further support the structure of **6**. Therefore, the reaction of **6a** with *Lawesson*'s reagent [19] was carried out, providing the



(*Z*)-**6b** (*E*)-**6b**

Fig. 2. *Configurations of* (Z)-**6b** *and* (E)-**6b**

respective cyclobutane-1,3-dithione analogue **6′a** (*Scheme 2*). Unfortunately, **6′a** was also insoluble in most of the solvents. The IR spectrum of **6′a** showed a $\tilde{\nu}$(C=O) absorption at 1735 cm^{-1}, whereas the $\tilde{\nu}$(C=O) absorption at 1696 cm^{-1} of the parent **6a** has disappeared. The EI-MS showed that the thiation process has occurred only at the two cyclic ketone groups, as it displayed a correct molecular ion peak *m*/*z* 376 (25%) and the $[4\text{-MeC}_6H_4CO]^+$ fragment *m*/*z* 119 (99%), besides the fragment *m*/*z* 344 for $[M-S]^+$ as the base peak. Thus, the CO absorption at 1696 cm^{-1} is assigned to the strained cyclobutanedione, whilst the one at 1735 cm^{-1} is assigned to the conjugated aroyl groups in **6a**. Two factors could affect these unexpected data; the conjugation of the ethylene bonds with the more electron-withdrawing dione ring rather than the aroyl groups, and the possible intramolecular H-bond between the vinylic H-atoms and the cyclic CO groups [20].

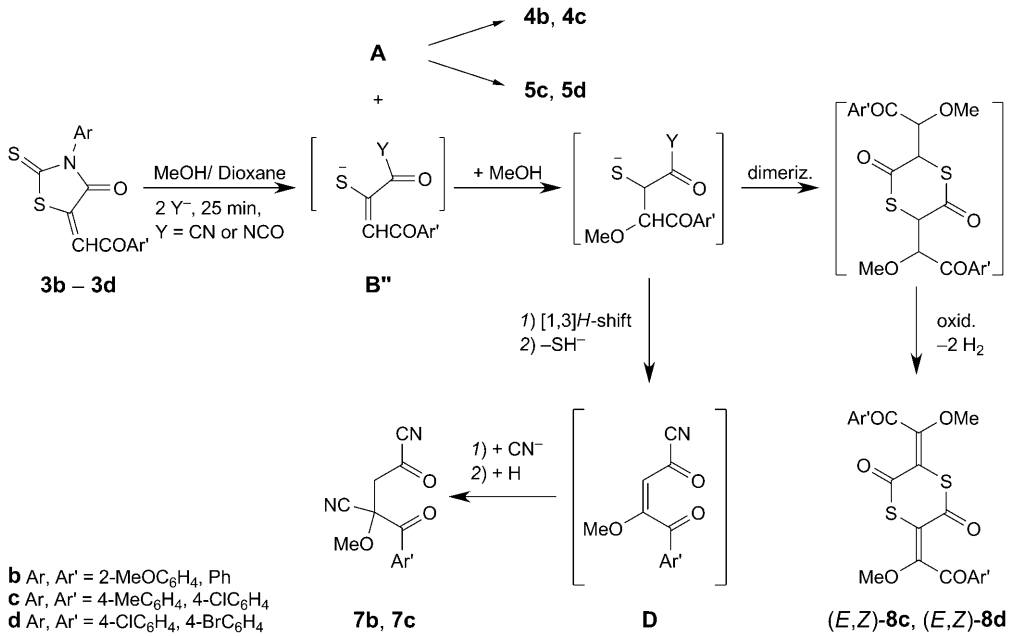
On the other hand, when the methylidene derivatives **3b** and **3c** were reacted with CN^- under the preceding conditions (*Method iii, Scheme 3*), they afforded **4b** and **4c** and 2-aroyl-2-methoxy-4-oxopentanedinitriles **7b** and **7c**, along with 3,6-bis[2-(4-chlorophenyl)-1-methoxy-2-oxoethylidene]-1,4-dithiane-2,5-dione (**8c**), in the case of **3c**.

Furthermore, allowing **3c** and **3d** to react with KOCN (*Method iii′*) gave **5c** and **5d**, respectively, in high yield, together with the dithianes **8c** and **8d** as minor products (*Scheme 3*). Since the thiolate ion **B″** lacks a MeO group; participation of the solvent (MeOH) was expected [21], providing **7**, as well as **8** (*Scheme 3*).

The IR spectra of **7b** and **7c** showed the stretching absorptions of C–H, broad C≡N, and two different C=O groups, as well as O–H, which supports its existence in the enolic form. The ^{1}H-NMR spectra exhibited a *singlet* at 3.90 ppm for MeO, and a broad *singlet*, most likely a collapsed *AB* system, for $-CH_2-$ attached to a chiral center [22]. The EI-MS exhibited correct molecular ion peaks, which showed elimination of MeOH to give the base peak of **7c** and an abundant peak in **7b**. Moreover, the ^{13}C-NMR spectrum of **7c** is in accord with the structure, as it showed two resonances for the two CN groups, whereas the high resonance for the C(3) was attributed to the existence of **7c** in the enolic form under the effect of the polar solvent (D_6)DMSO (*Fig. 3*).

The ^{1}H-NMR spectra of **8** displayed a *singlet* for the two MeO groups at *ca.* 3.72 ppm, beside the expected pattern of the aromatic H-atoms. Displaying only one *singlet* for the two MeO groups indicated that **8** could be assigned either the (3*Z*,6*Z*) or (3*E*,6*E*) configuration. The EI-MS did not exhibit the molecular ion peaks, but an $[M-S]^+$ ion peak was displayed. The IR spectra of **8c** and **8d** showed two C=O absorptions, and the microanalytical data agreed with the given structure.

Scheme 3. *Reactions of* **3b**–**3d** *with KCN and KOCN*



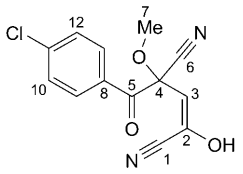


Fig. 3. *Carbon numbering of* **7c** *in the enolic form, in (D6)DMSO*

Moreover, formation of **5** could be also performed on treatment of **1**, **2**, and/or **3** with KCN, if the reaction mixtures were left at room temperature for 24 h before working up. During this long time, the sluggish elimination of CN^- took place affording **5** at the expense of **4**. Syntheses of [(cyanocarbonothioyl)amino]benzenes and arylisothiocyanates have been recently reported *via* different methods [14][23–25]. With the exception of **6**, which was filtered off from the reaction mixture, all products were separated by column chromatography.

A possible mechanism for all the above transformations is presented in *Schemes 1–3*: the nucleophilic anions Y^- (CN^- or CNO^-) attack the thiazolidine ring at C(2) or C(4) to cleave it providing the anion **A** or the thiolate **B**, **B′**, or **B″**. Protonation of **A** gave [(cyanocarbonothioyl)amino]benzenes **4**, whereas elimination of Y^- afforded the arylisothiocyanates **5** at the expense of the hypothetically formed [(cyanatocarbonothioyl)amino]benzenes. Elimination of Y^- from **B′** (*Scheme 2*) afforded the mercaptoketene **C**, which in turn gave the cyclobutane-1,3-diones **6** *via* head-to-tail cyclodimerization [18]. The unsaturated thiolate **B″** (*Scheme 3*) added a molecule of MeOH

and eliminated HS^- to give **D** or dimerized [26]. The intermediate [**D**] added a CN^- ion which afforded **7** on protonation, whereas dehydrogenation [27][28] of the dimer gave **8**.

3. Conclusions. – [(Cyanocarbonothioyl)amino]benzenes **4** and arylisothiocyanates **5** could be prepared in good yield *via* treatment of **2** and/or **3** with cyanide and cyanate ions, respectively; nevertheless, compound **2** is preferred, since the counterpart product **6** is so easy to be separated by filtration.

Experimental Part

General. Light petroleum was referred to the fraction b.p. = 60–80°. **1a**–**1d** [5] and **2a** [6] were prepared according to previously reported methods. Recorded yields of **6** are obtained from heating of **2a**–**2c** with KOCN. Thin layer chromatography (TLC) was performed on *Merck Kieselgel 60 F_{254}* aluminum packed plates. Column chromatography (CC) was carried out with silica gel *S* (SiO_2; 0.63–0.1 mm; *Riedel-de-Haen*; column dimensions: l = 17 cm, ∅ = 1.7 cm). M.p.: *Stuart Scientific*; uncorrected. IR Spectra: *Perkin Elmer 1600* instrument in KBr. Unless otherwise stated, spectra of ^{1}H-NMR (200 MHz) and ^{13}C-NMR (50 MHz, APT Technique) were measured in $CDCl_3$ soln. on *Varian Gemini* spectrometers; chemical shifts (δ) are reported in ppm downfield relative to Me_4Si. Mass Spectra: *Shimadzu GC-MS-QP 1000X* instrument operating at 70 eV.

Synthesis of 3-Aryl-5-(2-aryl-2-oxoethyl)-2-thioxo-1,3-thiazolidin-4-ones **2b**–**2d**. Ammonium (2-methoxyphenyl)carbamodithioate (2.3 g, 10.75 mmol), 2.15 g ammonium (4-methylphenyl)carbamodithioate (10.75 mmol), or 2.4 g ammonium (4-chlorophenyl)carbamodithioate (10.75 mmol) was added portionwise to a stirred soln. of 1.76 g 4-oxo-4-phenylbut-2-enoic acid (10 mmol), 2.1 g 4-(4-chlorophenyl)-4-oxobut-2-enoic acid (10 mmol), or 2.54 g 4-(4-bromophenyl)-4-oxobut-2-enoic acid (10 mmol) [29] in EtOH (10 ml) and stirred at r.t. for 30 min. Then, the mixture was acidified with conc. HCl (3 ml), boiled for 5 min, and left to cool. The precipitated solid was filtered off, washed with H_2O, air dried, and the crude product was recrystallized from the proper solvent to give the product.

3-(2-Methoxyphenyl)-5-(2-oxo-2-phenylethyl)-2-thioxo-1,3-thiazolidin-4-one (**2b**). 3.0 g (84%). M.p. 153–155° (toluene/MeOH). IR (KBr): 3050 (aryl-H), 2930, 2850 (alkyl-H), 1740, 1685 (C=O), 1240 (C=S), 750, 690 ($\delta_{5\text{-H}}$). ^{1}H-NMR: 3.64 (*dd*, J_{MX} = 19.6, J_{AX} = 11.8, 1 H_X); 3.83 (*s*, MeO); 4.21 (*dd*, J_{MX} = 19.6, J_{AM} = 3.0, 1 H_M); 4.77 (*dd*, J_{AX} = 11.6, J_{AM} = 3.0, 1 H_A); 7.10 (*t*, *J* = 8.0, H–C(5), 1 H_{anisyl}); 7.12 (*d*, *J* = 9.0, H–C(3), 1 H_{anisyl}); 7.23 (*d*, *J* = 7.8, H–C(6), 1 H_{anisyl}); 7.40–7.70 (*m*, 4 H_{arom}); 7.99 (*d*, *J* = 8.2, 2 H_{arom}). EI-MS: 357 (4, M^+), 252 (91, $[M - PhCO]^+$), 159 (90, $[M - MeOC_6H_4 - NCS_2H]^+$), 105 (100 $[PhCO]^+$), 77 (86, Ph^+). Anal. calc. for $C_{18}H_{15}NO_3S_2$: C 60.49, H 4.23, N, 3.92; found: C 60.51, H 4.18, N 3.89.

5-[2-(4-Chlorophenyl)-2-oxoethyl]-3-(4-methylphenyl)-2-thioxo-1,3-thiazolidin-4-one (**2c**). 2.9 g (77%). M.p. 169–171° (toluene). IR (KBr): 3060, 3030 (aryl-H), 2950, 2920, 2850 (alkyl-H), 1735, 1680 (C=O), 1230 (C=S), 820 ($\delta_{2\text{-H}}$). ^{1}H-NMR: 2.38 (*s*, Me); 3.76 (*dd*, J_{MX} = 18.8, J_{AX} = 8.0, 1 H_X); 4.06 (*dd*, J_{AM} = 3.0, J_{MX} = 18.8, 1 H_M); 5.02 (*dd*, J_{AX} = 8.0, J_{AM} = 3.0, 1 H_A); 7.21, 7.37 (2*d*, *J* = 8.2, 2 H_{arom}); 7.65, 8.03 (2*d*, *J* = 8.4, 2 H_{arom}). EI-MS: 375 (18, M^+), 236 (100, $[M - 4\text{-}ClC_6H_4CO]^+$), 149 (27, $[4\text{-}MeC_6H_4NCS]^+$), 139 (51, $[4\text{-}ClC_6H_4CO]^+$), 111 (38, $[4\text{-}ClC_6H_4]^+$). Anal. calc. for $C_{18}H_{14}ClNO_2S_2$: C 57.52, H 3.79, N 3.73; found: C 57.61, H 3.73, N 3.75.

5-[2-(4-Bromophenyl)-2-oxoethyl]-3-(4-chlorophenyl)-2-thioxo-1,3-thiazolidin-4-one (**2d**). 3.7 g (84%). M.p. 168–170° (toluene/MeOH). IR (KBr): 3050 (aryl-H), 2950, 2920, 2860 (alkyl-H), 1735, 1685 (C=O), 1235 (C=S), 810 ($\delta_{2\text{-H}}$). ^{1}H-NMR: 3.76 (*dd*, J_{MX} = 18.8, J_{AX} = 8.0, 1 H_X); 4.06 (*dd*, J_{MX} = 18.8, J_{AM} = 3.0, 1 H_M); 4.80 (*dd*, J_{AX} = 8.0, J_{AM} = 3.0, 1 H_A); 7.18, 7.49 (2*d*, *J* = 8.6, 2 H_{arom}); 7.69, 7.91 (2*d*, *J* = 8.6, 2 H_{arom}). EI-MS: 439 (26, M^+), 256 (100, $[M - 4\text{-}BrC_6H_4CO]^+$), 183 (49, $[4\text{-}BrC_6H_4CO]^+$), 155 (31, $[4\text{-}BrC_6H_4]^+$). Anal. calc. for $C_{17}H_{11}BrClNO_2S_2$: C 46.35, H 2.52, N 3.18; found: C 46.33, H 2.44, N 3.12.

Synthesis of (Z)- and (E,Z)-3-Aryl-5-(2-aryl-2-oxoethylidene)-2-thioxo-1,3-thiazolidin-4-ones **3a**–**3d**. A soln. of 0.5 ml Br_2 (3.0 mmol) in 5 ml AcOH was added to a soln. of (10 mmol) of each of **2a**,

2b, **2c**, or **2d** in hot AcOH (50 ml). The mixture was gently warmed until HBr gas evolution ceased (*ca.* 5 min). The precipitated solid was filtered off, washed with H_2O, air dried and crystallized from the proper solvent to give (*Z*)-**3a**, (*Z*)-**3b**, (*E*,*Z*)-**3c**, and (*E*,*Z*)-**3d**. CC of (*E*,*Z*)-**3c** and (*E*,*Z*)-**3d** over SiO_2, eluting with light petroleum/$CHCl_3$ (4:1 *v*/*v*) gave (*Z*)-**3c** and (*Z*)-**3d**, resp.

(5Z)-5-[2-(4-Methylphenyl)-2-oxoethylidene]-3-phenyl-2-thioxo-1,3-thiazolidin-4-one (**3a**). 3.0 g (88.4%) as yellow needles. M.p. 255–257° (toluene). IR (KBr): 3045 (aryl-H), 2950 (alkyl-H), 1726 (br.), 1683 (C=O), 1238 (C=S), 820 ($\delta_{2\text{-H}}$), 750, 700 ($\delta_{5\text{-H}}$). ^{1}H-NMR ((D$_6$)DMSO): 2.46 (*s*, Me); 7.28 (*d*, *J* = 8.0, 2 H_{Ph}); 7.50–7.63 (*m*, 3 H_{Ph}); 7.36, 8.02 (2*d*, *J* = 8.0, 2 H_{arom}); 8.01 (*s*, =CH). EI-MS: 339 (44, M^+), 204 (19, [*M* – 4-$CH_3C_6H_4NCS$]$^+$), 119 (100, [4-MeC_6H_4CO]$^+$), 91 (31, [C_7H_7]$^+$), 77 (11, Ph^+). Anal. calc. for $C_{18}H_{13}NO_2S_2$: C 63.70, H 3.86, N 4.13; found: C 63.45, H 3.70, N 3.72.

(5Z)-3-(2-Methoxyphenyl)-5-(2-oxo-2-phenylethylidene)-2-thioxo-1,3-thiazolidin-4-one (**3b**). 2.8 g (74.7%) as orange flakes. M.p. 237–239° (toluene). IR (KBr): 3040 (aryl-H), 2950 (alkyl-H), 1725 (br.), 1685 (C=O), 1240 (C=S), 840 ($\delta_{2\text{-H}}$), 750, 698 ($\delta_{5\text{-H}}$). ^{1}H-NMR ((D$_6$)DMSO): 3.77 (*s*, MeO); 7.14 (*t*, *J* = 8.0, H–C(5), 1 H_{anisyl}); 7.27 (*d*, *J* = 8.40, 1 H–C(3), 1 H_{anisyl}); 7.40 (*d*, *J* = 9.20, H–C(6), 1 H_{anisyl}); 7.56 (*t*, *J* = 8.0, H–C(4), 1 H_{anisyl}); 7.63 (*t*, 2 H_{Ph}); 7.76 (*t*, *J* = 7.1, 1 H_{Ph}); 8.23 (*d*, *J* = 7.10, 2 H_{Ph}); 8.17 (*s*, =CH). Anal. calc. for $C_{18}H_{13}NO_3S_2$: C 60.83, H 3.69, N 3.94; found: C 60.80, H 3.67, N 3.98.

(5E,5Z)-5-[2-(4-Chlorophenyl)-2-oxoethylidene]-3-(4-methylphenyl)-2-thioxo-1,3-thiazolidin-4-one (**3c**). 2.8 g (74.8%) as orange needles. M.p. 260–262° (toluene/dioxane). IR (KBr): 3050 (aryl-H), 2950 (alkyl-H), 1725 (br.), 1680 (C=O), 1225 (C=S), 840 ($\delta_{2\text{-H}}$). ^{1}H-NMR ((D$_6$)DMSO): for the (*Z*)-isomer (92%): 2.39 (*s*, Me); 7.36, 7.32 (two central peaks, 4 H_{arom}); 7.96, 8.28 (2*d*, *J* = 8.4, 2 H_{arom}); 8.14 (*s*, =CH); for the (*E*)-isomer (8%): 2.28 (*s*, Me); 7.18, 7.28 (two central peaks, 4 H_{arom}); 7.82, 8.42 (2*d*, *J* = 8.8, 2 H_{arom}); 8.01 (*s*, =CH). Anal. calc. for $C_{18}H_{12}ClNO_2S_2$: C 57.83, H 3.24, N 3.75; found: C 57.92, H 3.19, N 3.80.

(5E,5Z)-5-[2-(4-Bromophenyl)-2-oxoethylidene]-3-(4-chlorophenyl)-2-thioxo-1,3-thiazolidin-4-one (**3d**). 3.4 g (77.5%) as orange clusters. M.p. 274–276° (dioxane). IR (KBr): 3050 (aryl-H), 1725 (br.), 1685(C=O), 1225 (C=S), 840 ($\delta_{2\text{-H}}$). ^{1}H-NMR ((D$_6$)DMSO): for the (*Z*)-isomer (90%) 7.50, 7.67 (2*d*, *J* = 8.4, 2 H_{arom}); 7.84, 8.21 (2*d*, *J* = 8.1, 2 H_{arom}); 8.15 (*s*, =CH); for the (*E*)-isomer (10%): 7.43, 7.60 (2*d*, *J* = 9.0, 2 H_{arom}); 7.90, 8.27 (2*d*, *J* = 9.0, 2 H_{arom}); 8.08 (*s*, =CH). Anal. calc. for $C_{17}H_9BrClNO_2S_2$: C 46.54, H 2.07, N 3.19; found: C 46.70, H 2.25, N 3.40.

Reactions of **1**, **2**, *and* **3** *with KCN and KOCN. General Procedure.* A mixture of **1a**–**1d**, **2a**–**2d**, or **3b**–**3d** (1 mmol) and KCN or KOCN (2.2 equiv.) in dioxane (25 ml) was heated to 90° for 25 min. During this time, 30 ml of MeOH was added in five portions till the red color first formed faded away. The mixtures were worked up as mentioned below.

Reactions of **1a**–**d**. The mixture obtained from **1** on treatment with KCN (*Method i*) or KOCN (*Method i'*) was concentrated, poured into H_2O (50 ml), acidified with conc. HCl (1 ml), and extracted with $CHCl_3$ (100 ml). The dried extract was evaporated, the residue was chromatographed over SiO_2 with light petroleum/AcOEt (9:1 *v*/*v*) to give the [(cyanocarbonothioyl)amino]benzenes **4a**–**4d** and/or with light petroleum to afford arylisothiocyanates **5a**–**5d** [10–12] (TLC monitored separation).

Reactions of **2a**–**2d**. The insoluble creamy product **6**, which precipitated from the mixtures of **2a**–**2d** with KCN (*Method ii*) and/or KOCN (*Method ii'*), was filtered off, washed with H_2O, and then with MeOH. The dried product was recrystallized from nitrobenzene to afford the respective 2,4-bis(2-aryl-2-oxoethylidene)cyclobutane-1,3-diones **6a**–**6d**. The mother liquors were concentrated, poured into H_2O (50 ml), and worked up as previously mentioned to give **4a**–**4d** and **5a**–**5d**, which were matched TLC and IR with authentic samples [10–12].

Reactions of **3b**–**3d**. The dark brown mixtures obtained by reacting **3b** or **3c** with KCN (*Method iii*) and **3c** or **3d** with KOCN (*Method iii'*) were concentrated, poured into H_2O (50 ml), and extracted with 100 ml toluene. The org. extract was dried (anh. $CaCl_2$) and evaporated. The residue was chromatographed over SiO_2 with light petroleum to give **5**, then with light petroleum/$CHCl_3$ (4:1 *v*/*v*) to afford the dithianedione **8c** or **8d**. The original aq. soln. was acidified with conc. HCl (1 ml) and then extracted with $CHCl_3$ (100 ml). The extract was dried (anh. $CaCl_2$) and evaporated. The residue was chromatographed over SiO_2 with light petroleum/$CHCl_3$ (4:1 *v*/*v*) to afford the [(cyanocarbonothioyl)amino]benzenes **4**, and then with light petroleum/$CHCl_3$ (7:3 *v*/*v*) to give the pentanedinitriles **7b** and **7c** (TLC monitored separation).

[(Cyanocarbonothioyl)amino]benzene (**4a**). 0.13 g (83%, *Method i*), 0.14 g (87%, *Method ii*). Pale yellow needles. M.p. 80° (light petroleum), in agreement with m.p. and IR of an authentic sample [15].

1-[(Cyanocarbonothioyl)amino]-2-methoxybenzene (**4b**). 0.18 g (92%, *Method i*), 0.18 g (92%, *Method ii*), 0.16 g (82%, *Method iii*). Orange needles. M.p. 93–95° (light petroleum). IR (KBr): 3280 (NH), 3020 (aryl-H), 2230*w* (CN), 1120 (C=S), 750 ($\delta_{5\text{-H}}$). ^{1}H-NMR: for the H-bonded form (*Fig. 1*; 76%): 3.97 (*s*, MeO); 6.99 (*d*, *J* = 8.0, 1 H–C(6), 1 H_{anisyl}); 7.05 (*t*, *J* = 8.0, 1 H–C(4), 1 H_{anisyl}); 7.31 (*t*, *J* = 8.0, H–C(5), 1 H_{anisyl}); 8.96 (*d*, *J* = 8.2, H–C(3), 1 H_{anisyl}); 9.80 (br. *s*, NH); for the non-H-bonded, open form (24%): 3.39 (*s*, MeO); 6.99 (*d*, *J* = 8.0, 1 H–C(6), 1 H_{anisyl}); 7.06 (*t*, *J* = 8.0, 1 H–C(4), 1 H_{anisyl}); 7.34 (*t*, *J* = 8.0, H–C(5), 1 H_{anisyl}); 7.72 (*d*, *J* = 8.2, H–C(3), 1 H_{anisyl}); 9.80 (br. *s*, NH). EI-MS: 192 (37, M^+), 165 (14, $[M - HCN]^+$), 161 (100, $[M - MeO]^+$), 107 (21, $[M - NHCSCN]^+$). Anal. calc. for $C_9H_8N_2OS$: C 56.23, H 4.19, N 14.57; found: C 56.23, H 4.09, N 14.59.

1-[(Cyanocarbonothioyl)amino]-4-methylbenzene (**4c**). 0.16 g (91%, *Method i*), 0.16 g (91%, *Method ii*), 0.15 g (87%, *Method iii*). Orange needles. M.p. 131° (light petroleum/$CHCl_3$), in agreement with m.p. and IR of an authentic sample [14].

1-Chloro-4-[(cyanocarbonothioyl)amino]benzene (**4d**). 0.18 g (93%, *Method i*), 0.19 g (96%, *Method ii*). Yellow needles. M.p. 116–118° ($CHCl_3$/light petroleum). IR (KBr): 3260, 3050 (aryl-H), 2200*w* (CN), 1090 (C=S), 825 ($\delta_{2\text{-H}}$). ^{1}H-NMR ((D_6)DMSO): 7.57, 7.95 (2*d*, *J* = 9.0, 2 H_{arom}); 13.55 (br. *s*, NH). Anal. calc. for $C_8H_5N_2S$: C 48.85, H 2.54, N 14.25; found: C 48.83, H 2.57, N 14.29.

Phenyl Isothiocyanate (**5a**). 0.05 g (32%, *Method i'*), 0.13 g (93%, *Method ii'*) [11].

2-Methoxyphenyl Isothiocyanate (**5b**). 0.06 g (35%, *Method i'*), 0.15 g (91%, *Method ii'*) [10].

4-Methylphenyl Isothiocyanate (**5c**). 0.05 g (32%, *Method i'*), 0.15 g (93%, *Method ii'*), 0.14 g (91%, *Method iii'*) [11].

4-Chlorophenyl Isothiocyanate (**5d**). 0.06 g (35%, *Method i'*), 0.16 g (95%, *Method ii'*), 0.15 g (90%, *Method iii'*) [12].

2,4-Bis[2-(4-methylphenyl)-2-oxoethylidene]cyclobutane-1,3-dione (**6a**). 0.12 g (42%). M.p. > 360°. IR (KBr): 3080 (aryl-H), 1735, 1696 (C=O), 1595 (C=C), 810 ($\delta_{2\text{-H}}$). EI-MS: 344 (80, M^+), 316 (8, $[M - CO]^+$), 288 (48, $[M - 2\ CO]^+$), 172 (6, $[M - 4\text{-}MeC_6H_4COCH{=}C{=}CO]^+$), 119 (100, $[4\text{-}MeC_6H_4CO]^+$), 91 (8, $[4\text{-}MeC_6H_4]^+$). Anal. calc. for $C_{22}H_{16}O_4$: C 76.73, H 4.68; found: C 76.71, H 4.58.

2,4-Bis(2-oxo-2-phenylethylidene)cyclobutane-1,3-dione (**6b**). 0.10 g (40%). M.p. > 360°. IR (KBr): 3080 (aryl-H), 1738, 1695 (C=O), 1595 (C=C), 740, 680 ($\delta_{5\text{-H}}$). ^{1}H-NMR ((D_6)DMSO): 7.42 (br. *s*, 2 H, =CH); 7.61–7.45 (*m*, 6 H_{arom}); 7.96–8.01 (*m*, 4 H_{arom}). EI-MS: 316 (80, M^+), 288 (10, $[M - CO]^+$), 260 (8, $[M - 2\ CO]^+$), 158 (5, $[PhCOCH{=}C{=}CO]^+$), 105 (100, $[PhCO]^+$), 77 (77, Ph^+). Anal. calc. for $C_{20}H_{12}O_4$: C 75.94, H 3.82; found: C 75.94, H 3.82.

2,4-Bis[2-(4-chlorophenyl)-2-oxoethylidene]cyclobutane-1,3-dione (**6c**). 0.14 g (42%). M.p. > 360°. IR (KBr): 3090 (aryl-H), 1715, 1685 (br., C=O), 1595 (C=C), 810 ($\delta_{2\text{-H}}$). EI-MS: 384 (69, M^+), 356 (4, $[M - CO]^+$), 328 (29, $[M - 2\ CO]^+$), 192 (5.9, $[4\text{-}ClC_6H_4COCH{=}C{=}CO]^+$), 139 (100, $[4\text{-}ClC_6H_4CO]^+$), 111 (60, $[4\text{-}ClC_6H_4]^+$). Anal. calc. for $C_{20}H_{10}Cl_2O_4$: C 62.36, H 2.62; found: C 62.44, H 2.68.

2,4-Bis[2-(4-bromophenyl)-2-oxoethylidene]cyclobutane-1,3-dione (**6d**). 0.18 g (43%). M.p. > 360°. IR (KBr): 3050, 1715 (br.), 1678 (C=O), 1595 (C=C), 810. EI-MS: 472 (40, M^+), 444 (3, $[M - CO]^+$), 416 (3, $M - 2\ CO]^+$), 236 (2, $[4\text{-}BrC_6H_4COCH{=}C{=}CO]^+$), 183 (100, $[4\text{-}BrC_6H_4CO]^+$), 155 (80, $[4\text{-}BrC_6H_4]^+$). Anal. calc. for $C_{20}H_{10}Br_2O_4$: C 50.63, H 4.19; found: C 50.54, H 2.11.

2-Methoxy-4-oxo-2-(phenylcarbonyl)pentanedinitrile (**7b**). 0.035 g (15%). M.p. 169–171° (toluene). IR (KBr): 3450, 3260, 3200 (O–H), 3040 (aryl-H), 2910 (alkyl-H), 2220 (CN), 1710, 1685 (C=O), 760, 690. ^{1}H-NMR: 3.90 (*s*, MeO); 5.77 (br. *s*, CH_2CO); 7.38–7.49 (*m*, 3 H_{arom}); 7.89 (*d*, *J* = 7.8, 2 H_{arom}). EI-MS: 242 (55, M^+), 210 (87, $[M - MeOH]^+$), 105 (100, $[PhCO]^+$), 77 (77, $[Ph]^+$). Anal. calc. for $C_{13}H_{10}N_2O_3$: C 64.46, H 4.16, N 11.56; found: C 64.32, H 4.20, N 11.49.

2-[(4-Chlorophenyl)carbonyl]-2-methoxy-4-oxopentanedinitrile (**7c**). 0.04 g (15%). M.p. 194–196° (toluene). IR (KBr): 3500, 3300, 3200 (O–H), 3100 (aryl-H), 2950 (alkyl-H), 2215 (CN), 1710, 1680 (C=O), 820. ^{1}H-NMR: 3.90 (*s*, MeO); 5.79 (br. *s*, CH_2CO); 7.42, 7.82 (2*d*, *J* = 7.2, 2 H_{arom}). ^{13}C-NMR ((D_6)DMSO): 50.4 (C(7)); 85.6 (C(3)); 90.8 (C(4)); 113.6 (C(1)); 125.1 (C(10), C(12)); 125.6 (C(6)); 128.9 (C(9), C(13)); 133.6 (C(11)); 147.3 (C(8)); 161.1 (C(2)); 161.8 (C(5)). EI-MS: 276 (75.9, M^+), 244 (100, $[M - MeOH]^+$), 139 (82, $[4\text{-}ClC_6H_4CO]^+$), 111 (63, $[4\text{-}ClC_6H_4]^+$). Anal. calc. for $C_{13}H_9ClN_2O_3$: C 56.44, H 3.28, N 10.12; found: C 56.63, H 3.42, N 10.30.

3,6-Bis[2-(4-chlorophenyl)-1-methoxy-2-oxoethylidene]-1,4-dithiane-2,5-dione (**8c**). 0.08 g (30%). M.p. 212–214° ($CHCl_3$/light petroleum). IR (KBr): 3100 (aryl-H), 2950 (alkyl-H), 1725, 1680 (C=O), 810. ^{1}H-NMR: 3.72 (*s*, MeO); 7.41, 7.68 (2*d*, $J = 8.6$, 4 H_{arom}). EI-MS: 476 (13, $[M - S]^+$), 365 (23, $[M - S - 4\text{-}ClC_6H_4]^+$), 333 (20, $[M - S - 4\text{-}ClC_6H_4 - MeOH]^+$), 139 (100, $[4\text{-}ClC_6H_4CO]^+$). Anal. calc. for $C_{22}H_{14}Cl_2O_6S_2$: C 51.88, H 2.77, S 13.12; found: C 52.0, H 2.76, S 13.12.

3,6-Bis[2-(4-bromophenyl)-1-methoxy-2-oxoethylidene]-1,4-dithiane-2,5-dione (**8d**). 0.09 g (30%). M.p. 239–240° ($CHCl_3$/light petroleum). IR (KBr): 3100 (aryl-H), 2950 (alkyl-H), 1725, 1680 (C=O), 810. ^{1}H-NMR: 3.72 (*s*, MeO); 7.61, 7.59 (two central peaks, 4 H_{arom}). EI-MS: 564 (13, $[M - S]^+$), 409 (38, $[M - S - 4\text{-}BrC_6H_4]^+$), 377 (32, $[M - S - 4\text{-}BrC_6H_4 - MeOH]^+$), 183 (100, $[4\text{-}BrC_6H_4CO]^+$). Anal. calc. for $C_{22}H_{14}Br_2O_6S_2$: C 44.17, H 2.36, S 10.72; found: C 44.23, H 2.61, S 11.3.

Reaction of **6a** *with* Lawesson*'s Reagent.* A mixture of **6a** (0.35 g, 1 mmol) and *Lawesson*'s reagent (0.82 g, 0.2 mmol) was refluxed in dry xylene (50 ml) for 30 min. The mixture was filtered while hot and washed with H_2O (25 ml). The org. layer was separated, dried ($CaCl_2$), concentrated, and left to cool. The crude product was filtered off, dried, recrystallized and treated with charcoal before filtration to afford **6′a**.

2,2′-(2,4-Dithioxocyclobutane-1,3-diylidene)bis[(4-methylphenyl)ethan-1-one] (**6′a**). 0.30 g (85%) deep violet crystals. M.p. > 300° (nitrobenzene). IR (KBr): 3050 (aryl-H), 1735 (aroyl C=O), 1182 (C=S), 809. EI-MS: 376 (25, M^+), 361 (33, $[M - Me]^+$), 360 (66, $[M - CH_4]^+$), 344 (100, $[M - S]^+$), 332 (38, $[M - CS]^+$), 119 (99, $[4\text{-}MeC_6H_4CO]^+$), 91 (83, $[C_7H_7]^+$). Anal. calc. for $C_{22}H_{16}S_2O_2$: C 70.18, H 4.28, S 17.07; found: C 70.07, H 4.23, S 16.99.

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