The Behaviour of *E,Z*-5-Arylmethylidene-2-thioxo-1,3-thiazolidin-4-one and 3-[(2-Oxo-2*H*-1-benzopyran-3-yl)dithio]-2*H*-1-benzopyran-2-one Derivatives towards Some Amines

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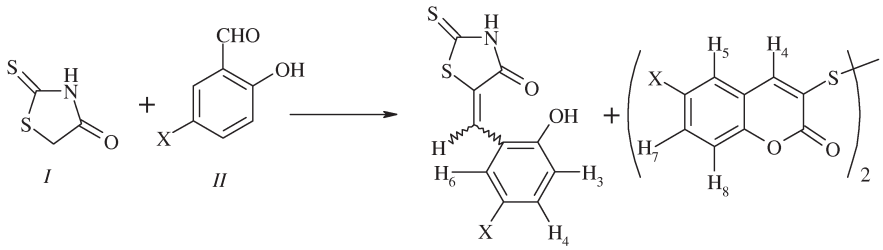
The reaction of 2-thioxo-1,3-thiazolidin-4-one with salicylaldehyde or its 5-bromo derivative in acetic acid and sodium acetate gave a mixture of *E,Z-* or *E*-5-arylmethylidene-2-thioxo-1,3-thiazolidin-4-ones (*IIIa* or *IIIb*) and the disulfide derivatives *IVa* and *IVb*, respectively. Treatment of *IIIa* with benzylamine or morpholine in dioxane at room temperature afforded 3-benzylamino-2*H*-1-benzopyran-2-one (*VIa*) or *E,Z*-2-thiazolin-4-one derivative together with the amine salt, respectively. Similar treatment of *IIIb* with benzylamine yielded the *E,Z*-2-thiazolin-4-one derivative and the disulfide *IVb* as the major product. The disulfide *IVa* reacted with benzylamine in cold dioxane to yield the disulfide derivative of 4-benzylamino-2*H*-benzopyran-2-one in addition to *VIa*, whereas in boiling dioxane it gave *VIa* and the corresponding bisbenzyl derivative. On the other hand, when *IIIb* or *IVa* was treated with dicyclohexylamine in dioxane, it gave *IVb* as well as the amine salt in the former case and 3-sulfanyl-2*H*-1-benzopyran-2-one in the latter one. Structures of all products were evidenced by elemental analysis and spectral data.

It has been reported that 2-thioxo-1,3-thiazolidin-4-one (*I*) and its 2-imino derivative condense with a variety of aliphatic, aromatic, and heterocyclic aldehydes and ketones to afford the corresponding 5-arylmethylidene derivatives [1—12]. On the other hand, *Turkevich* [13] had reported the formation of 3-[(2-oxo-2*H*-1-benzopyran-3-yl)dithio]-2*H*-1-benzopyran-2-one (*IVa*) when *I* was treated with salicylaldehyde (*IIa*) in the presence of glacial acetic acid or an ammonia buffer solution. However, in the present investigation, the author had obtained the respective *E,Z-* and *E*-5-arylmethylidene-2-thioxo-1,3-thiazolidin-4-ones *IIIa* and *IIIb* in addition to the 3-dithio-2*H*-1-benzopyran-2-one derivatives *IVa* and *IVb* upon treatment of *I* with *IIa* or 5-bromosalicylaldehyde (*IIb*) in the presence of glacial acetic acid and sodium acetate, respectively. In addition, it was found that the ratios of the isolated products *III* and *IV* are greatly affected by the reaction time and the solvent used. The reactions of compounds *III* and *IV* with some amines such as benzylamine, morpholine, and dicyclohexylamine were also investigated.

Thus, refluxing equimolar amounts of *I* [14] and *IIa* in the presence of acetic acid and sodium acetate for half an hour gave a solid from which *E*-5-(2-hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (*IIIa*, 60 %), *Z-IIIa* (10 %), and 3-[(2-oxo-2*H*-1-benzopyran-3-yl)dithio]-2*H*-1-benzopyran-2-one (*IVa*, 30 %) were separated by chromatography in an over yield of 70 %. Similar treatment of *I* with *IIb* afforded only one stereoisomer identified as *E*-5-(5-bromo-2-hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (*IIIb*) as the major product as well as a minor amount of 6-bromo-3-[(6-bromo-2-oxo-2*H*-1-benzopyran-3-yl)-dithio]-2*H*-1-benzopyran-2-one (*IVb*).

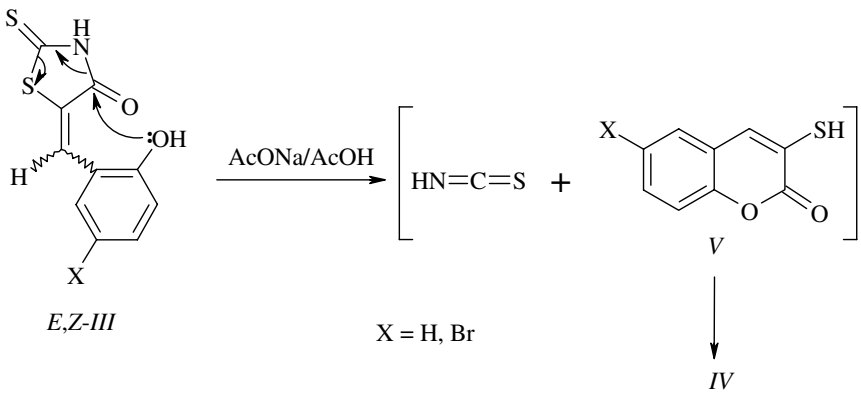
On the other hand, when these reactions were conducted under reflux for 6—7 h, the disulfides *IVa* and *IVb* were the main products and a minor amount of *E,Z-IIIa* was also isolated whereas *E-IIIb* was detected by TLC. Moreover, the disulfide *IVb* was the only isolated product when *I* was allowed to react with *IIb* in the presence of sodium acetate in dimethylformamide (DMF) under reflux for 6 h.

Structures of compounds *III* and *IV* were deduced from microanalytical and spectral data. The infrared spectra of *III* show besides ν_{OH} and ν_{NH} a carbonyl absorption consistent with the hetero ring as well as $\nu_{C=S}$ of the S—CS—N moiety. On the other hand, the infrared spectra of *IV* are devoid of any ν_{OH} and ν_{NH} absorptions but exhibit $\nu_{C=O}$ stretching frequency consistent with benzopyran-2-one structure. The ^{1}H NMR spectra of *III* and *IV* are in a good agreement with the proposed structure. The structures of *IIIa* and *IVa* get a further support by mass spectroscopy



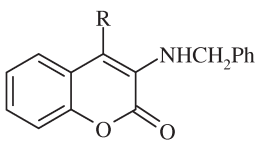
I *II* *E,Z-III* *IV*

a X = H
b X = Br

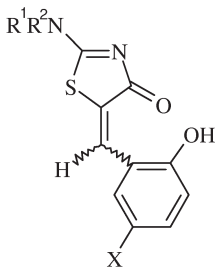


E,Z-III *V* *IV*

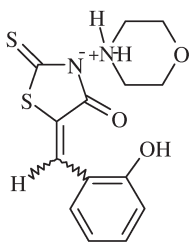
X = H, Br



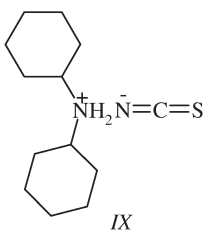
VI a R = H
b R = Ph—CH_2—NH—



VII a R^1,R^2 = $(CH_2)_2$—O—$(CH_2)_2$—; X = H
b R^1 = H; R^2 = $PhCH_2$—; X = Br



VIII



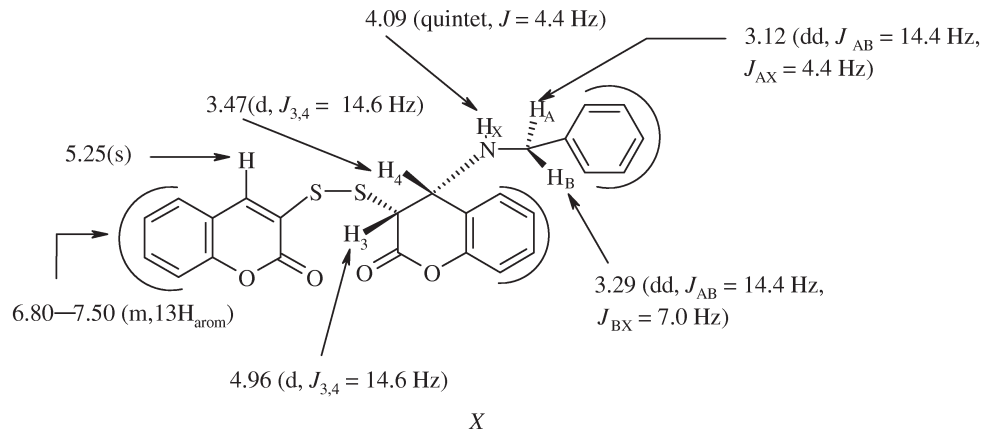
IX

where their EI-MS spectra show a correct molecular ion peaks as well as some of the abundant fragments.

Configurational assignments to *E-IIIa*, *Z-IIIa,* and *E-IIIb* are based exclusively on their ^{1}H NMR spectroscopy and on the assumption that the olefinic protons of the *Z*-configurated isomers are more deshielded by the 4-oxo group as compared with the *E*-counterparts. This relation is an accepted assumption in the elucidation of configuration of arylidene derivatives of many heterocycles [15].

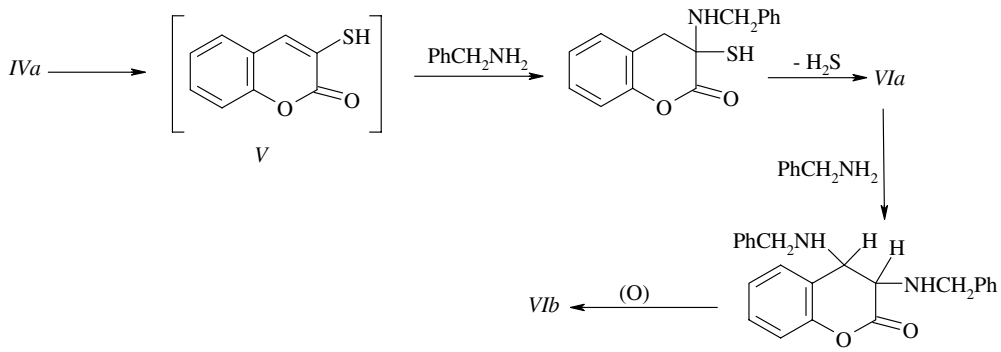
The formation of the disulfide *IV* can be explained through the arylidene derivative *III*. The phenolic —OH group in the presence of a base (sodium acetate) attacks the hetero-ring carbonyl carbon followed by elimination of isothiocyanic acid to give 3-sulfanyl-2*H*-1-benzopyran-2-one (*V*) (not isolated) which is oxidized in air to give *IV*.

The reactions of *IIIa* and *IIIb* and of the disulfide derivatives *IVa* and *IVb* with benzylamine, morpholine, and dicyclohexylamine were also investigated. Thus, *E,Z-IIIa* reacted with benzylamine in dioxane at room temperature to give 3-benzylamino-2*H*-1-benzopyran-2-one (*VIa*). On the other hand, when *E-IIIb* was treated with benzylamine under the same re-



X

Formula 1



action conditions, it afforded the *E,Z*-mixture of the 2-thiazolin-4-one derivative *E,Z-VIIb* together with the disulfide *IVb* as the major product.

Similar treatment of *E,Z-IIIa* with morpholine gave the *E,Z*-2-thiazolin-4-one derivative *E,Z-VIIa* in addition to a pure *Z*-isomer that were separated by chromatography and the amine salt *VIII* which was converted into *VIIa* in refluxing dioxane or decomposed into *IIIa* with AcOH or HCl. Such transformations are well documented [16—18] for similar amine salts.

It is noteworthy to mention that treating *E-IIIb* with dicyclohexylamine in dioxane at room temperature gave the disulfide *IVb* as the main product in addition to the dicyclohexylamine salt of isothiocyanic acid (*IX*). This result supports the suggested mechanism mentioned previously for the conversion of compounds *III* into *IV*.

The structures of *VIa*, *E,Z-VIIa* and *VIIb*, *VIII*, and *IX* were substantiated from their microanalytical and spectral data. Thus, the infrared spectra are consistent with the proposed structures. The *E,Z*-nature of compounds *VIIa* and *VIIb* was evidenced from their ^{1}H NMR spectra where each spectrum showed two singlets consistent with the exocyclic olefinic proton. Moreover, the observed integrated proton ratios indicate that the *E*-configurated isomers constitute 85 % and 35 % of the mixture, respectively.

Conversion of *E-IIIb* into *E,Z-VIIb* upon treating with benzylamine suggested that an isomerization had occurred during the course of the reaction where an attack of benzylamine molecule at the exocyclic double bond followed by its removal is also possible.

The reaction of disulfide *IVa* with benzylamine in dioxane at room temperature for 48 h afforded the disulfide derivative *X* in addition to *VIa*, whereas in boiling dioxane it gave *VIa* and *VIb* which were separated by chromatography. On the other hand, the reaction of *IVa* with dicyclohexylamine in cold or boiling dioxane yielded sulfanyl derivative *V* (X = H) the structure of which was rigidly confirmed from its spectral data (IR, ^{1}H NMR, and MS) as well as its melting point identity with that reported [19].

The structure of *VIa* was confirmed by the identity with an authentic sample (m.p., mixed m.p., IR, and TLC). The structures of compounds *VIb* and *X* were deduced from microanalytical and spectral evidence. Their infrared spectra show, besides ν_{NH}, $\nu_{=C-H}$, and ν_{C-H}, a carbonyl absorption consistent with a pyran-2-one ring system. The ^{1}H NMR spectrum of *VIb* shows, besides the expected aromatic protons resonances, two doublets, each for methylene protons and two exchangeable NH. However, the ^{1}H NMR spectrum of *X* in $CDCl_3$ (Formula 1) disclosed an ABX pattern consistent with —NH_X—CH_AH_B—Ph moiety in which each of these coupled protons appears as a doublet of doublets

with a geminal coupling constant of 14.4 Hz and vicinal coupling constants of 7.0 Hz and 4.4 Hz. Moreover, the spectrum showed two doublets, each corresponding to one proton (H-3 and H-4), in addition to a multiplet for aromatic proton resonances.

At the suggested route for the formation of compounds *VIa* and *VIb* upon treating the disulfide *IVa* with benzylamine in boiling dioxane, the disulfide *IVa* is first reduced to give compound *V* (X = H, not isolated) which is attacked by a benzylamine molecule at C-3 followed by an evolution of hydrogen sulfide gas (detected by a paper moistened with a lead acetate solution) to afford compound *VIa* which is then attacked by another molecule of benzylamine at C-4 followed by oxidation to give compound *VIb*. To verify this suggested mechanism an independent experiment was carried out by refluxing *VIa* and benzylamine in dioxane for 2 h, where *VIb* was isolated.

EXPERIMENTAL

All melting points are uncorrected. IR spectra were measured on Unicam SP 1200 spectrometer as KBr discs. Unless otherwise stated the ^{1}H NMR spectra were measured in DMSO-d_6 or $CDCl_3$ solutions on Varian Gemini 200 MHz instrument with chemical shifts (δ) downfield from Me_4Si. Mass spectra were recorded on Shimadzu GC-MS Qp 1000 EX instrument operating at 70 eV. Column chromatography and TLC were runned on Silica Gel Voeim, activity III 130 mm according to Brockmann and Schodder, and TLC aluminium sheets Silica Gel 60 F_{254} (Merck).

Reaction of 2-Thioxo-1,3-thiazolidin-4-one (*I*) with Salicylaldehyde (*IIa*) and 5-Bromosalicylaldehyde (*IIb*)

A mixture of *I* [14] (10 mmol), *IIa* or *IIb* (10 mmol), and anhydrous sodium acetate (30 mmol) in glacial acetic acid (30 cm^3) was refluxed for 0.5 h. The mixture was cooled, poured into iced cold water and the precipitated solid was filtered off.

The obtained solid from *I* and *IIa* showed that it is a mixture of three components, so it was chromatographed over silica gel. Elution with light petroleum (b.p. = 60—80 °C) gave (*IVa*) and elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 1:4) afforded *E-IIIa* followed by *Z-IIIa*.

3-[(2-Oxo-2H-1-benzopyran-3-yl)dithio]-2H-1-benzopyran-2-one (IVa), yield = 0.35 g (7 %), pale rose crystals, m.p. = 225—226 °C (methanol). For $C_{18}H_{10}O_4S_2$ (M_r = 354.38) w_i(calc.): 61.00 % C, 2.84 % H, 18.09 % S; w_i(found): 59.83 % C, 2.79 % H, 17.95 % S. IR spectrum, $\tilde{\nu}$/cm^{-1}: 3050 (H_{aryl}), 1715 (C═O), 1600 (C═C), 750 ($\delta_{4\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: 7.30—7.40 (m, H-6), 7.50 (d, H-8, J = 8.4 Hz), 7.50—7.70 (m, H-7), 7.76 (dd, H-5, J = 7.8 Hz and 1.4 Hz), 8.17 (s, H-4). EI MS, m/z (I_r/%): 356 ($M^{+\bullet}$ + 2, 5.9), 354 ($M^{+\bullet}$, 45.8), 180 (4), 179 (3.3), 178 (22.1), 177 (19).

E-5-(2-Hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (E-IIIa), yield = 0.99 g (42 %), pale yellow crystals, m.p. = 224—225 °C (chloroform). IR spectrum, $\tilde{\nu}$/cm^{-1}: 3350 (OH), 3180 (NH), 3060 (H_{aryl}), 1700 (C═O), 1580 (C═C), 1260 (S—CS—N), 750 ($\delta_{4\text{-H}}$). EI MS, m/z (I_r/%): 239 ($M^{+\bullet}$ + 2, 5.6), 237 ($M^{+\bullet}$, 50), 180 (3.9), 178 ($M^{+\bullet}$ − HNCS, 50.6), 152 (5.0), 150 ($M^{+\bullet}$ − HNCS and CO, 100), 121 (66), 122 (26), 90 (40.6), 89 (24.2), 78 (23.8), 77 (23.2). ^{1}H NMR spectrum (DMSO-d_6), δ: 6.97 (dd, 2, J = 8.0 Hz and 2.0 Hz, H_{arom}), 7.30—7.40 (m, 2H_{arom}), 7.87 (s, 1, ═CH), 10.70 (s, NH, exchangeable with D_2O), 13.75 (br s, OH, exchangeable).

Z-5-(2-Hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (Z-IIIa), yield = 0.49 g (21 %), pale yellow crystals, m.p. = 245—246 °C (methanol). For $C_{10}H_7NO_2S_2$ (M_r = 237.286) w_i(calc.): 50.61 % C, 2.97 % H, 5.90 % N, 27.02 % S; w_i(found): 50.53 % C, 3.01 % H, 5.79 % N, 26.88 % S. IR spectrum, $\tilde{\nu}$/cm^{-1}: 3410 (OH), 3140 (NH), 3040 (H_{aryl}), 1715 (C═O), 1580 (C═C), 1240 (S—CS—N), 750 ($\delta_{4\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: 6.96 (dd, 2, J = 8.2 Hz and 1.6 Hz, H_{arom}), 7.20—7.40 (m, 2H_{arom}), 8.04 (s, 1, ═CH), 10.50 and 13.80 (each br s, 1, NH and OH, exchangeable).

The obtained solid from *I* and *IIb* was chromatographed over silica gel and elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 2:1) gave *IVb* followed by *E-IIIb*.

6-Bromo-3-[(6-bromo-2-oxo-2H-1-benzopyran-3-yl)dithio]-2H-1-benzopyran-2-one (IVb), yield = 0.3 g (5 %), colourless crystals, m.p. = 304—306 °C (dioxane). For $C_{18}H_8Br_2O_4S_2$ (M_r = 512.234) w_i(calc.): 42.21 % C, 1.57 % H, 12.52 % S; w_i(found): 42.08 % C, 1.58 % H, 12.45 % S. IR spectrum, $\tilde{\nu}$/cm^{-1}: 3060 (H_{aryl}), 1715 (C═O), 1590 (C═C), 850. ^{1}H NMR spectrum (DMSO-d_6), δ: 7.39 (d, H-8, J = 9.0 Hz), 7.69 (dd, H-7, J = 9.0 Hz and 2.4 Hz), 7.95 (d, H-5, J = 2.4 Hz), 8.04 (s, H-4).

E-5-(5-Bromo-2-hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (E-IIIb), yield = 1.3 g (41 %), pale yellow crystals, m.p. = 231—233 °C (benzene). For $C_{10}H_6BrNO_2S_2$ (M_r = 316.178) w_i(calc.): 37.98 % C, 1.91 % H, 4.43 % N, 20.28 % S; w_i(found): 37.87 % C, 1.95 % H, 4.53 % N, 20.17 % S. IR spectrum, $\tilde{\nu}$/cm^{-1}: 3440 (OH), 3230 (NH), 3060 (H_{aryl}), 1700 (C═O), 1595 (C═C), 1250 (S—CS—N), 825, 750, 700. ^{1}H NMR spectrum (DMSO-d_6), δ: 6.94 (d, H-3, J = 8.8 Hz), 7.38 (s, H-6), 7.40 (d, H-4, J = 8.8 Hz), 7.72 (s, ═CH), 11.12 and 13.80 (each br s, NH and OH, exchangeable).

When the above reactions were carried out with the time of reflux 6—7 h, the reaction mixture was worked up as usual followed by chromatography of the obtained solid over silica gel. In case of *I* and *IIa*

compound *IVa* (yield 60 %) was obtained as the major product followed by a mixture of *E,Z-IIIa* containing 75 % of the *E*-isomer (yield ≅ 3 %). Similarly, in case of *I* and *IIb* compound *IVb* (yield 62 %) was isolated and a trace amount of *E-IIIb* was detected by TLC in the reaction mixture.

When a mixture of *I* (0.66 g; 5 mmol), *IIb* (1.0 g; 5 mmol), and sodium acetate (1.23 g; 15 mmol) in dimethylformamide (DMF) (25 cm^3) was refluxed for 6 h and the reaction mixture was worked up as usual, compound *IVb* (yield 50 %) was the only isolated product.

Reaction of *E,Z-IIIa* or *E-IIIb* with Benzylamine, Morpholine or Dicyclohexylamine

A mixture of *E,Z-IIIa* or *E-IIIb* (3.16 mmol) and benzylamine, morpholine or dicyclohexylamine (3.16 mmol) in dioxane (15 cm^3) was allowed to stand uncovered at room temperature for 48 h.

In case of *E,Z-IIIa* with benzylamine, dioxane was evaporated and the obtained solid was recrystallized to give 3-benzylamino-2*H*-1-benzopyran-2-one (*VIa*), yield = 0.3 g (40 %), colourless crystals, m.p. = 155—157 °C (methanol). For $C_{16}H_{13}NO_2$ (M_r = 251.274) w_i(calc.): 76.47 % C, 5.22 % H, 5.58 % N; w_i(found): 76.39 % C, 5.07 % H, 5.61 % N. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3390 (NH), 3060 (H_{aryl}), 2850 (H_{aliph}), 1700, 1695 (C═O), 770 ($\delta_{4\text{-H}}$), 750, 690 ($\delta_{5\text{-H}}$). ^{1}H NMR spectrum ($CDCl_3$), δ: 4.39 (d, HN—$\underline{CH_2}$, J = 5.6 Hz), 5.33 (t, $\underline{HN}$—CH_2, J = 5.6 Hz, exchangeable), 6.32 (s, H-4), 7.10—7.50 (m, 9H_{arom}).

In case of *E-IIIb* with benzylamine, dioxane was evaporated under reduced pressure and methanol was added. The insoluble part was recrystallized from dioxane to give *IVb*, 0.6 g (40 %) identical in all respects with an authentic sample (m.p., mixed m.p., and TLC), whereas the soluble part afforded *VIIb*.

E,Z-2-Benzylamino-5-(5-bromo-2-hydroxybenzylidene)-2-thiazolin-4-one (E,Z-VIIb), yield = 0.12 g (10 %), pale yellow crystals, m.p. = 230—231 °C (methanol). For $C_{17}H_{13}BrN_2O_2S$ (M_r = 389.254) w_i(calc.): 52.45 % C, 3.37 % H, 7.20 % N, 5.92 % S; w_i(found): 52.39 % C, 3.26 % H, 7.09 % N, 6.03 % S. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3380 (OH), 3200 (NH), 3070 (H_{aryl}), 2940 (H_{aliph}), 1700 (C═O), 1625 (C═N), 1600 (C═C), 820, 760, 700 ($\delta_{5\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: *E*-isomer (85 %): 4.75 (s, 2, N—CH_2), 6.90 (d, 1, J = 6.8 Hz, H_{arom}), 7.30—7.45 (m, 7H_{arom}), 7.80 (s, 1, ═CH), 10.1 and 10.35 (each br s, 1, NH and OH, exchangeable); *Z*-isomer (15 %): 4.60 (s, 2, N—CH_2), 8.27 (s, 1, ═CH) in addition to other absorptions for aromatic and acidic protons characteristic of *E*-isomer.

In case of *E,Z-IIIa* with morpholine, the precipitated solid was filtered off to give the morpholinium salt *VIII* and the dioxane mother liquor was evaporated under reduced pressure to give a solid which was chromatographed over silica gel. Elution with light petroleum (b.p. = 60—80 °C) gave a mixture of *E,Z-VIIa* containing 65 % of the *Z*-isomer followed by a pure *Z-VIIa*.

The morpholinium salt of E,Z-5-(2-hydroxybenzylidene)-2-thioxo-1,3-thiazolidin-4-one (VIII), yield = 0.48 g (40 %), pale yellow crystals, m.p. > 360 °C. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3400 (OH), 3040—3120 (NH and H_{aryl}), 2980, 2930 (H_{aliph}), 2880, 2740 (H_2N salt), 1735, 1705 (C═O), 1610 (C═N or C═C), 1250 (S—CS—N), 750 ($\delta_{4\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: 3.60—3.70 (m, 2, CH_2), 3.70—3.88 (m, 4, 2CH_2), 3.90—4.03 (m, 2, CH_2), 6.80—7.60 (m, 4H_{arom}), 7.96 (s, 1, ═CH), 10.32 (br s, OH and NH exchangeable).

E,Z-5-(2-Hydroxybenzylidene)-2-morpholino-2-thiazolin-4-one (E,Z-VIIa), yield = 0.12 g (10 %), colourless crystals, m.p. = 263—265 °C (ethanol) (Ref. [17] gives m.p. = 266—267 °C and no ^{1}H NMR data). For $C_{14}H_{14}N_2O_3S$ (M_r = 390.332): w_i(calc.): 43.08 % C, 3.62 % H, 7.18 % N, 8.21 % S; w_i(found): 42.89 % C, 3.54 % H, 7.09 % N, 8.13 % S. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3350 (OH), 3060 (H_{aryl}), 2870, 2720, 2600 (H_{aliph}), 1665 (C═O), 1600 (C═N), 1560 (C═C), 750 ($\delta_{4\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: 3.60–3.70 (m, 2, CH_2), 3.70—3.88 (m, 4, 2CH_2), 3.90—4.03 (m, 2, CH_2), 6.80—7.60 (m, 4H_{arom}), 7.83 (s, ═CH, *E*-isomer, 35 %), 7.96 (s, ═CH, *Z*-isomer, 65 %), 10.38 (s, OH, exchangeable). *Z-VIIa*, yield = 0.12 g (10 %), colourless crystals, m.p. = 243—245 °C (ethanol). ^{1}H NMR spectrum, δ: 3.60—3.70 (m, 2, CH_2), 3.77—3.90 (m, 4, 2CH_2), 4.03—4.12 (m, 2, CH_2), 6.80—7.60 (m, 4H_{arom}), 7.96 (s, ═CH), 10.38 (s, OH, exchangeable).

The morpholinium salt *VIII* (0.1 g) was refluxed in ethanol (15 cm^3) until cessation of hydrogen sulfide. The solid which precipitated after cooling was filtered, dried and recrystallized from ethanol to give *E,Z-VIIa* identical in all respects with an authentic sample (m.p., mixed m.p., and TLC).

The morpholinium salt *VIII* (0.1 g) was stirred in acetic acid (10 cm^3) at room temperature for 4 h, then poured into iced cold water, the precipitated solid was filtered off, dried and recrystallized from methanol to give *E,Z-IIIa* identical in all respects with an authentic sample (m.p., mixed m.p., and TLC).

In case of *E-IIIb* with dicyclohexylamine, the dioxane was concentrated under reduced pressure and cooled to give a solid from which *IVb*, yield = 0.69 g (40 %), and *IX* were separated by hand picking depending on the shape and colour difference of each crystal. The disulfide *IVb* was recrystallized from dioxane and was identified by comparison with an authentic sample (m.p., mixed m.p., and TLC).

Dicyclohexylammonium salt of isothiocyanic acid (IX), yield = 0.076 g (10 %), pale yellow crystals, m.p. = 228—230 °C. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3020, 2945, 2860, 2800, and 2720 (H_{aliph}), 2545 and 2450 (H_2N^+ salt), 2060 and 2010 (N═C═S). ^{1}H NMR spectrum (DMSO-d_6), δ: 1.00—1.40 (m, 10H), 1.59—1.80 (m,

6H), 1.85—2.10 (m, 4H), 2.99—3.20 (m, 2H), 6.60—8.40 (vbrs, 2H, $^{+}NH_2$, exchangeable).

Reaction of Disulfide *IVa* with Benzylamine and Dicyclohexylamine

A mixture of the disulfide *IVa* (0.5 g; 1.4 mmol) and benzylamine or dicyclohexylamine (1.4 mmol) in dioxane (15 cm^3) was allowed to stand at room temperature for 48 h. Dioxane was evaporated under reduced pressure and the obtained solid was chromatographed over silica gel.

In case of *IVa* and benzylamine, elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 1:1) gave *X*. Elution with ether afforded *VIa*, 0.013 g (5 %) which was identified by comparison with an authentic sample (m.p., mixed m.p., and TLC).

4-Benzylamino-3,4-dihydro-3-[(2-oxo-2H-1-benzopyran-3-yl)dithio]-2H-1-benzopyran-2-one (X), yield = 0.19 g (30 %), colourless crystals, m.p. = 162—163 °C (chloroform). For $C_{25}H_{19}NO_4S_2$ (M_r = 461.532) w_i(calc.):65.06 % C, 4.15 % H, 3.04 % N, 13.89 % S; w_i(found): 64.89 % C, 4.10 % H, 2.93 % N, 13.76 % S. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3360 (NH), 3030 (H_{aryl}), 2930 (H_{aliph}), 1707, 1695 (C═O), 1650, 1600, 1580 (C═C), 750, 740, 690.

In case of *IVa* with dicyclohexylamine, elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 2:1) gave *3-sulfanyl-2H-1-benzopyran-2-one* (*V*, X = H), yield = 0.072 g (30 %), colourless crystals, m.p. = 110—112 °C (Ref. [19] gives m.p. = 110 °C). IR spectrum, $\tilde{\nu}/cm^{-1}$: 3070 (H_{aryl}), 2550 (SH), 1705 (C═O), 1540 (C═C), 750 ($\delta_{5\text{-H}}$). ^{1}H NMR spectrum (DMSO-d_6), δ: 3.58 (s, 1, SH, exchangeable), 7.33 (dd, H-5, J = 7.4 Hz), 7.38—7.49 (m, H-6), 7.52—7.66 (m, H-7), 7.75 (dd, H-8, J = 7.4 Hz and 1.4 Hz), 8.19 (s, H-4). EI MS, m/z (I_r/%): 180 ($M^{+\bullet}$ + 2, 3), 178 ($M^{+\bullet}$, 40). The above reactions were carried out under reflux for 6 h and the obtained solid after evaporation of dioxane under reduced pressure was chromatographed over silica gel.

In case of *IVa* and benzylamine, elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 1:1) afforded *VIb*. Elution with ether gave *VIa*, yield = 0.024 g (7 %), which was identified by comparison with an authentic sample (m.p., mixed m.p., and TLC).

3,4-Bisbenzylamino-2H-1-benzopyran-2-one (VIb), yield = 0.17 g (35 %), colourless crystals, m.p. = 125—127 °C (ethanol). For $C_{23}H_{20}N_2O_2$ (M_r = 356.41): w_i(calc.): 77.50 % C, 5.66 % H, 7.87 % N; w_i(found): 77.35 % C, 5.57 % H, 7.94 % N. IR spectrum, $\tilde{\nu}/cm^{-1}$: 3420 and 3260 (NH), 3070 and 3040 (H_{aryl}), 2940 (H_{aliph}), 1705 and 1680 (C═O), 1530 (C═C), 762, 740, 700. ^{1}H NMR spectrum ($CDCl_3$), δ: 4.53 (d, 2, N—CH_2, J = 6.0 Hz), 4.84 (d, 2, N—CH_2, J = 5.8 Hz), 7.09—7.50 (m, 14H_{arom}), 8.47 and 9.65 (each br s, NH, exchangeable).

In case of *IVa* and dicyclohexylamine, elution with a mixture of light petroleum(b.p. = 60—80 °C)—ether (φ_r = 2:1) afforded *V* (X = H) identical in all respects (m.p., mixed m.p., and TLC) with an authentic sample.

The Conversion of *VIa* into *VIb*

A mixture of *VIa* (0.5 mmol) and benzylamine (0.6 mmol) in dioxane (8 cm^3) was refluxed for 2 h. Dioxane was evaporated and the residual oil was treated with methanol (2 cm^3) to give *VIb* which was recrystallized from ethanol and identified by TLC and m.p. comparison with an authentic sample prepared from *IVa* and benzylamine in refluxing dioxane.

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