Synthesis, Reactions, and Tautomerism of Ketene N,S-Acetals with Benzothiazoline Ring

Zhi-Tang Huang* and Xian Shi

Institute of Chemistry, Academia Sinica,
Beijing, PR of China

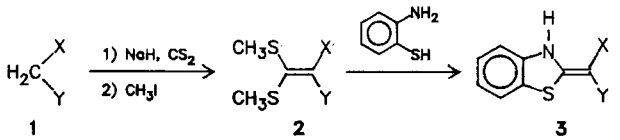
Received August 9, 1989

Key Words: Ketene N,S-acetals / 1*H*-Pyrido[2,1-*b*]benzothiazole, derivatives

Ketene dithioacetals **2** react with 2-aminothiophenol to afford the corresponding substituted 2(3*H*)-methylenebenzothiazoles **3**. Some compounds **3** react with α,β-unsaturated esters to give 1*H*-pyrido[2,1-*b*]benzothiazole derivatives **4** and **5** by an electrophilic addition and cyclocondensation sequence.

Heterocyclic ketene aminals are versatile starting materials for the synthesis of a wide variety of fused heterocycles. While the synthesis and reactions of heterocyclic ketene aminals have attracted much attention[1-18], the synthesis and reactions of their sulfur analogues, heterocyclic ketene N,S-acetals, have only been studied in a few cases[3-7,19-22]. Recently, the preparation and some reactions of ketene N,S-acetals with a thiazolidine ring have been reported by us[23]. Here, we describe the synthesis and some reactions of ketene N,S-acetals with a benzothiazoline ring. In addition, we also discuss the tautomerism problem of some benzothiazoline ring-substituted ketene N,S-acetals.

Ketene N,S-acetals **3a–l** are obtained by the reaction of ketene dithioacetals **2a–l** with 2-aminothiophenol. The starting materials **2** are prepared by the reaction of active methylene compounds **1** with sodium hydride and carbon disulfide, followed by methyl iodide treatment in a one-pot reaction. When both X and Y are electron-withdrawing groups, **3a–g** may be obtained by reaction of **2a–g** with 2-aminothiophenol in boiling absolute ethanol, in good to excellent yields. In the case of **2h–l**, where only one electron-withdrawing group is present, **3h–l** cannot be obtained by this method. In these cases, **3h–l** may be prepared from **2h–l** with 2-aminothiophenol in the presence of sodium in boiling dioxan, in order to increase the nucleophilicity of the 2-aminothiophenol. The reaction time is dependent on the structure of **2**; in general, the stronger the electron-withdrawing effect of X and Y, the more rapid the reaction.



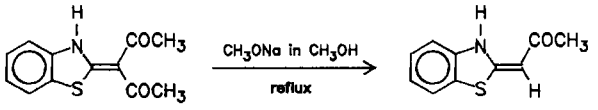
1 2 3

1-3	a	b	c	d	e	f
X	CH_3CO	CH_3CO	CH_3CO	C_2H_5OCO	CN	CH_3OCO
Y	CH_3CO	CH_3OCO	C_2H_5OCO	C_2H_5OCO	CN	CN

1-3	g	h	i	j	k
X	C_2H_5OCO	C_6H_5	C_6H_5CO	4-$CH_3C_6H_4CO$	4-$CH_3OC_6H_4CO$
Y	CN	CN	H	H	H

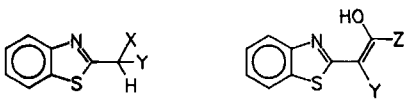
1-3	l	m
X	4-ClC_6H_4CO	CH_3CO
Y	H	H

Ketene N,S-acetal **3m** is synthesized by the reaction of **3a** with sodium methoxide by nucleophilic attack at the acetyl groups.



3a 3m

The constitutions of the products **3** are confirmed by elemental analyses and mass spectra. The ^{1}H- and ^{13}C-NMR data are listed in Tables 1 and 2, respectively. Only one set of signals was observed in the ^{1}H- and ^{13}C-NMR spectra of **3a–h**, indicating that these compounds are not a mixture. The absence of a methine proton signal and the presence of a nitrogen proton signal in the ^{1}H-NMR spectra of these products exclude the structure of tautomer **A**. The presence of a ketonic or ester carbonyl carbon signal in the ^{13}C-NMR spectra of these products also excludes the structure of tautomer **B**.

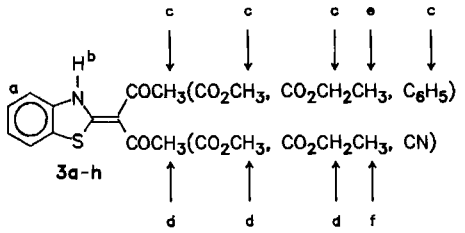


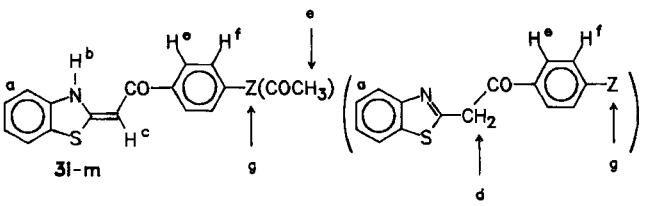
A B

However, in the ^{1}H-NMR spectra of ketene N,S-acetals **3i–m**, in addition to the signals of the nitrogen proton and the ethylenic proton, a methylene proton signal is also observed. This indicates that a tautomeric equilibrium between enamine form **3i–m** and imine form **3i′–m′** exists in these compounds. This fact is confirmed by the ^{13}C-NMR spectra,

  0009–2940/90/0303–0541 $ 02.50/0

Table 1. ^{1}H-NMR data of **3** in [D$_6$]DMSO with TMS as internal standard

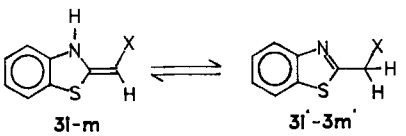




	H^a	H^b	H^c	H^d	H^e	H^f	H^g
3a[a]	7.25–7.83 (m)	15.17 (s)		2.55 (s)			
3b[a]	7.17–7.69 (m)	13.75 (s)	2.53 (s)	3.83 (s)			
3c[a]	7.14–7.67 (m)	13.97 (s)	2.56 (s)	4.28 (q)		1.38 (t)	
3d[a]	7.15–7.62 (m)	13.20 (s)	4.25 (q)		1.35 (t)		
3e	7.20–7.94 (m)	9.30 (s)					
3f	7.17–7.90 (m)	13.00 (s)	3.70 (s)				
3g	7.10–7.90 (m)	13.03 (s)	4.20 (q)		1.29 (t)		
3h	7.00–8.17 (m)	9.00 (s)	7.00–8.17 (m)				
3i	7.40–8.00 (m)	12.33 (s)	6.80 (s)	5.02 (s)		7.40–8.00 (m)	
3j	7.28–8.07 (m)	12.35 (s)	6.76 (s)	4.97 (s)	7.81 (d)	7.26 (d)	2.34 (s)
3k	7.10–8.13 (m)	12.40 (s)	6.71 (s)	4.93 (s)	7.85 (d)	7.02 (d)	3.80 (s)
3l	7.25–7.85 (m)	12.58 (s)	6.79 (s)	5.05 (s)	7.88 (d)	7.53 (d)	
3m	7.25–8.12 (m)	12.07 (s)	5.94 (s)	4.41 (s)	2.04 (s), 2.27 (s)		

[a] In $CDCl_3$.

and is in contrast to the thiazolidine ring-substituted ketene N,S-acetals[23], in which only the enamine form exists. This difference may be due to conjugation of the –N=C bond with the benzene ring in the imine form of benzothiazoline substituted ketene N,S-acetals. The ratios of **3i–m** to **3i′–m′**, estimated roughly from the ^{1}H-NMR spectra, are listed in Table 3.

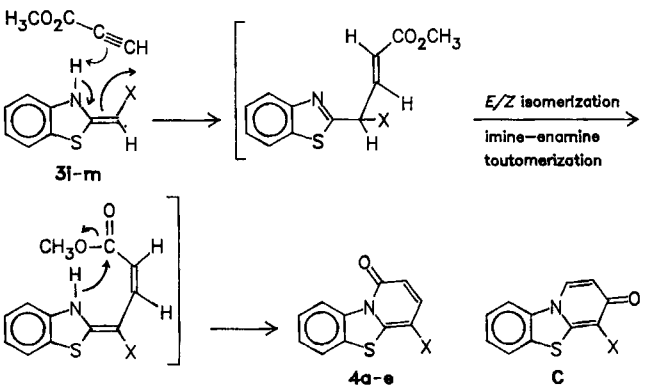


It is observed that the electron-withdrawing effect of substituents in the aroyl group favors the enamine form, and increase of the polarity of the solvent is also favorable for the enamine form.

The stereochemical problem of distinguishing the *E* and *Z* isomers of **3** is solved by intramolecular hydrogen bond formation. In general, compounds with intramolecular hydrogen bonds are more stable. Intramolecular hydrogen bond formation is proven by the downfield shift (δ = 12.07–15.17, see Table 1) of the nitrogen proton signal in the ^{1}H-NMR spectra, and it suggests that **3b** and **c** are *Z* configurated, whereas **3f,g, 3i–m** prefer the *E* configuration. By this method, the stereochemical problem of **3h** is still unsolved.

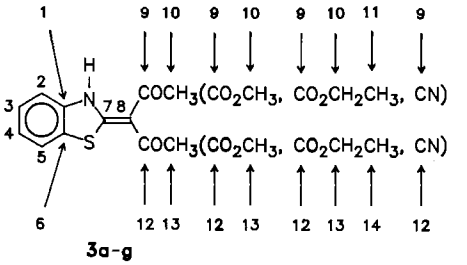
From the spectroscopic data listed in Tables 1 and 2 and in the experimental part, a bathochromic shift of the carbonyl and double bond absorptions in the IR spectra and upfield shift of the carbonyl carbon signal in the ^{13}C-NMR spectra are observed, due to conjugation of the carbonyl group with the double bond and nitrogen and sulfur atoms. The upfield shift of the C-8 signal indicates that this atom possesses higher electron density, and electrophilic attack may be expected to occur at this carbon atom. Recently, we have reported the reaction of thiazolidine ring substituted ketene N,S-acetals with α,β-unsaturated esters to give thiazolo[3,2-*a*]pyridin-5-one derivatives by an electrophilic addition and cyclocondensation sequence[23]. Similarly, the reactions of **3i–m** with α,β-unsaturated esters provide 1*H*-pyrido[2,1-*b*]benzothiazole derivatives.

3i–m react smoothly with methyl propiolate in boiling absolute ethanol to give crystalline products in good to excellent yields. The elemental analyses and mass spectra indicate that an addition of **3i–m** to methyl propiolate takes place, which is accompanied, however, by a condensation reaction with elimination of one mole of methanol. The downfield shift of H^a signals (^{1}H NMR) and amide carbonyl carbon signal (^{13}C NMR) prove the structure of the products to be **4a–e** and exclude their isomer **C**. The reaction mech-



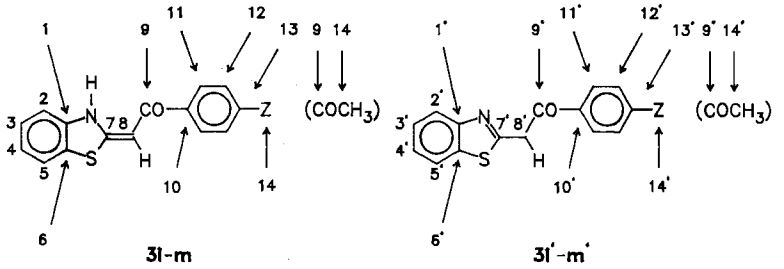
4, 5	a	b	c	d	e
X	C_6H_5CO	4-$CH_3C_6H_4CO$	4-$CH_3OC_6H_4CO$	4-ClC_6H_4CO	CH_3CO

Table 2. ^{13}C-NMR data of **3** in [D_6]DMSO with TMS as internal standard



3a–g

	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	C-11	C-12	C-13	C-14
3a	135.3	114.9	126.8	124.1	121.9	130.9	172.1	94.8	192.6	31.0		192.6	31.0	
3b[a]	138.3	113.7	126.9	124.0	121.6	128.6	169.2	97.5	193.2	30.0		168.5	51.3	
3c[a]	138.3	113.5	126.7	123.9	121.5	128.5	169.0	97.6	193.1	30.2		168.0	60.3	14.2
3d	138.7	113.7	126.3	123.0	122.5	126.8	168.3	98.9	166.8	59.3	13.9	166.8	59.3	13.9
3e	141.1	113.8	127.6	124.0	122.7	124.9	170.8	98.8	115.6			115.6		
3f	139.5	113.7	127.1	123.6	122.2	128.5	168.2	98.8	166.0	51.4		114.1		
3g	139.4	113.7	127.1	123.5	122.1	128.6	168.2	94.7	165.9	60.0	14.5	117.0		



3l–m **3l'–m'**

	C-1–C-6 C-1′–C-6′				C-10–C-13 C-10′–C-13′			C-7	C-8	C-9	C-14 C-14′	C-7′	C-8′	C-9′
3i[a]	139.2	138.7	135.8	134.4	133.8	131.3	130.3	167.9	90.8	179.5		165.5	43.7	192.4
	128.5	126.4	125.9	125.0	124.7	124.1	121.4							
	119.9	119.8												
3j[a]	144.8	140.6	136.0	133.3	132.0	129.5	129.2	168.2	90.3	180.2	21.6	165.7	43.8	193.6
	128.8	128.4	128.3	126.4	125.9	125.4	125.0				21.5			
	124.6	124.4	124.0	122.9	121.5	119.8								
3k[a]	163.9	161.5	135.8	133.3	132.4	131.8	130.9	168.1	89.3	178.8	55.4	166.0	43.4	192.4
	127.5	126.3	126.1	125.8	124.9	123.7	122.7				55.2			
	121.4	121.2	119.4	114.3	113.9	113.3								
3l[a]	139.6	138.0	136.0	133.2	131.2	130.0	129.7	167.7	90.9	179.6		164.9	44.0	192.8
	129.4	128.8	128.1	127.8	127.7	127.3	126.4							
	124.8	124.3	122.8	121.4	119.9	119.8								
3m[a]	139.4	135.6	126.0	125.4	125.0	123.7	123.4	169.5	92.4	193.2	29.7	162.6	48.2	202.0
	122.7	121.6	121.4	120.9	119.4						22.0			

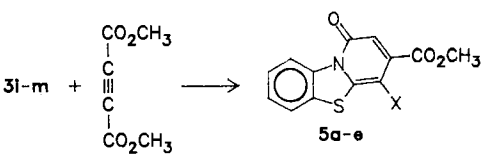
[a] In $CDCl_3$.

Tab. 3. The ratios of **3i–m** to **3i′–m′**

	3i/3i′	**3j/3j′**	**3k/3k′**	**3l/3l′**	**3m/3m′**
In [D_6]DMSO	82/18	78/22	65/35	92/8	46/54
In $CDCl_3$	67/33	53/47	33/67	81/19	30/70

anism probably resembles the reaction of ketene aminals with propiolate[15].

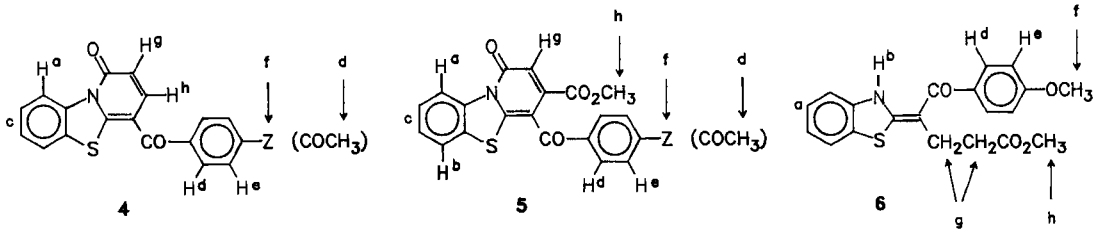
3i–m react easily with dimethyl acetylenedicarboxylate to give crystalline products in excellent yields. The structures of these products are similar to **4** and were confirmed to be **5a–e** by spectroscopic data and elemental analyses.



5a–e

3i–m react sluggishly with methyl acrylate, only the more reactive 4-methoxybenzoyl-substituted ketene N,S-acetal **3k** can react with methyl acrylate, and an addition

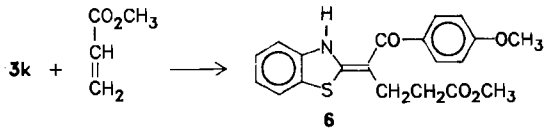
Table 4. ^{1}H-NMR data of **4**, **5**, and **6** in $CDCl_3$ with TMS as internal standard



	H^a	H^b	H^c	H^d	H^e	H^f	H^g	H^h
4a	9.19–9.36 (m)			7.41–7.71 (m)			6.38 (d)	7.84 (d)
4b	9.19–9.35 (m)		7.13–7.48 (m)	7.61 (d)	7.21 (d)	2.40 (s)	6.36 (d)	7.84 (d)
4c	9.15–9.31 (m)		7.34–7.70 (m)	7.55 (d)	6.87 (d)	3.81 (s)	6.35 (d)	7.83 (d)
4d	9.19–9.35 (m)			7.29–7.75 (m)			6.37 (d)	7.77 (d)
4e	9.14–9.30 (m)		7.35–7.75 (m)	2.53 (s)			6.40 (d)	7.89 (d)
5a[a]	9.04–9.18 (m)	8.11–8.26 (m)		7.60–7.78 (m)			6.77 (s)	3.20 (s)
5b[a]	9.02–9.19 (m)	7.96–8.16 (m)		7.16–7.63 (m)		2.35 (s)	6.59 (s)	3.18 (s)
5c[a]	9.10–9.27 (m)	8.03–8.18 (m)	7.50–7.73 (m)	7.60 (d)	7.01 (d)	3.80 (s)	6.64 (s)	3.27 (s)
5d[a]	8.97–9.13 (m)	7.97–8.13 (m)		7.44–7.60 (m)			6.59 (s)	3.23 (s)
5e	9.12–9.29 (m)	7.39–7.82 (m)		2.42 (s)			6.52 (s)	3.95 (s)
6	7.22–7.88 (m)	5.31 (s)		8.08 (d)	6.87 (d)	3.80 (s)	2.20–2.67 (m)	3.60 (s)

[a] In $[D_6]$DMSO.

product with the assumed structure **6** is isolated in poor yield.



The ^{1}H- and ^{13}C-NMR data of **4**, **5** and **6** are listed in Tables 4 and 5, respectively.

This work was supported by the *National Nature Science Foundation of China.*

Experimental

Melting points are not corrected. – IR: Perkin-Elmer 782. – UV: Hitachi 340. – ^{1}H NMR: Varian EM-360L. – ^{13}C NMR: Jeol FX-100. – MS: AEI MS-50. – Elemental analyses: Analytical Laboratory of the Institute.

2(3H)-(Diacetylmethylene)benzothiazole (**3a**): A mixture of 0.82 g (4 mmol) of **2a** and 0.51 g (4.1 mmol) of 2-aminothiophenol in 25 ml of absolute ethanol was heated for 16 h at reflux. On cooling, the product crystallized; 0.80 g (86%) of **3a** was obtained by recrystallization from absolute ethanol, m.p. 158.5–159.5°C. – IR (KBr): $\tilde{\nu}$ = 3140 cm^{-1} (NH), 1595 (C=O), 1545, 1490. – UV (ethanol): λ_{max} (lg ε) = 238 nm (3.65), 260 (3.79), 272 (3.77), 340 (4.45). – MS: *m/z* = 233 [M^+].

$C_{12}H_{11}NO_2S$ (233.3) Calcd. C 61.78 H 4.75 N 6.00
Found C 61.52 H 4.60 N 5.89

2(3H)-[(Z)Acetyl(methoxycarbonyl)methylene]benzothiazole (**3b**): Preparation as described for **3a**; 0.80 g (80%) of **3b**, m.p. 155–156°C (ethanol), from 0.88 g (4 mmol) of **2b** and 0.51 g (4.1 mmol) of 2-aminothiophenol. – IR (KBr): $\tilde{\nu}$ = 3180 cm^{-1} (NH), 1648 (ester C=O), 1560 (C=O), 1500. – UV (ethanol): λ_{max} (lgε) = 240 nm (3.90), 252 (sh), 338 (4.52). – MS: *m/z* = 249 [M^+].

$C_{12}H_{11}NO_3S$ (249.3) Calcd. C 57.81 H 4.45 N 5.62
Found C 57.59 H 4.42 N 5.72

2(3H)-[(Z)Acetyl(ethoxycarbonyl)methylene]benzothiazole (**3c**): Preparation as described for **3a**; 0.83 g (79%) of **3c**, m.p. 128.5–129.5°C (ethanol), from 0.94 g (4 mmol) of **2c** and 0.51 g (4.1 mmol) of 2-aminothiophenol. – IR (KBr): $\tilde{\nu}$ = 3175 cm^{-1} (NH), 1640 (ester C=O), 1555 (C=O), 1500. – UV (ethanol): λ_{max} (lgε) = 240 nm (3.91), 252 (sh), 339 (4.67). – MS: *m/z* = 263 [M^+].

$C_{13}H_{13}NO_3S$ (263.3) Calcd. C 59.30 H 4.98 N 5.32
Found C 59.30 H 4.88 N 5.22

2(3H)-[Bis(ethoxycarbonyl)methylene]benzothiazole (**3d**): Preparation as described for **3a**; 0.92 g (78%) of **3d**, m.p. 137.5–138.5°C (ethanol), from 1.06 g (4 mmol) of **2d** and 0.51 g (4.1 mmol) of 2-aminothiophenol. – IR (KBr): $\tilde{\nu}$ = 3170 cm^{-1} (NH), 1634 (ester C=O), 1605, 1585, 1508. – UV (ethanol): λ_{max} (lgε) = 234 nm (4.12), 330 (4.65). – MS: *m/z* = 293 [M^+].

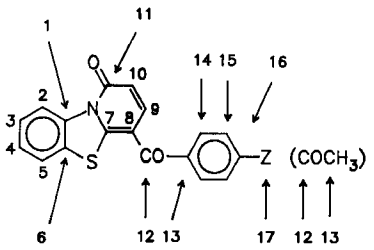
$C_{14}H_{15}NO_4S$ (293.3) Calcd. C 57.32 H 5.15 N 4.78
Found C 57.41 H 5.10 N 4.64

2(3H)-(Dicyanomethylene)benzothiazole (**3e**): Preparation as described for **3a**; 0.72 g (90%) of **3e**, m.p. 289.5–290.5°C (dimethyl sulfoxide), from 0.68 g (4 mmol) of **2e** and 0.51 g (4.1 mmol) of 2-aminothiophenol (reflux, 6 h). – IR (KBr): $\tilde{\nu}$ = 3160 cm^{-1} (NH), 2215 (CN), 2200 (CN), 1600, 1565. – UV (ethanol): λ_{max} (lgε) = 228 nm (3.89), 327 (4.79). – MS: *m/z* = 199 [M^+].

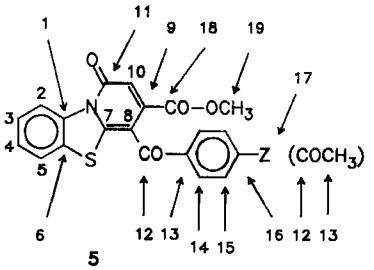
$C_{10}H_5N_3S$ (199.2) Calcd. C 60.28 H 2.53 N 21.09
Found C 60.25 H 2.50 N 21.18

2(3H)-[(E)-Cyano(methoxycarbonyl)methylene]benzothiazole (**3f**): Preparation as described for **3a**; 0.82 g (88%) of **3f**, m.p. 245–246°C (dimethyl sulfoxide), from 0.81 g (4 mmol) of **2f** and 0.51 g (4.1 mmol) of 2-aminothiophenol (reflux, 10 h). – IR (KBr): $\tilde{\nu}$ = 3160 cm^{-1} (NH), 2205 (CN), 1680 (ester C=O), 1546. – UV

Table 5. ^{13}C-NMR data of **4** and **5** in $CDCl_3$ with TMS as internal standard



4



5

	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
4a	137.9	127.1	128.5	121.7	120.4	129.5	154.7	109.7	139.3	111.6
4b	137.1	126.8	127.0	121.7	120.2	129.4	154.2	110.0	139.4	111.6
4c	137.4	127.0	127.1	121.7	120.4	128.9	154.7	110.2	139.4	111.6
4d	136.2	126.6	127.3	121.5	120.4	129.0	152.5	107.9	139.1	111.9
4e	136.6	126.7	126.9	121.5	120.1	128.7	156.6	110.5	137.1	111.9
5a[a]	138.4	126.4	126.9	122.0	118.8	130.0	154.8	105.3	140.8	112.6
5b[a]	136.6	126.4	126.9	122.0	118.6	127.3	156.7	108.2	140.7	112.6
5c[a]	136.6	126.2	126.8	121.9	118.8	127.3	159.2	108.2	140.5	112.5
5d[a]	137.1	126.8	128.0	121.9	118.8	127.5	157.0	112.6	140.8	112.8
5e	136.7	127.0	127.3	121.5	120.2	129.2	158.5	112.3	141.8	112.6

	C-11	C-12	C-13	C-14	C-15	C-16	C-17	C-18	C-19
4a	162.0	190.7	137.3	128.7	128.5	131.4			
4b	162.1	190.4	134.9	129.1	128.9	142.1	21.5		
4c	162.2	190.0	130.3	131.1	114.0	162.7	55.5		
4d	162.2	190.0	134.3	130.1	128.9	139.9			
4e	162.0	192.4	25.5						
5a[a]	159.9	190.9	136.5	128.0	127.5	131.7		164.9	51.7
5b[a]	159.8	190.5	135.0	128.6	127.7	142.3	20.6	165.0	51.8
5c[a]	160.5	189.4	130.8	130.0	113.6	162.5	55.2	164.9	51.9
5d[a]	159.9	190.7	136.4	129.2	128.1	138.4		164.8	51.8
5e	160.7	192.4	28.0					167.6	53.3

[a] In [D$_6$]DMSO.

(ethanol): λ_{max} (lgε) = 230 nm (4.01), 330 (4.62). – MS: *m/z* = 232 [M$^+$].

$C_{11}H_8N_2O_2S$ (232.3) Calcd. C 56.88 H 3.47 N 12.06
Found C 56.93 H 3.34 N 12.09

2(3H)-[(E)-Cyano(ethoxycarbonyl)methylene]benzothiazole (**3g**): Preparation as described for **3a**; 0.85 g (86%) of **3g**, m.p. 219.5–220.5°C (dimethyl sulfoxide), from 0.87 g (4 mmol) of **2g** and 0.51 g (4.1 mmol) of 2-aminothiophenol (reflux, 10 h). – IR (KBr): $\tilde{\nu}$ = 3160 cm^{-1} (NH), 1660 (ester C=O), 1534. – UV (ethanol): λ_{max} (lgε) = 230 nm (3.97), 331 (4.61). – MS: *m/z* = 246 [M$^+$].

$C_{12}H_{10}N_2O_2S$ (246.3) Calcd. C 58.52 H 4.09 N 11.38
Found C 58.54 H 3.97 N 11.15

2(3H)-[Cyano(phenyl)methylene]benzothiazole (**3h**): 0.02 g of sodium was added to a solution of 0.51 g (4.1 mmol) of 2-aminothiophenol in 30 ml of dry dioxan. When the sodium had reacted, 0.89 g (4 mmol) of **2h** was added, and the mixture was heated for 26 h at reflux. After removal of the solvent, the crude product was washed with ca. 5 ml of ethanol; 0.76 g (76%) of **3h** was obtained by recrystallization from ethyl acetate, m.p. 107.5–108.5°C. – IR (KBr): $\tilde{\nu}$ = 3165 cm^{-1} (NH), 2175 (CN), 1595, 1575. – UV (ethanol): λ_{max} (lgε) = 252 nm (3.60), 348 (3.66). – MS: *m/z* = 250 [M$^+$].

$C_{15}H_{10}N_2S$ (250.3) Calcd. C 71.97 H 4.03 N 11.19
Found C 71.43 H 4.00 N 11.06

2(3H)-[(E)-Benzoylmethylene]benzothiazole (**3i**): Preparation as described for **3h**; 0.88 g (87%) of **3i**, m.p. 113–114°C (ethyl acetate), from 0.90 g (4 mmol) of **2i**, 0.51 g (4.1 mmol) of 2-aminothiophenol, and 0.02 g of sodium (reflux, 22 h). – IR (KBr): $\tilde{\nu}$ = 3220 cm^{-1} (NH), 1605 (C=O), 1565, 1490. – UV (ethanol): λ_{max} (lgε) = 248 nm (3.91), 380 (3.74). – MS: *m/z* = 253 [M$^+$].

$C_{15}H_{11}NOS$ (253.3) Calcd. C 71.12 H 4.38 N 5.53
Found C 70.99 H 4.47 N 5.54

2(3H)-[(E)-(4-Methylbenzoyl)methylene]benzothiazole (**3j**): Preparation as described for **3h**; 0.88 g (82%) of **3j**, m.p. 132.5 to 133.5°C (ethyl acetate), from 0.95 g (4 mmol) of **2j**, 0.51 g (4.1 mmol) of 2-aminothiophenol and 0.02 g of sodium (reflux, 24 h). – IR (KBr): $\tilde{\nu}$ = 3320 cm^{-1} (NH), 1675, 1600 (C=O), 1565, 1490. – UV (ethanol): λ_{max} (lgε) = 256 nm (4.07), 378 (4.53). – MS: *m/z* = 267 [M$^+$].

$C_{16}H_{13}NOS$ (267.3) Calcd. C 71.88 H 4.90 N 5.24
Found C 71.93 H 4.95 N 5.20

2(3H)-[(E)-(4-Methoxybenzoyl)methylene]benzothiazole (**3k**): Preparation as described for **3h**; 0.85 g (75%) of **3k**, m.p. 117–118°C (ethyl acetate), from 1.02 g (4 mmol) of **2k**, 0.51 g (4.1 mmol) of 2-aminothiophenol, and 0.02 g of sodium (reflux, 30 h). – IR (KBr): $\tilde{\nu}$ = 3300 cm^{-1} (NH), 1615 (C=O), 1600, 1507, 1470. – UV (ethanol): λ_{max} (lgε) = 272 nm (3.93), 378 (4.21). – MS: *m/z* = 283 [M$^+$].

$C_{16}H_{13}NO_2S$ (283.3) Calcd. C 67.82 H 4.62 N 4.94
Found C 67.75 H 4.76 N 4.94

2(3H)-[(E)-(4-Chlorobenzoyl)methylene]benzothiazole (**3l**): Preparation as described for **3h**; 1.04 g (90%) of **3l**, m.p. 140.5–141.5°C (ethyl acetate), from 1.04 g (4 mmol) of **2l**, 0.51 g (4.1 mmol) of 2-aminothiophenol, and 0.02 g of sodium (reflux, 19 h). – IR (KBr): $\tilde{\nu}$ = 3300 cm^{-1} (NH), 1613 (C=O), 1582, 1560, 1485. – UV (ethanol): λ_{max} (lgε) = 251 nm (4.05), 384 (4.65). – MS: *m/z* = 287 [M$^+$].

$C_{15}H_{10}ClNOS$ (287.8) Calcd. C 62.61 H 3.50 N 4.87
Found C 62.70 H 3.73 N 4.70

2(3H)-[(E)-Acetylmethylene]benzothiazole (**3m**): A mixture of 2.33 g (10 mmol) of **3a** and sodium methoxide (1.00 g of sodium in 30 ml of methanol) was heated for 4 h at reflux. 20 ml of water was then added. The crude product precipitated; 1.79 g (94%) of **3m** was obtained after recrystallization from absolute ethanol, m.p. 114–115°C. – IR (KBr): $\tilde{\nu}$ = 3115 cm^{-1} (NH), 1605 (C=O), 1585, 1510. – UV (ethanol): λ_{max} (lgε) = 250 nm (sh), 352 (3.91). – MS: *m/z* = 191 [M$^+$].

$C_{10}H_9NOS$ (191.2) Calcd. C 62.80 H 4.74 N 7.32
Found C 62.94 H 4.84 N 7.34

4-Benzoyl-1H-pyrido[2,1-b]benzothiazol-1-one (**4a**): A mixture of 0.51 g (2 mmol) of **3i** and 0.18 g (2.1 mmol) of methyl propiolate in 20 ml of absolute ethanol was heated for 35 h at reflux. After partial removal of the solvent, the product crystallized; 0.48 g (79%)

of **4a** was obtained after recrystallization from dimethyl sulfoxide, m.p. 238–239°C. – IR (KBr): $\tilde{\nu}$ = 1662 cm^{-1} (amide C=O), 1605 (C=O), 1553. – UV (ethanol): λ_{max} (lgε) = 246 nm (4.02), 330 (4.05), 368 (4.17). – MS: *m/z* = 305 [M^+].

$C_{18}H_{11}NO_2S$ (305.3) Calcd. C 70.80 H 3.63 N 4.59
Found C 70.89 H 3.79 N 4.41

4-(4-Methylbenzoyl)-1H-pyrido[2,1-b]benzothiazol-1-one (**4b**): Preparation as described for **4a**; 0.52 g (82%) of **4b**, m.p. 240.5–241.5°C (dimethyl sulfoxide), from 0.53 g (2 mmol) of **3j** and 0.18 g (2.1 mmol) of methyl propiolate (reflux, 32 h). – IR (KBr): $\tilde{\nu}$ = 1680 cm^{-1} (amide C=O), 1610 (C=O), 1600, 1550. – UV (ethanol): λ_{max} (lgε) = 260 nm (4.06), 332 (4.12), 368 (4.23). – MS: *m/z* = 319 [M^+].

$C_{19}H_{13}NO_2S$ (319.4) Calcd. C 71.45 H 4.10 N 4.39
Found C 71.57 H 4.07 N 4.41

4-(4-Methoxybenzoyl)-1H-pyrido[2,1-b]benzothiazol-1-one (**4c**): Preparation as described for **4a**; 0.58 g (87%) of **4c**, m.p. 226–227°C (dimethyl sulfoxide), from 0.57 g (2 mmol) of **3k** and 0.18 g (2.1 mmol) of methyl propiolate (reflux, 30 h). – IR (KBr): $\tilde{\nu}$ = 1678 cm^{-1} (amide C=O), 1600 (C=O), 1552. – UV (ethanol): λ_{max} (lgε) = 265 nm (3.85), 333 (4.12), 368 (4.24). – MS: *m/z* = 335 [M^+].

$C_{19}H_{13}NO_3S$ (335.4) Calcd. C 68.04 H 3.91 N 4.18
Found C 67.82 H 3.84 N 4.10

4-(4-Chlorobenzoyl)-1H-pyrido[2,1-b]benzothiazol-1-one (**4d**): Preparation as described for **4a**, 0.48 g (71%) of **4d**; m.p. 246.5–247.5°C (dimethyl sulfoxide), from 0.58 g (2 mmol) of **3l** and 0.18 g (2.1 mmol) of methyl propiolate (reflux, 40 h). – IR (KBr): $\tilde{\nu}$ = 1690 cm^{-1} (amide C=O), 1610 (C=O), 1582, 1560, 1550. – UV (ethanol): λ_{max} (lgε) = 256 nm (4.04), 333 (4.04), 368 (4.16). – MS: *m/z* = 339 [M^+].

$C_{18}H_{10}ClNO_2S$ (339.8) Calcd. C 63.62 H 2.97 N 4.12
Found C 63.49 H 2.97 N 4.10

4-Acetyl-1H-pyrido[2,1-b]benzothiazol-1-one (**4e**): Preparation as described for **4a**, 0.43 g (89%) of **4e**, m.p. 223.5–224.5°C (dimethyl sulfoxide), from 0.38 g (2 mmol) of **3m** and 0.18 g (2.1 mmol) of methyl propiolate (reflux, 28 h). – IR (KBr): $\tilde{\nu}$ = 1660 cm^{-1} (amide C=O), 1625 (C=O), 1564. – UV (ethanol): λ_{max} (lgε) = 237 nm (4.02), 318 (4.45), 349 (4.17), 362 (4.16). – MS: *m/z* = 243 [M^+].

$C_{13}H_9NO_2S$ (243.3) Calcd. C 64.18 H 3.73 N 5.76
Found C 64.45 H 3.73 N 6.03

Methyl 4-Benzoyl-1-oxo-1H-pyrido[2,1-b]benzothiazole-3-carboxylate (**5a**): A mixture of 0.51 g (2 mmol) of **3i** and 0.28 g (2 mmol) of dimethyl acetylenedicarboxylate in 25 ml of methanol was stirred at ambient temperature for 2 h, then heated for 6 h at reflux. After partial removal of the solvent the product crystallized; 0.65 g (89%) of **5a** was obtained by recrystallization from dimethyl sulfoxide, m.p. 245.5–246.5°C. – IR (KBr): $\tilde{\nu}$ = 1715 cm^{-1} (ester C=O), 1670 (amide C=O), 1615 (C=O), 1592, 1555, 1488. – UV (ethanol): λ_{max} (lgε) = 223 nm (3.97), 250 (4.12), 356 (3.93). – MS: *m/z* = 363 [M^+].

$C_{20}H_{13}NO_4S$ (363.4) Calcd. C 66.10 H 3.61 N 3.85
Found C 66.00 H 3.48 N 3.86

Methyl 4-(4-Methylbenzoyl)-1-oxo-1H-pyrido[2,1-b]benzothiazole-3-carboxylate (**5b**): Preparation as described for **5a**; 0.68 g (90%) of **5b**, m.p. 204.5–205°C (dimethyl sulfoxide), from 0.53 g (2 mmol) of **3j** and 0.28 g (2 mmol) of dimethyl acetylenedicarboxylate (reflux, 6 h). – IR (KBr): $\tilde{\nu}$ = 1712 cm^{-1} (ester C=O), 1666 (amide C=O), 1625 (C=O), 1598, 1555, 1492. – UV (ethanol): λ_{max} (lgε) = 225 nm (4.17), 255 (4.23), 352 (4.05). – MS: *m/z* = 377 [M^+].

$C_{21}H_{15}NO_4S$ (377.4) Calcd. C 66.83 H 4.01 N 3.71
Found C 66.87 H 4.17 N 3.59

Methyl 4-(4-Methoxybenzoyl)-1-oxo-1H-pyrido[2,1-b]benzothiazole-3-carboxylate (**5c**): Preparation as described for **5a**; 0.71 g (90%) of **5c**, m.p. 216–217°C (dimethyl sulfoxide), from 0.57 g (2 mmol) of **3k** and 0.28 g (2 mmol) of dimethyl acetylenedicarboxylate (reflux, 4 h). – IR (KBr): $\tilde{\nu}$ = 1715 cm^{-1} (ester C=O), 1662 (amide C=O), 1625 (C=O), 1600, 1555, 1495. – UV (ethanol): λ_{max} (lgε) = 226 nm (4.42), 247 (4.05), 279 (3.95), 348 (4.09). – MS: *m/z* = 393 [M^+].

$C_{21}H_{15}NO_5S$ (393.4) Calcd. C 64.11 H 3.84 N 3.56
Found C 64.11 H 3.79 N 3.58

Methyl 4-(4-Chlorobenzoyl)-1-oxo-1H-pyrido[2,1-b]benzothiazole-3-carboxylate (**5d**): Preparation as described for **5a**; 0.67 g (84%) of **5d**, m.p. 215–216°C (dimethyl sulfoxide), from 0.58 g (2 mmol) of **3l** and 0.28 g (2 mmol) of dimethyl acetylenedicarboxylate (reflux, 7 h). – IR (KBr): $\tilde{\nu}$ = 1720 cm^{-1} (ester C=O), 1665 (amide C=O), 1620 (C=O), 1580, 1550, 1490. – UV (ethanol): λ_{max} (lgε) = 222 nm (4.25), 255 (4.41), 357 (4.14). – MS: *m/z* = 397 [M^+].

$C_{20}H_{12}ClNO_4S$ (397.8) Calcd. C 60.38 H 3.04 N 3.52
Found C 60.30 H 3.19 N 3.49

Methyl 4-Acetyl-1-oxo-1H-pyrido[2,1-b]benzothiazole-3-carboxylate (**5e**): Preparation as described for **5a**; 0.55 g (91%) of **5e**, m.p. 205.5–206.5°C (dimethyl sulfoxide), from 0.38 g (2 mmol) of **3m** and 0.28 g (2 mmol) of dimethyl acetylenedicarboxylate (reflux, 2 h). – IR (KBr): $\tilde{\nu}$ = 1720 cm^{-1} (ester C=O), 1675 (amide C=O), 1630 (C=O), 1550, 1480. – UV (ethanol): λ_{max} (lgε) = 226 nm (3.84), 246 (3.92), 326 (4.05), 351 (3.94), 366 (3.91). – MS: *m/z* = 301 [M^+].

$C_{15}H_{11}NO_4S$ (301.3) Calcd. C 59.79 H 3.68 N 4.65
Found C 59.70 H 3.72 N 4.80

2(3H)-[(E)-1-(4-Methoxybenzoyl)-3-(methoxycarbonyl)propylidene]benzothiazole (**6**): A mixture of 1.42 g (5 mmol) of **3k** and 0.86 g (10 mmol) of methyl acrylate in 30 ml of methanol was heated for 100 h at reflux. After removal of the solvent, **6** crystallized from the viscous residue on standing for several days, yield 0.66 g (36%), m.p. 74.5–75.5°C. – IR (KBr): $\tilde{\nu}$ = 3200 cm^{-1} (NH), 1730 (ester C=O), 1670, 1600, 1570, 1510. – UV (ethanol): λ_{max} (lgε) = 228 nm (4.32), 291 (4.18). – MS: *m/z* = 369 [M^+].

$C_{20}H_{19}NO_4S$ (369.4) Calcd. C 65.02 H 5.18 N 3.79
Found C 64.69 H 5.23 N 3.35

CAS Registry Numbers

1a: 123-54-6 / **1b**: 105-45-3 / **1c**: 141-97-9 / **1d**: 105-53-3 / **1e**: 109-77-3 / **1f**: 105-34-0 / **1g**: 105-56-6 / **1h**: 140-29-4 / **1i**: 98-86-2 / **1j**: 122-00-9 / **1k**: 100-06-1 / **1l**: 99-91-2 / **1m**: 67-64-1 / **2a**: 15908-50-6 / **2b**: 29866-43-1 / **2c**: 54893-95-7 / **2d**: 55084-15-6 / **2e**: 5147-80-8 / **2f**: 3490-92-4 / **2g**: 17823-58-4 / **2h**: 29866-38-4 / **2i**: 13636-88-9 / **2j**: 41467-27-0 / **2k**: 33868-76-7 / **2l**: 41467-26-9 / **2m**: 17649-86-4 / **3a**: 123150-21-0 / **3b**: 123150-22-1 / **3c**: 123150-23-2 / **3d**: 49811-47-4 / **3e**: 4464-52-2 / **3f**: 123150-24-3 / **3g**: 123150-25-4 / **3h**: 123150-26-5 / **3i**: 123150-27-6 / **3j**: 123150-28-7 / **3k**: 123150-29-8 / **3l**: 123150-30-1 / **3m**: 123150-31-2 / **4a**: 123150-32-3 / **4b**: 123150-33-4 / **4c**: 123150-34-5 / **4d**: 123150-35-6 / **4e**: 123150-36-7 / **5a**: 123150-37-8 / **5b**: 123150-38-9 / **5c**: 123150-39-0 / **5d**: 123150-40-3 / **5e**: 123150-41-4 / **6**: 123150-42-5 / 2-aminothiophenol: 137-07-5 / methyl propiolate: 922-67-8 / dimethyl acetylenedicarboxylate: 762-42-5 / dimethyl acrylate: 96-33-3

[1] R. Gompper, H. Schaefer, *Chem. Ber.* **100** (1967) 591.
[2] S. Rajappa, R. Sreenivasan, B. G. Advani, R. H. Summervill, R. Hoffmann, *Indian J. Chem., Sect. B*, **15** (1977) 297.
[3] W.-D. Rudorf, M. Augustin, *J. Prakt. Chem.* **319** (1977) 545.
[4] M. Augustin, C. Groth, *J. Prakt. Chem.* **321** (1979) 205.
[5] M. Augustin, C. Groth, *J. Prakt. Chem.* **321** (1979) 215.
[6] M. Augustin, G. Jahreis, *J. Prakt. Chem.* **321** (1979) 699.
[7] M. Augustin, W. Doelling, *J. Prakt. Chem.* **324** (1982) 3.
[8] M. D. Nair, S. Rajappa, J. A. Desai, *Indian J. Chem., Sect. B*, **21** (1982) 1.
[9] M. D. Nair, J. A. Desai, *Indian J. Chem., Sect. B*, **21** (1982) 4.
[10] S. Rajappa, M. D. Nair, R. Sreenivasan, B. G. Advani, *Tetrahedron* **38** (1982) 1673.
[11] Z.-T. Huang, H. Wamhoff, *Chem. Ber.* **117** (1984) 622.
[12] Z.-T. Huang, H. Wamhoff, *Chem. Ber.* **117** (1984) 1856.
[13] Z.-T. Huang, H. Wamhoff, *Chem. Ber.* **117** (1984) 1926.
[14] Z.-T. Huang, L.-H. Tzai, *Chem. Ber.* **119** (1986) 2208.
[15] Z.-T. Huang, Z.-R. Liu, *Heterocycles* **24** (1986) 2247.
[16] Z.-T. Huang, X.-J. Wang, *Tetrahedron Lett.* **28** (1987) 1527.
[17] Z.-T. Huang, X.-J. Wang, *Chem. Ber.* **120** (1987) 1803.
[18] Z.-T. Huang, Z.-R. Liu, *Synthesis* **1987**, 357.
[19] R. Gompper, W. Toepfl, *Chem. Ber.* **95** (1962) 2861.
[20] K. Hirai, H. Matsuda, Y. Kishda, *Chem. Pharm. Bull.* **20** (1971) 97.
[21] N. B. Mansour, W.-D. Rudorf, M. Augustin, *Z. Chem.* **21** (1981) 69.
[22] S. Rajappa, B. G. Advani, *Proc. Indian Acad. Sci., (Chem. Sci.)* **91** (1982) 463.
[23] Z.-T. Huang, X. Shi, *Synthesis*, paper to be published.

[254/89]