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Bridgehead Nitrogen Systems. X. Cycloadditions with Thiazolium *N*-Ylides[1]

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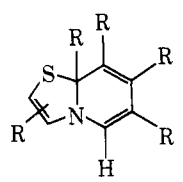
The thiazolium ylides, derived from 3-(2-aryl-2-oxoethyl)-4-methylthiazolium bromides and triethylamine, gave with dimethyl acetylenedicarboxylate and dibenzoylacetylene derivatives of the 1*H*-pyrrolo[2,1-*c*][1,4]thiazine system that were formed by rearrangement of the intermediate 5,7a-dihydropyrrolo[2,1-*b*]thiazole system. With ethyl propiolate a 1,2 adduct was formed by further reaction of a hydroxyl substituent in the thiazine system with ethyl propiolate and, in one instance, dibenzoylacetylene gave a dihydrothiazolo[3,2-*a*]azepine derivative. *N*-Phenylmaleimide also formed an adduct of the above pyrrolo[2,1-*b*]thiazole system but with phenyl isocyanate and phenyl isothiocyanate, ring closure of the initially formed 1,5-dipolar intermediate did not occur, these betaines being readily isolated.

Thiazole and its alkyl derivatives[2] undergo condensation with dimethyl acetylenedicarboxylate, giving 1:2 adducts. In contrast to the reaction of pyridine with acetylenic dienophiles, reactions of this type have recently been shown[3–5] to lead to isomeric rearrangement products such as **1**. Δ^2-Thiazolines also react[6] with acetylenic esters and an interesting variation occurs when 2-ethyl-Δ^2-thiazoline and the acetylenic ester react in the presence of 1 mol of an unsaturated compound such as methyl vinyl ketone. In this case the pyrrolo[2,1-*b*]thiazole derivative **2** was formed, with the ethylenic compound being involved in a transient quaternization of the thiazoline nitrogen atom.[7] Other 2-alkylthiazoles, converted into 3-acetonyl- and 3-phenacyl-2-alkylthiazolium salts, are cyclized with sodium acetate in aprotic solvents into pyrrolo[2,1-*b*]thiazoles.[8] Thiazole itself reacted[9] with tetracyanoethylene oxide to form the ylide **3** which, with dimethyl acetylenedicarboxylate, gave **4**. The ready quaternization of thiazoles suggested that deprotonation and subsequent 1,3-dipolar cycloaddition of the resulting ylide with dipolarophiles would be an attractive and versatile route to pyrrolo[2,1-*b*]thiazole derivatives with a variety of functional groups in the 6 and 7 positions. Our efforts to obtain these products, intermediates in the synthesis of analogues of the thieno[3,4-*c*]pyrrole system,[10] are described below.



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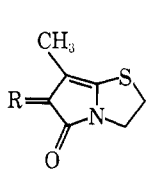

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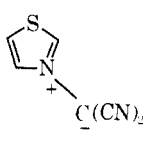

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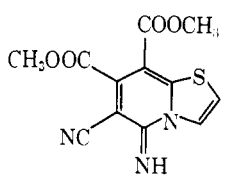

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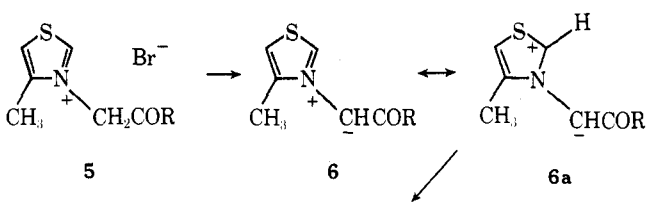
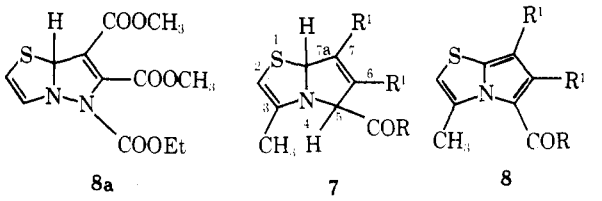
4-Methylthiazole and 2-bromoacetophenone, as well as 2,4′-dibromoacetophenone, reacted readily in boiling ethanol, giving the corresponding thiazolium salt **5** (R = Ph, *p*-BrC_6H_4, respectively). Similarly, ethyl bromoacetate in ether at room temperature gave the corresponding salt **5** (R = OEt). In the reactions described below the ylide **6** was generated in situ from the salt **5** and triethylamine in the



5 **6** **6a**



8a **7** **8**

Table I. Cycloadducts Derived from Thiazolium *N*-Ylides and Acetylenic Dipolarophiles

R	R^1	R^2	R^3	Mp °C	Yield %	Formula	Crystal Habit[a]	M^+	IR Data (KBr, cm^{-1})	UV Data $\lambda_{max}^{CH_3OH}$ nm (log ε)	NMR Data (δ) J (Hz)
Ph	OH	$COOCH_3$	$COOCH_3$	172	89	$C_{18}H_{17}NO_5S$	A[b]	359	3350 (OH) 1730, 1695 (CO)	214 (4.38)	7.66-7.22 (m, 5, aromatic), 7.40 (s, 1, H_6), 5.85 (bs, 1, H_3), 4.74 (s, 1, OH), 3.72 (s, 3, CO_2CH_3), 3.19 (s, 3, CO_2CH_3), 2.30 (bs, 3, 4-CH_3)[c]
p-BrC_6H_4	OH	$COOCH_3$	$COOCH_3$	182	61	$C_{18}H_{16}BrNO_5S$	A[d]	437	3350 (OH) 1725, 1685 (CO)		7.48 (s, 4, aromatic), 7.26 (s, 1, H_6), 5.86 (bs, 1, H_3), 4.53 (s, 1, OH), 3.80 (s, 3, CO_2CH_3), 3.36 (s, 3, CO_2CH_3), 2.35 (bs, 3, 4-CH_3)[c]
Ph	OH	COPh	COPh	165	89	$C_{28}H_{21}NO_3S$	B[b]	—	3325 (OH) 1625 (CO)	245 (4.40) 287 (4.10)	7.60-6.89 (m, 16, aromatic and H_6), 5.96 (bs, 1, H_3), 5.02 (s, 1, OH), 2.34 (bs, 3, CH_3)[c]
p-BrC_6H_4	OH	COPh	COPh	201-202	47	$C_{28}H_{20}BrNO_3S$	C[b]	—	3330 (OH) 1645 (CO)	235 (4.48) 285 (4.23)	7.77-7.0 (m, 15, aromatic and H_6), 6.23 (bs, 1, H_3), 2.42 (bs, 3, CH_3)[e]
Ph	$OCH=CHCOOC_2H_5$	H	$COOC_2H_5$	135-137	36	$C_{22}H_{23}NO_5S$	C[b]	413	1725, 1695 (CO) 1635 (C=C)	208 (4.33) 233 (4.29) 292 (4.43)	7.91-7.43 (m, 5, aromatic), 7.47 (d, 1, J = 1.5, H_6), 7.19 (d, 1, J = 1.5, H_8), 7.03 (d, 1, J = 10.0, OCH), 6.29 (bs, 1, H_3), 5.76 (d, 1, J = 10.0, vinylic), 4.29 (q, 2, J = 7.0, CH_2CH_3), 4.11 (q, 2, J = 7.0, CH_2CH_3), 2.29 (bs, 3, 4-CH_3), 1.34 (t, 3, J = 7.0, CH_2CH_3), 1.22 (t, 3, J = 7.0, CH_2CH_3)[c]
p-BrC_6H_4	$OCH=CHCOO_2H_5$	H	$COOC_2H_5$	170-172	47	$C_{22}H_{22}BrNO_5S$	A[b]	491	1725, 1720, 1685 (CO) 1635 (C=C)	293 (4.46)	7.80-7.54 (m, 4, aromatic), 7.49 (d, 1, J = 1.5, H_6), 7.14 (d, 1, J = 1.5, H_8), 7.00 (d, 1, J = 10.0, OCH), 6.26 (bs, 1, H_3), 5.77 (d, 1, J = 10.0, vinylic), 4.29 (q, 2, J = 7.0, CH_2CH_3), 4.12 (q, 2, J = 7.0, CH_2CH_3), 2.28 (bs, 3, 4-CH_3), 1.34 (t, 3, J = 7.0, CH_2CH_3), 1.23 (t, 3, J = 7.0, CH_2CH_3)[c]
Ph	$OCH=CHCOOC_2H_5$	$COOCH_3$	$COOCH_3$	152-153	37	$C_{23}H_{23}NO_7S$	D[d]	457	1720, 1695 (CO) 1635 (C=C)	238 (4.22) 290 (4.38)	7.93-7.20 (m, 5, aromatic), 7.41 (s, 1, H_6), 6.90 (d, 1, J = 10.0, OCH), 6.28 (bs, 1, H_3), 5.73 (d, 1, J = 10.0, vinylic), 4.16 (q, 2, J = 7.5, CH_2CH_3), 3.83 (s, 3, CO_2CH_3), 3.26 (s, 3, CO_2CH_3), 2.26 (bs, 3, 4-CH_3), 1.25 (t, 3, J = 7.5, CH_2CH_3)[c]
p-BrC_6H_4	$OCH=CHCOOC_2H_5$	$COOCH_3$	$COOCH_3$	141	86	$C_{23}H_{22}BrNO_7S$	E[d]	535	1740, 1720 (CO) 1640 (C=C)		7.73-7.40 (m, 4, aromatic), 7.33 (s, 1, H_6), 6.81 (d, 1, J = 10.0, OCH), 6.21 (bs, 1, H_3), 5.70 (d, 1, J = 10.0, vinylic), 4.13 (q, 2, J = 7.0, CH_2CH_3), 3.81 (s, 3, CO_2CH_3), 3.33 (s, 3, CO_2CH_3), 2.26 (bs, 3, 4-CH_3), 1.25 (t, 3, J = 7.0, CH_2CH_3)[c]
Ph	OCH=CHCOOH	H	COOH	232-234	70	$C_{18}H_{15}NO_5S$	E[b]	—	1695, 1680 (CO) 1640 (C=C)	235 (4.21) 290 (4.33)	7.86-7.55 (m, 6, aromatic and H_6), 7.41 (d, 1, J = 10.0, OCH), 6.95 (d, 1, J = 1.5, H_8), 6.70 (bs, 1, H_3), 5.81 (d, 1, J = 10.0, vinylic), 2.26 (bs, 3, 4-CH_3)[e]
p-BrC_6H_4	OCH=CHCOOH	H	COOH	265	92	$C_{18}H_{14}BrNO_5S$	F[f]	—	1675 (CO) 1640 (C=C)	260 (4.29) 287 (4.38)	7.87 (d, 1, J = 1.5, H_6), 7.80 (m, 4, aromatic), 7.48 (d, 1, J = 10.0, OCH), 7.06 (d, 1, J = 1.5, H_8), 6.77 (bs, 1, H_3), 5.88 (d, 1, J = 10.0, vinylic), 2.25 (bs, 3, 4-CH_3)[e]

[a] A = colorless needles; B = cream plates; C = plate yellow needles; D = colorless plates; E = colorless prisms; F = pale yellow prisms. Satisfactory analytical values (± 0.4% for C, H, N) were reported for all compounds in Table: Ed. [b] Crystallized from CH_3OH. [c] $CDCl_3$. [d] Crystallized from EtOH. [e] DMSO-d_6. [f] Crystallized from EtOH-H_2O.

Table II
^{13}C Chemical Shifts (ppm) for Products Obtained from 6 and Acetylenic Dipolarophiles[13]

Compd	Atom no. in 10									
	1	3	4	6	7	8	8a	C_4 CH_3	C_7 CO	C_8 CO
10 R = Ph; R^1 = $COOCH_3$	78.6	104.34	129.97	121.61	112.84	112.76	129.71	19.55	162.84	164.56
10 R = Ph; R^1 = COPh	78.98	104.52	131.26	123.46	122.54	119.31	130.00	19.38	188.23	191.50

presence of the dipolarophile, its presence being indicated by the deep-orange color of the reaction mixture.

Acetylenic Dipolarophiles. The ylide **6** (R = Ph, *p*-BrC_6H_4) readily gave 1:1 adducts with dimethyl acetylenedicarboxylate and dibenzoylacetylene in high yields expected to have structure **7** or its oxidation product **8** (R = Ph, *p*-BrC_6H_4; R^1 = $COOCH_3$). Analytical and mass spectral data (Table I) established a molecular composition for these products corresponding to **7**. However, a variety of oxidizing agents such as DDQ, tetrachloro-*o*- and -*p*-benzoquinone, $Pb(OAc)_4$, Ag_2O, and $Hg(OAc)_2$ could not convert **7** into the heteroaromatic system **8**, an oxidation that is extremely facile and often occurs on reaction work-up in related bicyclic systems.[11]

The principal ^{1}H NMR spectral characteristics of the 1:1 adduct from **6** (R = Ph) and dimethyl acetylenedicarboxylate interpreted in terms of structure **7** (R = Ph; R^1 = $COOCH_3$) were slightly broadened singlets at δ 5.85 (H_2) and 2.3 (3-CH_3) that on expansion were recognized as a quartet and a doublet, respectively ($J \simeq 1$ Hz, 100 MHz), and singlets at δ 7.4 (H_{7a}) and 4.74 (H_5), the last undergoing ready exchange with D_2O ($CDCl_3$ solution).

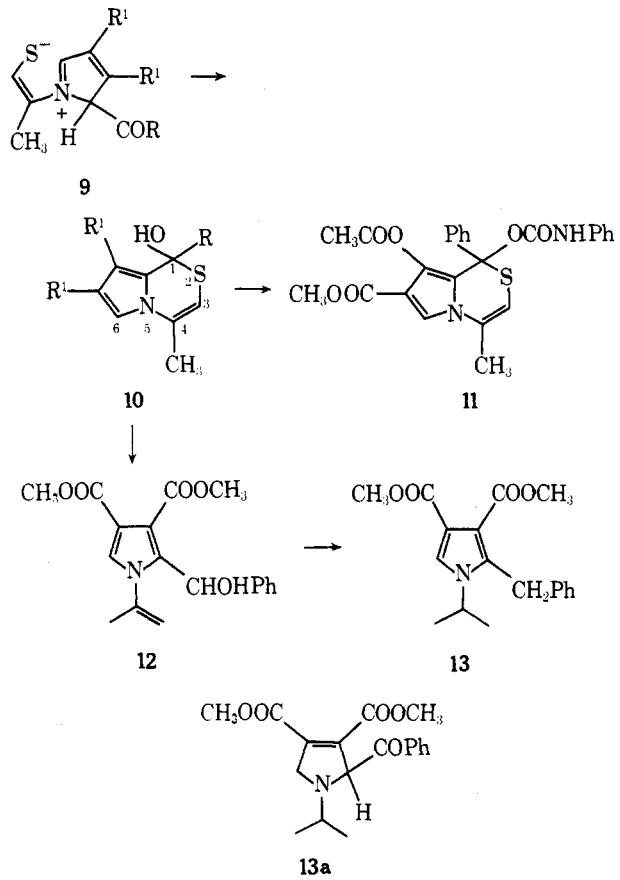
Although the chemical shift of H_2 at δ 5.85 is at higher field than the analogous proton in 2-methylthiazole itself (δ 6.83), the loss of ring current in **7** may account for this shift. Similarly, the chemical shift of H_{7a} at δ 7.4 approximates[12] that of H_{7a} in **8a** (δ 7.97).

The infrared spectrum of the product showed ν_{COOCH_3} at 1695 and 1730 cm^{-1} and a strong, broad absorption at 3350 cm^{-1} which was still retained even after extensive drying in vacuo. There was no absorption due to an aryl ketone.

These spectral and chemical properties make it very likely that the product obtained in this reaction is not the simple 1:1 adduct but rather some isomeric rearrangement product. In analogy to rearrangements observed in the thiazole[3] and benzimidazole systems,[5] the most likely bond to break in **7** is the C_{7a}–S bond. The intermediate vinyl sulfide formed, by rotation and condensation at the carbonyl group initially at C_5, would give rise to the hemithioketal **10** (R = Ph; R^1 = $COOCH_3$), the formation of the aromatic pyrrole nucleus no doubt providing driving force for the rearrangement.

Chemical evidence in support of structure **10** is twofold. Reaction of **10** with phenyl isocyanate gave the urethane **11**, characterized by ν_{NH} 3330 cm^{-1} and ν_{OCONH} 1740 cm^{-1}, and also by the disappearance in its ^{1}H NMR spectrum of the resonance at δ 4.74 which can be attributed to the OH group in **10**. In addition, treatment of **10** with W-2 Raney nickel resulted in desulfurization and formation of methyl 1-isopropyl-2-benzylpyrrole-3,4-dicarboxylate (**13**), probably via the intermediate product **12**, as tertiary alcohols have been observed[13] to undergo ready hydrogenolysis under these conditions. This last transformation excludes structure **7** as its desulfurization product would be anticipated to be the dihydropyrrole **13a**.

Structure **10** is consistent with both the ^{1}H NMR and ^{13}C NMR spectra. In the former resonances at δ 7.4, 5.85, and 2.3 are consistent with H_6, H_3, and 4-CH_3, respectively, and the exchangeable proton at δ 4.74 may be assigned to



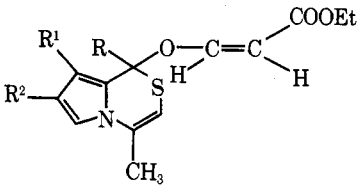
the 1-OH group. In Me_2SO-d_6 or $(CD_3)_2CO$ this proton undergoes an upfield shift, being obscured by the solvent water absorption. The ^{13}C spectrum[14] provided definitive evidence in support of structure **10**. Two resonances only were observed in the carbonyl region at 164.56 and 162.84 ppm attributable to the ester carbonyl groups, the remaining assignments being shown in Table II. Particularly important is the absence of an absorption that could be assigned to the tertiary C_5 in **7**, this absorption being anticipated[3] at ca. 65.5 ppm in analogy to that found for C_4 in tetramethyl 7,9-dimethyl-4*H*-quinolizine-1,2,3,4-tetracarboxylate.

Similarly, the reaction of **6** (R = *p*-BrC_6H_4) with DMAD gave an analogous adduct **10** (R = *p*-BrC_6H_4; R^1 = $COOCH_3$). Its ^{1}H NMR spectrum showed a readily exchangeable (D_2O) singlet at δ 4.53 assigned to the OH proton and the H_6 pyrrole proton was observed at δ 7.26, a chemical shift consistent with those reported[14] for pyrrole protons in similar environments.

Dibenzoylacetylene, a less reactive dipolarophile than DMAD, also gave 1:1 adducts with **6** (R = Ph, *p*-BrC_6H_4). The similarity of their spectral characteristics (Tables I and II) with those described above indicate that rearrangement also had occurred in this instance and that these products are best represented as **10** (R = Ph, *p*-BrC_6H_4; R^1 = COPh).

In contrast to the above acetylenes, ethyl propiolate un-

derwent reaction with the ylide 6 (R = Ph, p-BrC_6H_4) to yield a 1:2 adduct. The most important features of this product's infrared spectrum (KBr) was the absence of an OH absorption and the presence of a new strong olefinic absorption at 1635 cm^{-1}. Its ^1H NMR spectrum was likewise devoid of any resonance attributable to the OH proton while a characteristic cis olefinic coupling was observed at δ 7.03–5.76. These and the other spectral data (Table I) are in agreement with structure 14. Two doublets (δ 7.49, 7.14;



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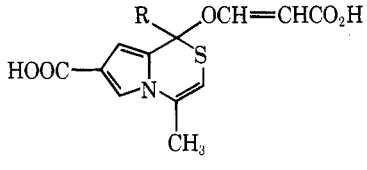

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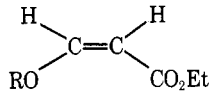

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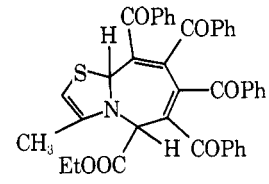
J = 1.5 Hz) assignable to H_6 and H_8 in the ^1H NMR spectrum of 14 (R = p-BrC_6H_4; R^1 = H; R^2 = COOEt) establish the mode of addition of the ylide 6 to ethyl propiolate. In 14 (R = Ph; R^1 = H; R^2 = COOEt) the H_6 proton occurred in the phenyl region at δ 7.47 (100 MHz). Hydrolysis of 14 resulted in formation of 15 (R = Ph, p-BrC_6H_4) described in Table I.

The formation of a 1:2 adduct from 6 and ethyl propiolate is no doubt due to the greater reactivity of this ester when compared to DMAD and dibenzoylacetylene. This was also illustrated by the conversion of 10 (R = Ph, p-BrC_6H_4; R^1 = $COOCH_3$) into 14 (R = Ph, p-BrC_6H_4; R^1 = R^2 = $COOCH_3$) with ethyl propiolate and triethylamine, providing additional evidence in support of 10. The chemical shift of the OCH proton in 14 was observed in the range δ 7.03–6.81, consistent with the chemical shift[16] of the analogous proton in 16 [R = Ph, $(CH_3)_2CH$] at δ 6.85–6.45. It should also be noted that the addition of 2-propanol to ethyl propiolate in the presence of triethylamine results in formation of the cis product only.[16] In the reactions of 10 with ethyl propiolate described above only the cis product was obtained.

In contrast to the 1,5-dipolar cyclization and rearrangement described above, the reaction of 6 (R = OEt) with dibenzoylacetylene resulted in a 1:2 adduct assigned structure 17 and assumed to involve a 1,7-dipolar intermediate. Presence of a strong absorption at 1725 cm^{-1} due to the ester carbonyl group and absence of an OH absorption indicates that a rearrangement analogous to that described above has not occurred. Structures such as 18 and 19 can be excluded on the basis of the following ^1H NMR data. The chemical shift of H_5 was observed at δ 5.12 and those of H_2 and H_{9a} occurred at δ 6.36 and 6.56, respectively. Selective D_2O exchange of H_5 was not possible, base catalysis (Na_2CO_3 or $NaOCD_3$) causing exchange of all three protons. These chemical shifts are at too high field to be due to a pyrrole proton of 19 or to one in the side chain of structures 18 or 19. In *trans*-dibenzoylethylene the chemical shifts of the olefinic protons are δ 8.09–7.90, in 1-(2-pyridyl)benzoylethylene the protons are in the range δ 8.0–7.5, and in 4-methylchalcone[17] the analogous protons are at δ 7.75–7.30.



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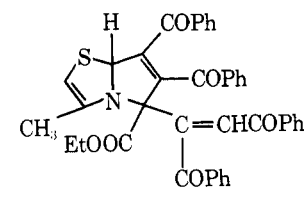

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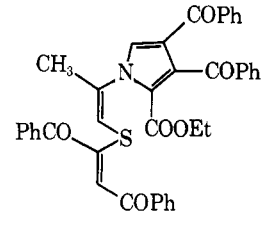
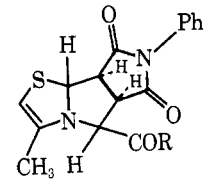
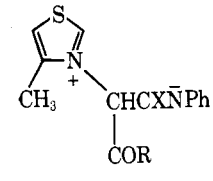


19

N-Phenylmaleimide Adduct. A 1:1 adduct was readily obtained from 6 (R = Ph) and N-phenylmaleimide in DMF in the presence of triethylamine at room temperature. Structure 20 was assigned to this product on the basis of



20



21

the spectral data described in the Experimental Section. The chemical shift of the bridgehead proton at C_{7a} observed at δ 5.35 (d, J = 8.25 Hz) can only be accommodated by the assigned structure. Other olefinic dipolarophiles such as tetracyanoethylene, fumaronitrile, and *trans*-dibenzoylethylene did not yield any identifiable cycloadducts.

Heterocumulenes. Under conditions analogous to those above, phenyl isocyanate and phenyl isothiocyanate resulted in 1:1 adducts in which cyclization to a bicyclic ring system had not occurred. Spectral data favor structure 21 for these adducts. The features associated with the thiazolium nucleus in the initial salts 6 were present in 21 (X = O; R = Ph) but especially important was a D_2O-exchangeable proton singlet at δ 12.63, attributed to the side-chain methine hydrogen atom which, in addition to its β-diketone environment, is adjacent to a positive nitrogen atom. When X = S, this hydrogen underwent a downfield shift to δ 14.6. The absence of a NH absorption in the infrared spectrum also excludes this hydrogen atom being on the nitrogen atom.

Experimental Section[18]

General Procedure for Preparation of 4-Methylthiazolium Salts 5. 4-Methylthiazole (100 mmol), the bromo ketone (100 mmol), and absolute ethanol (50 ml) were refluxed for 2 hr. On cooling the salt separated and was recrystallized as below.

3-(2-Phenyl-2-oxoethyl)-4-methylthiazolium bromide (5, R = Ph) crystallized from dry ethanol as colorless needles: 84%; mp 210° dec; ir (KBr) 1680 cm^{-1} (CO); NMR (Me_2SO-d_6) δ 10.38 (d, 1, J = 2.8 Hz, H_2), 8.10 (m, 2, aromatic), 8.05 (d, 1, J = 2.8 Hz, H_5), 7.70 (m, 3, aromatic), 6.67 (s, 2, CH_2), 2.50 (s, 3, CH_3).

Anal. Calcd for $C_{12}H_{12}BrNOS$: C, 48.33; H, 4.06; N, 4.69. Found: C, 48.28; H, 4.05; N, 4.70.

3-[2-(4′-Bromophenyl)-2-oxoethyl]-4-methylthiazolium bromide (5, R = p-BrC_6H_4) crystallized from dry ethanol as cream needles: 58%; mp 244° dec; ir (KBr) 1690 cm^{-1} (CO); NMR (Me_2SO-d_6) δ 10.23 (d, 1, J = 2.8 Hz, H_2), 8.16–7.46 (m, 5, aromatic and H_5), 6.50 (s, 2, CH_2), 2.50 (s, 3, CH_3).

Anal. Calcd for $C_{12}H_{11}Br_2NOS$: C, 38.22; H, 2.94; N, 3.71. Found: C, 38.17; H, 3.16; N, 3.69.

3-(2-Ethoxy-2-oxoethyl)-4-methylthiazolium bromide (**5**, R = OEt) was prepared in anhydrous ether at room temperature and crystallized from dry ethanol–ether as colorless needles: 57%; mp 149–150°; ir (KBr) 1745 cm^{-1} (CO); NMR ($CDCl_3$) δ 11.30 (d, 1, J = 2.8 Hz, H_2), 8.15 (d, 1, J = 2.8 Hz, H_5), 5.98 (s, 2, NCH_2), 4.30 (q, 2, J = 7.0 Hz, CH_2), 2.63 (s, 3, 4-CH_3), 1.33 (t, 3, J = 7.0 Hz, CH_3).

Anal. Calcd for $C_8H_{12}BrNO_2S$: C, 36.09; H, 4.51; N, 5.26. Found: C, 35.94; H, 4.60; N, 5.24.

General Procedure for Reaction of 4-Methylthiazolium N-Ylides with Dipolarophiles. A stirred solution of the appropriate thiazolium salt and an equimolar amount of the dipolarophile in dry dimethylformamide was treated dropwise with an equimolar amount of triethylamine. A deep-orange color developed immediately and an exothermic reaction ensued. After stirring for 2 hr at room temperature, the reaction mixture was poured into ice–water and the precipitated solid was filtered, dried, and recrystallized from the appropriate solvent (Table I).

5-Ethoxycarbonyl-3-methyl-6,7,8,9-tetrabenzoyl-5,9a-dihydrothiazolo[3,2-*a*]azepine (**17**) was obtained as colorless needles after repeated recrystallization from chloroform–hexane: 62%; mp 230°; ir (KBr) 3115, 3050, 2975 (CH), 1725, 1685, 1670 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.01–7.21 (m, 20, aromatic), 6.56 (s, 1, H_{9a}), 6.36 (bs, 1, H_2), 5.12 (s, 1, H_5), 3.67 (q, 2, J = 7.5 Hz, CH_2CH_3), 2.2 (bs, 3, 3-CH_3), 0.67 (t, 3, J = 7.5 Hz, CH_2CH_3).

Anal. Calcd for $C_{40}H_{31}NO_6S$: C, 73.50; H, 4.78; N, 2.14. Found: C, 73.08; H, 4.71; N, 2.45.

Reaction of the Pyrrolo[2,1-*c*][1,4]thiazines 10 with Ethyl Propiolate. An equimolar mixture of **10** and triethylamine in dry DMF was stirred and treated dropwise with an equimolar amount of ethyl propiolate. After 4 hr at room temperature, the reaction mixture was poured into ice–water and the product that separated purified by recrystallization or by PLC on silica gel (Table I).

Reaction of 1-Hydroxy-1-phenyl-4-methyl-1*H*-pyrrolo[2,1-*c*][1,4]thiazine-7,8-dicarboxylate (10) with Phenyl Isocyanate. A mixture of **10** (R = Ph; R^1 = $COOCH_3$) (0.2 g, 0.56 mmol), phenyl isocyanate (0.36 g, 3 mmol), benzene (2 ml) and a drop of pyridine was refluxed for 1 hr. The mixture was cooled, and hexane was added until the solution became cloudy. On cooling in ice a colorless solid separated which crystallized from benzene–hexane as colorless prisms (**11**): 0.27 g (0.56 mmol, 100%); mp 153°; ir (KBr) 3330 (NH), 1710, 1740 cm^{-1} (CO); NMR ($CDCl_3$) δ 8.06–7.08 (m, 12, aromatic, NH and H_6), 6.63 (d, 1, J = 1 Hz, H_3), 3.78 (s, 3, CH_3), 3.43 (s, 3, CH_3), 2.21 (d, 3, J = 1 Hz, 4-CH_3).

Anal. Calcd for $C_{25}H_{22}N_2O_6S$: C, 62.75; H, 4.63; N, 5.85. Found: C, 63.01; H, 4.68; N, 5.75.

Desulfurization of 10 (R = Ph; R^1 = $COOCH_3$) with Raney Nickel. The pyrrolothiazine (0.3 g, 0.85 mmol), freshly prepared Raney nickel (W-2)[19] (4 g), and ethanol (15 ml) were refluxed with stirring for 2 hr and filtered. Ethanol was evaporated from the filtrate and the residue was recrystallized from methanol, forming fine colorless needles of **13**: 0.15 g (56%); mp 101°; ir (KBr) 1718, 1700 cm^{-1} (CO); NMR ($CDCl_3$) δ 7.21 (s, 1, H_5), 7.18–7.08 (m, 5, aromatic), 4.21 (s, 2, CH_2), 4.16 (septet, 1, CH), 3.77 (d, 6, J = 1 Hz, CO_2CH_3), 1.16 (d, 6, J = 6.5 Hz, CH_3).

Anal. Calcd for $C_{18}H_{21}NO_4$: C, 68.55; H, 6.71; N, 4.44. Found: C, 68.54; H, 6.67; N, 4.40.

5-Benzoyl-3-methyl-*N*-phenyl-5,6,7,7a-tetrahydropyrrolo[2,1-*b*]thiazole-6,7-dicarboximide (20, R = Ph) was obtained as pale yellow prisms from acetone: 36%; mp 174–176°; ir (KBr) 3100, 3055 (CH), 1700 cm^{-1} (CO); λ_{max} (CH_3OH) 200 nm (log ϵ 4.38), 245 (4.22); NMR ($CDCl_3$) δ 9.05 (m, 2, aromatic), 7.20–7.70 (m, 8, aromatic), 5.83 (s, 1, H_2), 5.35 (d, 1, J = 8.25 Hz, H_{7a}), 4.92 (s, 1, H_5), 3.86 (d, 1, J = 8.25, 0.75 Hz, H_6), 3.55 (t, 1, J = 8.25 Hz, H_7), 1.87 (d, 3, J = 1.25 Hz, 3-CH_3); $M^{\cdot+}$ m/e 390 (34).

Anal. Calcd for $C_{22}H_{18}N_2O_3S$: C, 67.68; H, 4.65; N, 7.18. Found: C, 67.61; H, 4.63; N, 7.26.

anhydro-3-(1′-Benzoyl-2′-oxo-2′-phenylimino)-4-methylthiazolium hydroxide (**21**, R = Ph; X = O) was obtained as yellow plates from methanol: 87%; mp 187°; ir (KBr) 3025 (CH), 1610 cm^{-1} (CO); λ_{max} (CH_3OH) 242 nm (log ϵ 4.24), 296 (3.95); NMR (Me_2SO-d_6) δ 12.63 (s, 1, COCH), 9.95 (d, 1, J = 3 Hz, H_2), 7.83 (m, 1, H_5), 7.18–7.65 (m, 10, aromatic), 2.35 (s, 3, CH_3).

Anal. Calcd for $C_{19}H_{16}N_2O_2S$: C, 67.85; H, 4.80; N, 8.33. Found: C, 67.78; H, 4.63; N, 8.43.

anhydro-3-(1′-Benzoyl-2′-phenylimino-2′-thioxo)-4-methylthiazolium hydroxide (**21**, R = Ph; X = S) was obtained as pale yellow needles from methanol: 81%; mp 190° dec; ir (KBr) 3000, 2990 (CH), 1600 (CO), 1500 cm^{-1} (CS); λ_{max} (CH_3OH) 210 nm (log ϵ 4.31), 326 (4.43); NMR (Me_2SO-d_6) δ 14.60 (s, 1, COCH), 10.16 (d, 1, J = 2.0 Hz, H_5), 7.93 (d, 1, J = 2.0 Hz, H_5). 7.78 (m, 2, aromatic), 7.20 (m, 8, aromatic), 2.32 (s, 3, 3-CH_3).

Anal. Calcd for $C_{19}H_{16}N_2OS_2$: C, 64.77; H, 4.58; N, 7.95. Found: C, 64.93; H, 4.70; N, 7.90.

anhydro-3-[1′-(4-Bromobenzoyl)-2′-oxo-2′-phenylimino]-4-methylthiazolium hydroxide (**21**, R = *p*-BrC_6H_4; X = O) crystallized from benzene as pale yellow needles: 54%; mp 176–178° dec; ir (KBr) 3060, 2990 (CH), 1630 cm^{-1} (CO); λ_{max} (CH_3OH) 248 nm (log ϵ 4.28), 300 (4.28); NMR (Me_2SO-d_6) δ 12.53 (s, 1, COCH), 10.00 (d, 1, J = 3.0 Hz, H_2), 7.86 (s, 1, H_5), 6.90–7.70 (m, 10, aromatic), 2.36 (s, 3, 3-CH_3).

Anal. Calcd for $C_{19}H_{15}BrN_2O_2S$: C, 54.95; H, 3.64; N, 6.75. Found: C, 55.05; H, 3.68; N, 6.75.

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Registry No.—$C_{18}H_{17}NO_5S$, 57132-30-6; $C_{18}H_{16}BrNO_5S$, 57132-31-7; $C_{28}H_{21}NO_3S$, 57132-32-8; $C_{28}H_{20}BrNO_3S$, 57132-33-9; $C_{22}H_{23}NO_5S$, 57132-34-0; $C_{22}H_{22}BrNO_5S$, 57132-35-1; $C_{23}H_{23}NO_7S$, 57132-36-2; $C_{23}H_{22}BrNO_7S$, 57132-37-3; $C_{18}H_{15}NO_5S$, 57132-38-4; $C_{18}H_{14}BrNO_5S$, 57132-39-5; **5** (R = Ph), 6274-00-6; **5** (R = *p*-BrC_6H_4), 57132-40-8; **5** (R = OEt), 57132-41-9; **6** (R = Ph), 57132-42-0; **6** (R = *p*-BrC_6H_4), 57132-43-1; **6** (R = OEt), 57132-44-2; **7** (R = Ph; R′ = $COOCH_3$), 57132-45-3; **11**, 57132-46-4; **13**, 57132-47-5; **17**, 57132-48-6; **20** (R = Ph), 57132-49-7; **21** (R = Ph; X = O) 57132-50-0; **21** (R = Ph; X = S), 57132-51-1; **21** (R = *p*-BrC_6H_4; X = O), 57132-52-2; 4-methylthiazole, 693-95-8; 2-bromoacetophenone, 70-11-1; 2,4′-dibromoacetophenone, 99-73-0; ethyl bromoacetate, 105-36-2; dimethyl acetylenedicarboxylate, 762-42-5; dibenzoylacetylene, 1087-09-8; *N*-phenylmaleimide, 941-69-5; phenyl isocyanate, 103-71-9; phenyl isothiocyanate, 103-72-0.

References and Notes

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