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New Synthesis of Thiophenes. Use of N-(1,3-Oxathiol-2-ylidene)ternary Iminium Salts[1]

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A number of simple reactions of N-(1,3-oxathiol-2-ylidene)ternary iminium salts with active methylene compounds have been studied and are shown to produce thiophene derivatives readily. The reaction intermediates have been isolated and a reaction mechanism is proposed. The cleavage of benzoylthiophenes gave benzoic acid and the thiophenes having no substituents at the C-2 position. Spectroscopic investigation of the thiophene derivatives have shown the effect of 2-dialkylamino group on their spectra.

In a continuation of our previous studies on the chemistry of sulfur-containing heterocyclic compounds, we have synthesized a novel trihetero cation system, the N-(1,3-oxathiol-2-ylidene)ternary iminium cation (I),[3-7] which has a resonance contribution from the 2-dialkylamino-1,3-oxathiolium form (I'). We have also demonstrated that reaction of this cation with some active methylene compounds gives 1,4-oxathiafulvenes (II)[5,6] and ketens S,N-acetals (III).[8] We now wish to report a novel and ready synthesis of thiophene[9] from I.

When N-(5-phenyl-1,3-oxathiol-2-ylidene)piperidinium hydrosulfate (Ia: R_2N=piperidino, X=HSO_4)[4] was allowed to react with acetylacetone in the presence of triethylamine in CH_2Cl_2 solution, yellow crystals of mp 121—123° were obtained. The ultraviolet (UV) spectrum of this compound showed strong absorptions at 250 and 360 nm and the infrared (IR) spectrum showed two C=O stretching absorptions at 1683 and 1616 cm^{-1} due to acetyl and benzoyl groups, respectively. The nuclear magnetic resonance (NMR) spectrum exhibited methyl and acetyl singlets. These spectral data suggest the structure of the product to be the thiophene IVa. However, reaction of Ia·HSO_4^- with three molar equivalents of the sodium salt of the anion, prepared from sodium hydride and acetylacetone in absolute tetrahydrofuran, gave a 30% yield of IVa accompanied by a 33% yield of Va, mp 101—103°. On standing in ether at room temperature, compound Va was readily converted to IVa. Elemental analysis of Va agreed with the value having H_2O more than IVa, and the IR spec-

1) This paper forms Part VIII of "Studies on Heterocyclic Cation Systems," Part VII: see Ref. 6. A part of this paper was presented at the 3rd International Congress of Heterocyclic Chemistry, Sendai, Japan, August, 1971, Abstracts of the papers, p. 612. A preliminary account of this work has been reported; K. Hirai and T. Ishiba, *Chem. Pharm. Bull.* (Tokyo), **19**, 2194 (1971).

2) Location: *Sagisu, Fukushima-ku, Osaka.*

3) K. Hirai, *Tetrahedron Letters*, **1971**, 1137.

4) K. Hirai and T. Ishiba, *Chem. Pharm. Bull.* (Tokyo), **20**, 304 (1972).

5) K. Hirai, T. Ishiba, and H. Sugimoto, *Chem. Pharm. Bull.* (Tokyo), **20**, 1711 (1972).

6) K. Hirai and H. Sugimoto, *Chem. Pharm. Bull.* (Tokyo), in contribution.

7) Ternary iminium salts are the compounds having the $>C^{+}=N<$ X^- function (M. Lamchen, W. Pugh, and A.M. Stephen, *J. Chem. Soc.*, **1954**, 4418; N.J. Leonard and J.P. Pankstelis, *J. Org. Chem.*, **28**, 3021 (1963)).

8) R. Gompper and W. Elser, *Ann.*, **725**, 64 (1969).

9) Recently, thiophene synthesis by various methods has been reported. *a*) For 1962—1968, see C.D. Hurd, *Quart. Rep. Sulfur Chem.*, **4**, 79 (1969); *b*) H. Wynberg and H.J. Kooreman, *J. Am. Chem. Soc.*, **87**, 1739 (1965); *c*) E.J. Smutny, *ibid.*, **91**, 208 (1968); *d*) S. Rajappa and B.G. Advani, *Tetrahedron Letters*, **1969**, 5067; *e*) M. Takaku, Y. Hayashi, and H. Nozaki, *Bull. Chem. Soc. Japan*, **43**, 1917 (1970); *f*) I.T. Kay and N. Punja, *J. Chem. Soc.* (*C*), **1970**, 2409; *g*) R. Laliberté and G. Médawa, *Can. J. Chem.*, **48**, 2709 (1970).

trum showed an OH band at 3460 cm^{-1} and two C=O stretching absorptions, at 1684 (C_6H_5-COCH〈) and 1615 cm^{-1} (CH_3CO-Ċ=Ċ-N〈). Therefore, Va is an intermediate in the formation of thiophene and the structure is seen to be a dihydrothiophene having β-hydroxycarbonyl group. For the preparation of thiophene isolation of the intermediate Va was not necessary, and when the reaction of Ia·BF_4^- with 1.2 molar equivalents of the sodium salt of the anion was carried out in tetrahydrofuran, thiophene IVa was obtained in 73% yield.

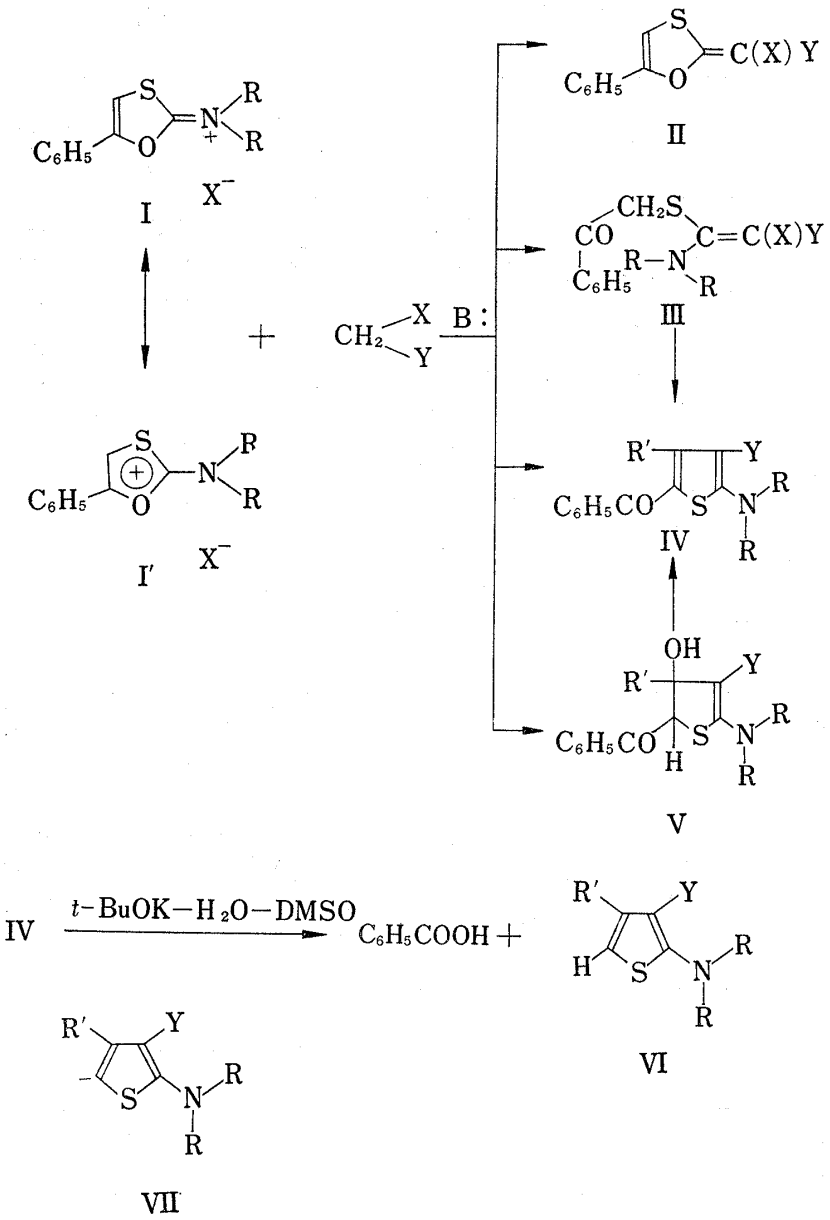
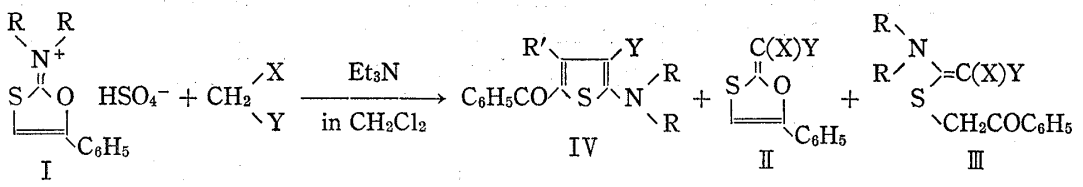


Chart 1

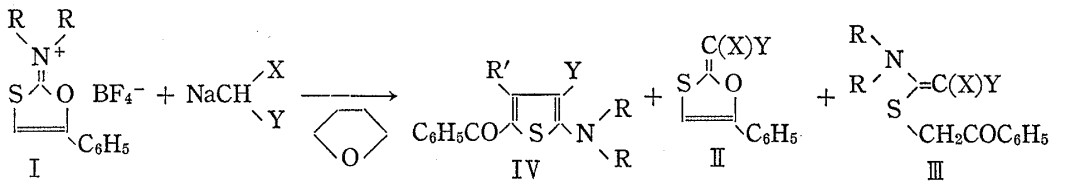
In an analogous reaction with benzoylacetone (Ia·BF_4^- and the sodium salt of the anion in tetrahydrofuran) ketol Vb, mp 112—114°, and thiophene IVb, mp 132—133°, were obtained in 71 and 11% yield, respectively. The possibility of the compounds having the alternative structure, R′=C_6H_5 and Y=$COCH_3$, arising from condensation in another direction, was eliminated since IVb showed two benzoyl C=O bands in its IR spectrum, at 1648 (4-COC_6H_5) and 1615 cm^{-1} (2-COC_6H_5), and a methyl signal in the NMR spectrum at δ 2.22. Comparison of the IR spectra of the 2- and 3-thienyl substituted carbonyl compounds has shown that the C=O frequency of the 2-isomer is lower than that of the 3-isomer due to the stronger conjugation in the 2-isomer; and it has been reported that 2-benzoyl and 3-benzoyl-

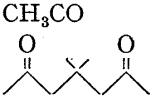
TABLE I. Reactions of 5-Phenyl-N-(1,3-oxathiol-2-ylidene)ternary Iminium Hydrosulfate with Active Methylene Compounds in Methylene Chloride in the Presence of Triethylamine



R_2N–	X	Y	IV R′	IV (%)	II (%)	III (%)
Piperidino	CH_3CO	$COCH_3$	CH_3	41.5	—	—
Piperidino	CH_3CO	COC_6H_5	CH_3	35.5	—	—
Piperidino				—	59[5]	—
Piperidino	(*o*)–CO–C_6H_4–CO–			—	46[5]	—
Piperidino	C_6H_5CO	C_6H_5	C_6H_5	4	—	—
Piperidino	CH_3CO	$COOC_2H_5$		—	22[5]	—
Piperidino	CN	$COOC_2H_5$		—	—	84[5]
Dimethylamino	CN	$COOC_2H_5$		—	—	84.5
Piperidino	CN	CN	NH_2	86	—	—
Dimethylamino	CN	CN	NH_2	94.5	—	—
Dimethylamino	CN	$CONH_2$	NH_2	17	—	11
Piperidino	CN	$CONH_2$		—	—	25[4]

TABLE II. Reactions of 5-Phenyl-N-(1,3-oxathiol-2-ylidene)ternary Iminium Fluoroborate with the Sodium Salt of Active Methylene Compounds in Tetrahydrofuran



R_2N	X	Y	IV R′	IV (%)	II (%)	(III %)
Piperidino	CH_3CO	$COCH_3$	CH_3	73	—	—
Dimethylamino	CH_3CO	$COCH_3$	CH_3	74	—	—
Piperidino	CH_3CO	COC_6H_5	CH_3	82	—	—
Dimethylamino	CH_3CO	COC_6H_5	CH_3	45	—	—
Morpholino	CH_3CO	COC_6H_5	CH_3	85	—	—
Piperidino				—	49[5]	—
Piperidino	C_6H_5CO	C_6H_5	C_6H_5	41	—	—
Morpholino	C_6H_5CO	C_6H_5	C_6H_5	67	—	—
Piperidino	CH_3CO	$COOC_2H_5$	CH_3	68	—	—
Dimethylamino	CH_3CO	$COOC_2H_5$	CH_3	74.5	—	—
Piperidino	C_6H_5CO	$COOC_2H_5$	C_6H_5	60	—	—
Piperidino	$COOC_2H_5$	CN	OH	50	—	25[5]
Dimethylamino	C_6H_5CO	$COOC_2H_5$	C_6H_5	65	—	—
Piperidino	C_6H_5CO	CN	C_6H_5	69	—	—

thiophene show C=O band absorption at 1636 and 1652 cm^{-1}, respectively.[10] It is seen therefore that the amino group situated at the β and δ position shifted these bands to lower frequencies[11,12] and that this effect is stronger for the 2-C=O band. The UV spectrum also showed a strong absorption at 375 nm ($\log \varepsilon$ 4.27). Treatment of IVb by Gassman's pros-

Table III. Analytical Data of 2-Benzoyl-5-dialkylaminothiophenes (IVa—r)

No.	R_2N–	R′	Y	mp (°C)	Crystals from
IVa	piperidino	CH_3	$COCH_3$	121—123	ether
IVb	piperidino	CH_3	COC_6H_5	132—133	AcOEt
IVc	piperidino	C_6H_5	C_6H_5	151—153	ether
IVd	piperidino	CH_3	$COOC_2H_5$	73— 75	*n*-hexane
IVe	piperidino	C_6H_5	$COOC_2H_5$	84— 86	*n*-hexane
IVf	piperidino	NH_2	CN	155—156	AcOEt
IVg	piperidino	OH	CN	168—170	AcOEt
IVh	piperidino	NH_2	$CONH_2$	219—220	Acetone
IVi	dimethylamino	CH_3	$COCH_3$	134—136	AcOEt
IVj	dimethylamino	CH_3	COC_6H_5	146—147	AcOEt
IVk	dimethylamino	CH_3	$COOC_2H_5$	79— 81	petr. benzene
IVl	dimethylamino	NH_2	CN	213—215	AcOEt
IVm	dimethylamino	NH_2	$CONH_2$	216—217	AcOEt
IVn	dimethylamino	OH	CN	156—158	EtOH
IVo	morpholino	CH_3	COC_6H_5	160—162	AcOEt
IVp	morpholino	C_6H_5	C_6H_5	191—193	AcOEt
IVq	dimethylamino	C_6H_5	$COOC_2H_5$	oil	
IVr	piperidino	C_6H_5	CN	163—164	AcOEt

No.	Formula	Analysis (%) Calcd. C	H	N	S	Found C	H	N	S
IVa	$C_{19}H_{21}O_2NS$	69.70	6.46	4.28	9.80	69.55	6.46	4.27	9.76
IVb	$C_{24}H_{23}O_2NS$	74.01	5.95	3.60	8.23	74.39	6.09	3.57	8.71
IVc	$C_{28}H_{25}ONS$	79.39	5.95	3.30	7.57	78.93	5.93	3.26	7.97
IVd	$C_{20}H_{23}O_3NS$	67.19	6.49	3.92	8.97	67.40	6.53	3.98	9.18
IVe	$C_{25}H_{25}O_3NS$	71.57	6.00	3.34	7.64	71.69	6.09	3.35	7.69
IVf	$C_{17}H_{17}ON_3S$	65.58	5.50	13.50	10.31	65.59	5.64	13.40	10.16
IVg	$C_{17}H_{16}O_2N_2S$	65.36	5.16	8.97	10.26	65.60	5.40	8.96	10.49
IVh	$C_{17}H_{19}O_2N_3S$	61.96	5.81	12.75	9.74	62.12	5.56	12.74	9.52
IVi	$C_{16}H_{17}O_2NS$	66.87	5.96	4.87	11.16	67.15	6.03	5.07	11.22
IVj	$C_{21}H_{19}O_2NS$	72.18	5.48	4.01	9.18	72.04	5.29	4.22	9.01
IVk	$C_{17}H_{19}O_3NS$	64.33	6.03	4.42	10.10	64.36	5.96	4.21	10.18
IVl	$C_{14}H_{13}ON_3S$	61.97	4.83	15.49	11.82	62.05	4.77	15.60	11.77
IVm	$C_{14}H_{15}O_2NS \cdot \frac{1}{2}CH_3COOC_2H_5$	57.64	5.74	12.61	9.62	57.27	5.53	12.64	9.69
IVn	$C_{14}H_{12}O_2N_2S$	61.75	4.44	10.29	11.78	61.47	4.45	10.00	11.59
IVo	$C_{23}H_{21}O_3NS$	70.56	5.41	3.58	8.19	70.79	5.18	3.58	8.18
IVp	$C_{27}H_{23}O_2NS$	76.20	5.45	3.29	7.53	76.26	5.24	3.39	7.66
IVb	$C_{22}H_{21}O_3NS$	69.64	5.58	3.70	8.45	69.47	5.68	3.47	8.62
IVr	$C_{23}H_{29}ON_2S$	74.16	5.41	7.52	8.61	74.16	5.41	7.52	8.61

10) S. Gronowitz, *Arkiv. Kemi*, **13**, 295 (1958).
11) N.H. Cromwell, F.A. Miller, A.R. Johnson, R.L. Frank, and D.J. Wallace, *J. Am. Chem. Soc.*, **71**, 3337 (1949).
12) N.J. Leonard and J.A. Adamcik, *J. Am. Chem. Soc.*, **81**, 595 (1959).

cedure[13,14] for the cleavage of non-enolizable ketones using *tert*-BuOK–H_2O–DMSO gave excellent yields of benzoic acid and oily VIa, whose NMR spectrum showed a quartet due to the thiophene ring proton at δ 6.36 (J=1.2 Hz), and a doublet due to the CH_3 group at δ 2.19 (J=1.2 Hz), and whose UV spectrum showed a much weakened absorption at about 379 nm suggesting the disappearance of conjugation at the C-2 position.

The IR spectrum of Vb showed a broad OH band at 3373, a 2-C=O band at 1690, and a 4-C=O band at 1605 cm^{-1}. The 4-COC_6H_5 group in Vb absorbed at very low frequency as a result of conjugation with the β-amino group.[11]

Analogous treatment of I with ketones, β-ketoesters, and cyano compounds gave products as shown in Tables I and II. Thiophene IVc, obtained from the reaction of Ia·BF_4^- and the sodium salt of the anion of deoxybenzoin, showed C=O stretching absorption at 1610 cm^{-1} due to the 2-COC_6H_5 group. Treatment of IVc with *tert*-BuOK–H_2O–DMSO gave benzoic acid and thiophene VIb, mp 156—158°, in 92% yield. Though, in contrast to IVc, IVb

Table IV. Spectral Data of 2-Benzoyl-5-dialkylaminothiophenes (IVa—r)

No.	δ ppm (J in Hz)[a]	λ_{max}^{EtOH} nm (log ε)	$\tilde{\nu}_{max}$ cm^{-1} (KBr)
IVa	2.22 (CH_3), 2.44 ($COCH_3$)	250, 360 (4.14, 4.15)	1683, 1616
IVb	2.22 (CH_3)	256, 278[sh], 375 (4.37, 4.06, 4.27)	1648, 1615
IVc		222, 260[sh], 398 (4.16, 3.94, 4.16)	1610
IVd	2.35 (3-CH_3), 1.37[t] (CH_3CH_2, J=7), 4.33[q] (CH_3CH_2, J=7)	230, 258, 315[sh], 376 (4.17, 4.05, 3.73, 4.21)	1702, 1627, 1253
IVe	0.86[t] (CH_3, J=7), 3.94[q] (CH_2, J=7)	227, 256, 300[sh], 388 (4.49, 4.29, 4.05, 4.18)	1690, 1608, 1245
IVf	7.02 (NH_2)	248, 290, 363 (4.21, 4.17, 4.38)	2198, 1601, 1550
IVg		236, 252, 279[sh], 366 (4.25, 4.28, 3.90, 4.29)	3500[b], 2200, 1600, 1550[b]
IVh	7.00[b] (NH_2)	256, 303, 320[sh], 368 (4.04, 3.98, 3.94, 4.26)	1653, 1600
IVi	2.30 (3-CH_3), 2.48 ($COCH_3$), 2.95 ($N(CH_3)_2$)	248, 374 (4.19, 4.19)	1681, 1605
IVj	2.10 (3-CH_3), 2.86 ($N(CH_3)_2$)	255, 377 (4.39, 4.27)	1660, 1645
IVk	1.37[t] (CH_3CH_2, J=7), 4.32[q] (CH_3CH_2, J=7), 3.02 ($N(CH_3)_2$)	228, 250[sh], 305, 378 (4.24, 4.11, 3.68, 4.29)	1696, 1615, 1220
IVl	3.26 ($N(CH_3)_2$)	246, 288, 360 (4.25, 4.13, 4.37)	2200
IVm	2.88 ($N(CH_3)_2$)	232, 257, 298, 367 (4.40, 4.09, 4.04, 4.11)	1645[b]
IVn	3.38 ($N(CH_3)_2$)	236, 250, 280[sh], 362 (4.24, 4.26, 3.85, 4.35)	3430[b], 2200, 1580
IVo	2.27 (CH_3)	257, 280[sh], 364 (4.18, 3.84, 4.04)	1640, 1615
IVp		233, 275[sh], 384 (4.22, 3.87, 3.95)	1606, 1594
IVq	1.06[t] (CH_3CH_2, J=7), 3.89[q] (CH_3CH_2, J=7), 3.10 ($N(CH_3)_2$)	222[sh], 250[sh], 295[sh], 388 (4.22, 4.12, 3.80, 4.26)	1710, 1599, 1225 (Film)
IVr		224, 258, 288, 384 (4.36, 4.19, 4.05, 4.21)	2290, 1608

a) For multiple signals the following abbreviation have been used: d=doublet, q=quartet, b=broad J was expressed in Hz.

13) P.G. Gassman, J.T. Lumb, and F.V. Zalar, *J. Am. Chem. Soc.*, **89**, 946 (1967).
14) D.G. Davies, M. Derenkey, and P. Hodge, *J. Chem. Soc.* (*C*), **1971**, 455.

has two benzoyl groups to be cleaved by Gassman's procedure, only the 2-CO_6C_5 group was removed. If the facility of cleavage depends on stability of the aryl anion produced in the course of the cleavage reaction,[13-15] then the stability of the thiophene anion would be expected to be important in determining the direction of the cleavage. Since the negative charge on the carbanion is originated from the σ-electrons, the sulfur atom stabilized the adjacent carbanion by inductive effect and d-σ overlap.[16] Thus thiophene C-2 carbanion VII is more stable than the C-4 carbanion and the benzoyl group at the C-2 position in IVb was removed. In addition, the cleavage of the bond to the thipohene ring bearing the substituents occurred to bring about the greatest relief of steric strain to the ring.

Reaction of Ia·BF_4^- with the sodium salt of the anion of ethyl benzoylacetate in tetrahydrofuran gave thiophene IVe, mp 84—86°, and ketol Vc, mp 117—118°, in 43 and 17% yield, respectively. The IR spectrum of IVe showed absorption bands at 1690, 1245 (COO-C_2H_5), and 1608 cm^{-1} (2-COC_6H_5), but Vc showed bands at 3400[b] (OH), 1699 (COC_6H_5), 1615, and 1315 cm^{-1} ($COOC_2H_5$). When Ia·HSO_4^- was allowed to react with malononitrile in the presence of triethylamine in CH_2Cl_2, thiophene IVf was obtained in 86% yield. Ketene S,N-acetals (III) obtained as described in the previous reports[3-6] were treated with sodium alkoxide to give the cyclized products IVg, h in good yield.

Table V. Analytical Data of 5-Dialkylaminothiophenes (VIa—d)

No.	R_2N–	R′	Y	mp (°C)	Crystals from
VIa	piperidino	CH_3	COC_6H_5	oil	
VIb[a]	piperidino	C_6H_5	C_6H_5	156—158	AcOEt
VIc	morpholino	CH_3	COC_6H_5	68— 70	
VId[a]	morpholino	C_6H_5	C_6H_5	193—194	AcOEt

a) H. Hartmann and R. Mayer, *Z. Chem.*, 6, 28 (1966)

No.	Yield (%)	Formula	Analysis (%) Calcd. C	H	N	S	Found C	H	N	S
VIa	91	$C_{17}H_{19}ONS$	71.54	6.71	4.91	11.23	71.41	6.76	4.87	11.03
VIb	92	$C_{21}H_{21}NS$	78.95	6.63	4.39	10.04	79.06	6.80	4.21	10.24
VIc	80	$C_{16}H_{17}O_2NS$	66.87	5.96	4.87	11.16	67.06	5.93	4.88	10.95
VId	91.5	$C_{20}H_{19}ONS$	74.73	5.97	4.36	9.98	74.98	5.70	4.49	9.93

Table VI. Spectral Data of 5-Dialkylaminothiophenes (VIa—d)

No.	δ ppm (J in Hz)	λ_{max}^{EtOH} nm (log ε)	$\tilde{\nu}_{max}$ cm^{-1} (KBr)
VIa	2.19[d] (CH_3, J=1.2), 6.36[q] (2–H, J=1.2)	253, 287[sh], 379 (4.22, 3.95, 3.24)	1648
VIb	6.77 (2–H)	249.5 (4.40)	
VIc	2.15[d] (CH_3, J=1.2), 6.35[q] (2–H, J=1.2)	254, 280[sh], 366 (4.18, 3.88, 3.19)	1638
VId	6.83 (2–H)	247, 290[sh] (4.38, 3.62)	

A very similar reaction occurred with N-(1,3-oxathiol-2-ylidene)morpholinium (Ib) and dimethylammonium salts (Ic), from which the corresponding thiophene derivatives were prepared; typical results are summarized in the Tables I and II.

15) J.F. Bunnett and B.F. Hrutfiord, *J. Org. Chem.*, **27**, 4152 (1962).
16) *a*) R.A. Olofson and J.M. Landesberg, *J. Am. Chem. Soc.*, **88**, 4263 (1966); *b*) R.A. Olofson, J.M. Landesberg, K.N. Houk, and J.S. Michelman, *ibid.*, **88**, 4265 (1966); *c*) W.G. Salmond, *Quart. Rev.* (London), **22**, 253 (1968).

Since this method readily affords thiophene derivatives in high yield by a simple procedure from easily accessible starting materials, it is a particularly advantageous route for thiophene synthesis. The capability of I of providing syntheses of a wide variety of heterocycles is now being extensively investigated.

Table VII. Analytical Data of Dihydrothiophenes (Va—d)

No.	R_2N	R′	Y	mp (°C)	Yield (%)
Va	piperidino	CH_3	$COCH_3$	101—103	33
Vb	piperidino	CH_3	COC_6H_5	112—114	71
Vc	piperidino	C_6H_5	$COOC_2H_5$	117—118	17
Vd	dimethylamino	CH_3	COC_6H_5	120—122	56.5

No.	Formula	Analysis (%) Calcd. C	H	N	S	Found C	H	N	S
Va	$C_{19}H_{23}O_3NS$	66.05	6.71	4.06	9.28	66.42	6.59	4.48	9.62
Vb	$C_{24}H_{25}O_3NS$	70.73	6.18	3.43	7.87	71.52	6.19	3.68	8.31
Vc	$C_{25}H_{27}O_4NS$	68.62	6.22	3.20	7.33	68.72	6.05	3.18	7.79
Vd	$C_{21}H_{21}O_3NS$	68.64	5.76	3.82	8.73	68.44	5.74	3.88	8.62

Table VIII. Spectral Data of Dihydrothiophenes (Va—d)

No.	δ ppm (J in Hz)[a]	$\tilde{\nu}_{max}$ cm^{-1} (KBr)
Va		3460[b], 1684, 1615
Vb	1.88 (CH_3), 3.33[b] (OH), 4.93 (COCHS)	3373[b], 1690, 1605
Vc	0.88[t] (CH_3, J=7), 3.90[q] (CH_2, J=7), 4.60 (OH) 5.22 (COCHS)	3400[b], 1699, 1615, 1315
Vd		1692, 1597, 1560

a) Under the conditions taken the spectra, Va and Vb converted into thiophenes IVa and IVj, respectively. Spectra of Vb and Vc showed the presence of IVb and IVe, respectively, which were formed during the spectra measurements.

We believe the mechanism of this reaction to be as follows: the anion of the active methylene compound attacks the C-2 position of the 1,3-oxathiole ring to give the adduct. This adduct has a very acidic proton on the carbon carrying two electronegative groups. Loss of this proton results in C-O bond or C-N bond fission. When the active methylene compound is dimedone or indane-1,3-dione, thiophene formation is strained in this equilibrium reaction, and elimination of amine is favored, giving 1,4-oxathiafulvene. This amine elimination is also favored in neutral to acidic conditions rather than in basic conditions. In other cases, however, this 1,2-elimination occurs in the direction of C-O bond fission giving ketene S,N-acetal (VIII). Here, VIII carries substituents with push-pull effect. It is assumed that there is an unusually low barrier to rotation around the C=C double bond[17] enabling a favorable geometry for cyclization.

When X is ketone and Y is ketone, ester, or nitrile, an aldol type condensation occurs and in some cases ketol can be isolated by careful treatment. This β-hydroxycarbonyl com-

17) a) G. Isaksson, J. Sandström, and I. Wennerbeck, *Tetrahedron Letters*, **1967**, 2233; b) Y. Shvo and I. Belsky, *Tetrahedron*, **25**, 4649 (1969); c) J. Sandström and I. Wennerbeck, *Acta Chem. Scan.*, **24**, 1191 (1970).

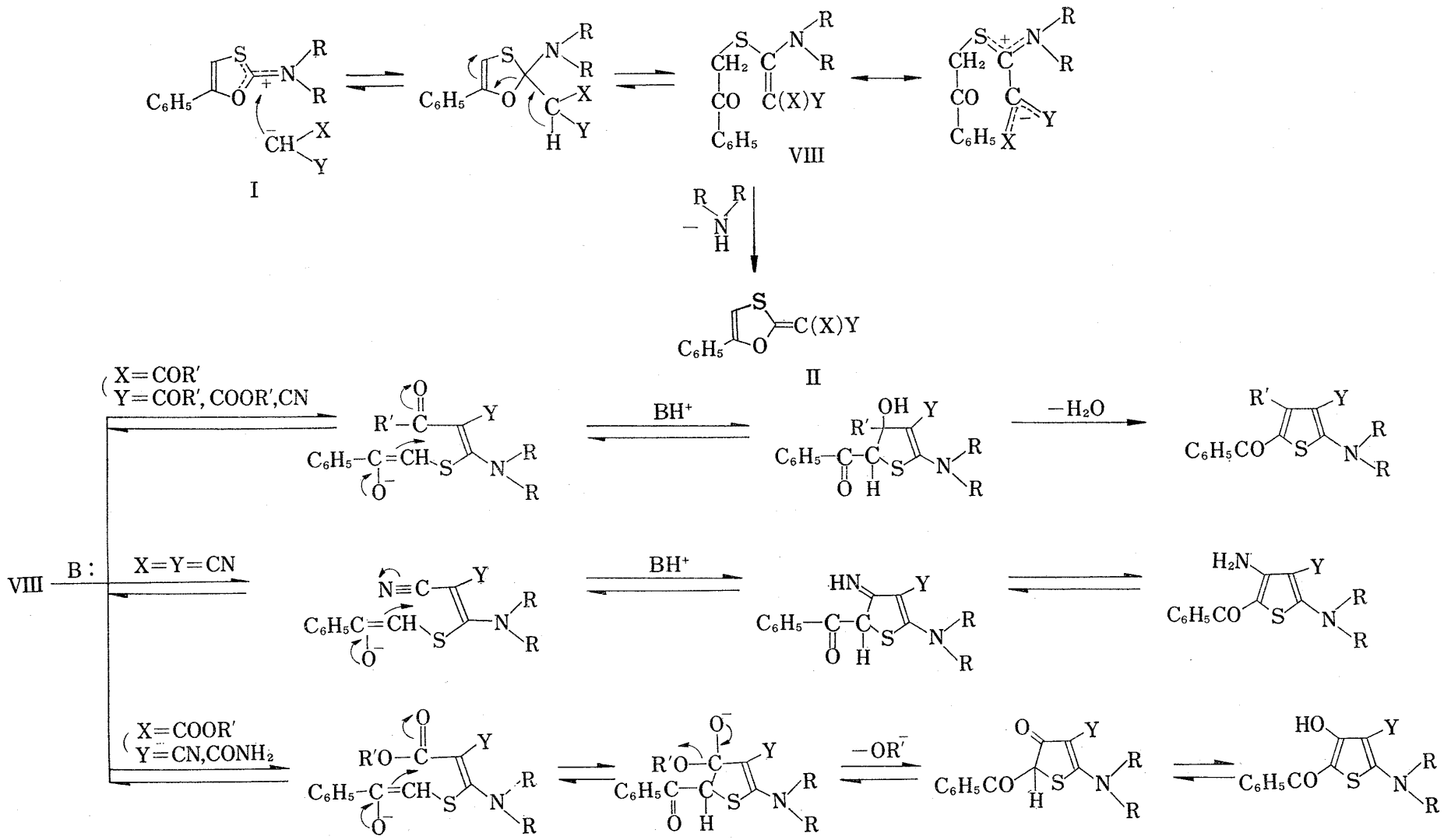


Chart 2

pound is dehydrated easily to form thiophene and the reaction is completed. When X and Y are nitrile, a Thorpe–Ziegler type condensation occurs to give 3-aminothiophene; when X is ester and Y is nitrile, Claisen or Dieckmann type condensation occurs to give 3-hydroxythiophene.[18]

Table IX. Analytical Data of Ketene S,N-Acetals (IIIa,b)

No.	R_2N	X	Y	mp (°C)	Crystals from
IIIa	dimethylamino	$COOC_2H_5$	CN	132—134	AcOEt
IIIb	dimethylamino	CN	$CONH_2$	130—131	AcOEt

No.	Formula	Analysis (%) Calcd. C	H	N	S	Found C	H	N	S
IIIa	$C_{16}H_{18}O_3N_2S$	60.36	5.70	8.80	10.07	60.20	5.47	9.01	10.19
IIIb	$C_{14}H_{15}O_2N_3S$	58.11	5.22	14.52	11.09	57.95	5.30	14.32	11.23

Table X. Spectral Data of Ketene S,N-Acetals (IIIa,b)

No.	δ ppm (J in Hz)	λ_{max}^{EtOH} mμ (log ε)	$\tilde{\nu}_{max}$ cm^{-1} (KBr)
IIIa	1.23[t] ($C\underline{H}_3CH_2$, J=7), 4.13[q] ($CH_3C\underline{H}_2$, J=7) 3.30 ($N(CH_3)_2$), 4.65 (CH_2S)	248.5, 275[sh], 324.5 (4.17, 3.02, 4.11)	2195, 1695, 1685, 1265
IIIb	3.26 ($N(CH_3)_2$), 5.48 (NH_2), 4.58 (CH_2S)	248, 324 (4.14, 4.11)	2180

Experimental

Melting points are uncorrected. The UV spectra were measured in EtOH on a Hitachi EPS-2 spectrophotometer. The IR spectra were recorded on a JASCO DS-402G spectrophotometer (nujol mull or KBr), and the NMR spectra were recorded on a Varian A-60 instrument in $CDCl_3$ with TMS as an internal standard.

Reaction of N-(5-Phenyl-1,3-oxathiol-2-ylidene)dialkylammonium Salts with Active Methylene Compounds——The following typical procedures were employed in the presence of Et_3N.

a) A solution of 0.81 g of benzoylacetone and 1.0 g of Et_3N in 30 ml of CH_2Cl_2 was stirred for 5 min at room temperature. To this solution 1.7 g of Ia·HSO_4^- was added and the mixture was refluxed for 2 hr. Chilling of the solution followed by washing with water, drying, and evaporation gave a residue which was submitted to silica gel column chromatography with $CHCl_3$. The first eluate contained 0.35 g of benzoylacetone and the following eluate gave 0.70 g of IVb as crystals. Recrystallization from AcOEt gave yellow prisms of mp 132—133°. Physicochemical data are given in the Tables III and IV.

b) A solution of 0.33 g of malononitrile and 1 g of Et_3N in 30 ml of CH_2Cl_2 was stirred for 20 min at room temperature. Ia·HSO_4^- (1.7 g) was added and the solution was stirred for 30 min at room temperature. The solution was washed with H_2O, then the organic layer was dried and evaporated to give 1.33 g of IVf, which on recrystallization from AcOEt gave yellow pillars of mp 155—156°.

The typical procedure employed with the sodium salt of the anion was as follows. To a solution of 0.49 g of benzoylacetone in 30 ml of abs. tetrahydrofuran, 0.13 g of 55% NaH was added and the mixture was stirred for 30 min at room temperature. Ia·BF_4^- (0.83 g) was added and the mixture was stirred for 2 hr at room temperature. After concentration of the reaction mixture, the residue was extracted with $CHCl_3$, and the extract was washed with H_2O, dried, and evaporated. Treatment of the residue with ether–pet. ether caused the separation of 0.72 g of Vb as yellow prisms, mp 112—114°. The filtrate was con-

18) After this work was completed, we received a personal communication from Dr. Hartmann who obtained 2-aryl-4-amino(hydroxy, phenyl)thiophene from the reaction of 2-aryl-1,3-oxathiolium salts with active methylene compounds in the presence of base (H. Hartmann, *Z. Chem.*, **11**, 421 (1971)).

centrated and the residue was submitted to silica gel column chromatography with $CHCl_3$ to give 0.11 g of IVb. To a solution of 0.204 g of Vb in 5 ml of CH_2Cl_2 was added 0.05 g of Et_3N and the mixture was stirred for 2 hr at room temperature. The solution was concentrated *in vacuo* to give 0.185 g of IVb. Further results are summarized in the Tables I and II.

Cyclization of Ketene S,N-Acetals (III) to Thiophenes (IV)——A typical reaction was as following. To a solution of 0.023 g of Na in 10 ml of abs. EtOH 0.318 g of IIa (R_2N=dimethylamino, X=CN, Y=$COOC_2H_5$) was added and the mixture was stirred for 1 hr at room temperature. The solution was concentrated *in vacuo* and the residue was extracted with $CHCl_3$. The $CHCl_3$ extract was dried, evaporated, and the residue was treated with ether to give 0.245 g (90%) of IVn. Recrystallization from EtOH gave yellow prisms of mp 156—158°. Similarly, IVg, IVh, and IVm were prepared from the corresponding III in 82, 55, and 77% yield, respectively.

Ketone Cleavage of Benzoylthiophene Derivative——A typical cleavage reaction was as following. A cleavage mixture was prepared from 3.015 g of *t*-BuOK and 0.16 ml of H_2O in 24 ml of DMSO under a nitrogen atmosphere. IVo (0.587 g) was then added, the mixture was stirred for 3 hr, and 300 ml of water was added. The solution was acidified with 10% HCl then extracted with ether. The extract was washed with 10% aqueous Na_2CO_3 solution, then the aqueous layer was acidified with 10% HCl and extracted with ether. The extracts were dried and evaporated to give 0.152 g of benzoic acid. The ether layer was dried and evaporated, and the residue was submitted to silica gel column chromatography with ether to give 0.34 g of VIc, mp 68—70°, as yellow prisms (Tables VII and VIII).

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