Some Heterocyclic Sulfonyl Chlorides and Derivatives

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The syntheses of 4- and 5-chlorosulfonylfuran-2-carboxylic acid (Ia,IIa), 4-chlorosulfonylfuran-2-carboxamide (Ib), 3,5-dimethylpyrazole and isoxazole-4-sulfonyl chlorides (IIIa,IVa) and 2,4-dimethylthiazole-5-sulfonyl chloride (Va) are described. The sulfonyl chlorides were converted into a range of amides, hydrazides and azides. Condensation of the sulfonohydrazides with β-dicarbonyl compounds, gave the corresponding β-ketohydrazones (VII), which, with the exception of the derivatives (VIIe,f,g,i), were converted to the sulfonylpyrazoles (VIII). The structures and spectral data of these compounds are briefly discussed. The reaction of the sodio derivative of acetylacetone with thiophene-2-sulfonyl chloride (VIc) gave 3-(thiophene-2-sulfonyl)pentane-2,4-dione (XII), which with hydrazine gave 4-(thiophene-2-sulfonyl)-3,5-dimethylpyrazole (XIII). However, the analogous reaction with thiophene-2-sulfonohydrazide (VIa) failed to give the expected 1,4-bisthiophenesulfonylpyrazole.

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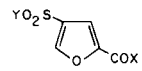
Heterocyclic compounds have proved to be a fertile source of pesticides (1), and in our search for novel pesticides previous studies have included pyridine (2) and thiophenesulfonyl derivatives (3). The present work extends the research to sulfonyl derivatives of furan, pyrazole and isoxazole.

Chlorosulfonation of 2-carboxyfuran gave mixtures of the 4- and 5-sulfonyl chlorides (Ia,IIa) Table I, but only the 4-sulfonyl chloride (Ib) with 2-carbamoylfuran. This follows a similar pattern to that observed with the chlorosulfonation of the corresponding thiophene derivatives (3), and can again be attributed to the competition between the electron-withdrawal by the substituent and the electron-donation by the heteroatom.

1,2-Azoles in acid media undergo electrophilic substitution in the 4-position (4), and 1,3-azoles in the 5-position (5), resulting from the combined effects of the heteroatoms in each case. Consequently it was possible to convert 3,5-dimethylpyrazole and isoxazole (6,7) into the 4-sulfonyl chlorides (IIIa,IVa), and 2,4-dimethylthiazole into the 5-sulfonyl chloride (Va), on reaction with chlorosulfonic acid. Data for the sulfonyl chlorides (Ia-Va) are given in Table I; they have been characterized by conversion into derivatives (*e.g.*, amides, azides and hydrazides) which are useful for biocidal evaluation.

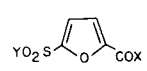
The amides (Table II) were obtained by reaction of the appropriate sulfonyl chloride with amines (1 mole) in the presence of sodium acetate (1 mole). The hydrazides (Table III) were prepared by treatment of the sulfonyl chlorides with an excess of hydrazide hydrate (3 moles). The sulfonohydrazides were condensed with carbonyl compounds (1 mole) in boiling ethanol for a half hour and then left overnight to give the corresponding hydrazones (Table IV). Reaction of the heterocyclic sulfonyl chlorides with sodium azide in aqueous acetone gave the azides (Table V).

The nucleophilic character of the sulfonohydrazide group was investigated by acylation of the thiophene derivative (VIa) under a variety of conditions. Reaction with acetic anhydride gave the *N*-acetyl derivative (VIb) (Table VI), which was also obtained by reaction of thiophene-2-sulfonyl chloride (VIc) with acetylhydrazine. This derivative (IVb) was then converted into a *N*-trichloromethanesulfonyl derivative by reaction with trichloromethanesulfonyl chloride-sodium hydroxide. The structure can be assigned as (VId), as the intermediate anion is more stable than the corresponding amido anion. The hydrazide (VIa) with acetyl chloride at room temperature afforded a *N,N*-diacetyl derivative which is then (VIe) as its reaction with trichloromethanesulfenyl chloride-sodium hydroxide gave a product (VIf) that could be hydrolysed to the *N*-trichlorosulfenyl derivative (VId). The structure (VIe) is supported by the observation that *N,N*-diacetyl groups are readily hydrolysed to *N*-acetyl (8). Thiophene-2-sulfonohydrazide (VIa) with acetyl chloride under more drastic conditions (120°/4 hours) gave the triacetyl derivative (VIg), which was also obtained by acetylation of the diacetyl derivative (VIe).



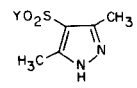
I

(a) X = OH, Y = Cl
(b) X = NH_2, Y = Cl
(c) X = OH, Y = morpholino
(d) X = OH, Y = *p*-ClC$_6$H$_4$NH
(e) X = NH_2, Y = morpholino



II

(a) Y = OH, Y = Cl
(b) X = OH, Y = *p*-ClC$_6$H$_4$NH



III

(a) Y = Cl
(b) X = C$_6$H$_5$NH
(c) X = morpholino
(d) X = *p*-ClC$_6$H$_4$NH
(e) X = $NHNH_2$
(f) X = NHN=CHC$_6$H$_4$OCH$_3$-*p*
(g) X = NHN=CHC$_6$H$_4$N(CH$_3$)$_2$-*p*
(h) X = NHN=CHC$_6$H$_4$Cl-*p*
(i) X = NHN=CHC$_6$H$_3$Cl$_2$-3,4
(i) X = N_3

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Table I

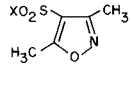
Heterocyclic Sulfonyl Chlorides

Compound No.	Moles of Sulfonyl chloride	Reaction Conditions Temperature (°C)	Time (hours)	Yield (%)	M.p. (°C)	Ir (cm^{-1})
Ia + IIa	5	100	1	60	103-105	3000 (br OH), 1710 (CO), 1380, 1190 (So_2)
Ib	3	100	1	65	138-140	3160 (NH), 1660 (CO), 1370, 1150 (So_2)
IIIa	4	100	6	50	99-100 (a)	3180 (NH), 1590 (C=C), 1365, 1190 (SO_2)
IVa	4	100	3	52	38-39 (b)	1370, 1180 (SO_2)
Va	3+ phosphorus pentachloride (2 moles)	150 120	16 1	66	oil	1370, 1180 (SO_2)

(a) Lit. (6) m.p. 100°. (b) Lit. (7) m.p. 34°.

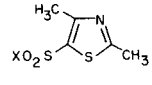
NMR (deuteriochloroform) δ

Compound No.	Thiophene-3H	Thiophene-4H	Thiophene-5H	$J_{3,4}$	$J_{3,5}$
Ia	7.9		7.2		1.0
IIa	6.7	7.1		3.0	
Ib	8.6		7.5		0.8



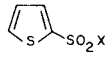
IV

(a) X = Cl
(b) X = morpholino
(c) X = *p*-ClC$_6$H$_4$NH
(c) X = NHCH$_3$
(d) X = NHNH$_2$
(e) X = NHN=C(CH$_3$)$_2$
(f) X = NHN=CHC$_6$H$_4$OCH$_3$-*p*
(g) X = NHN=CHC$_6$H$_4$N(CH$_3$)$_2$-*p*
(h) X = NHN=CHC$_6$H$_4$Cl-*p*
(i) X = NHN=CHC$_6$H$_3$Cl$_2$-3,4
(j) X = N$_3$
(k) X = NHNHCOCH$_3$
(l) X = NHN(COCH$_3$)$_2$
(m) X = N(COCH$_3$)N(COCH$_3$)$_2$



V

(a) X = Cl
(b) X = NH$_2$
(d) X = morpholino
(e) X = NHC$_6$H$_5$
(f) X = NHNH$_2$
(g) X = NHN=C(CH$_3$)$_2$
(h) X = NHN=CHC$_6$H$_4$Cl-*p*
(i) X = NHN=CHC$_6$H$_3$Cl$_2$-3,4
(j) X = N$_3$
(k) X = NHNHCOCH$_3$
(l) X = NHNHCOC$_6$H$_5$

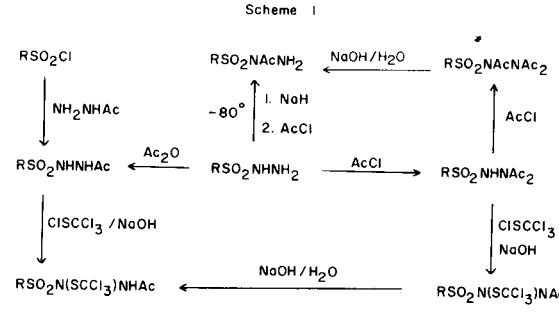


VI

(a) X = NHNH$_2$
(b) X = NHNHCOCH$_3$
(c) X = Cl
(d) X = N(SCCl$_3$)NHCOCH$_3$
(e) X = NHN(COCH$_3$)$_2$
(f) X = N(SCCl$_3$)N(COCH$_3$)$_2$
(g) X = N(COCH$_3$)N(COCH$_3$)$_2$
(h) X = N(COCH$_3$)NH$_2$
(i) X = NHNHCOC$_6$H$_5$
(j) X = N(COC$_6$H$_5$)NHCOC$_6$H$_5$
(k) X = NHCOCH$_3$
(l) X = NHCOC$_6$H$_5$
(m) X = N(SCCl$_3$)COCH$_3$

Attempts to obtain the *N*-acetylhydrazide (VIh) by reaction of the hydrazide-sodium hydride with acetyl chloride failed, although the compound (VIh) was obtained by alkaline hydrolysis of the triacetylhydrazide VIg. The reactions are summarised in Scheme 1 (R = 2-thiophenyl).

Scheme I



Thiophene-2-sulfonohydrazide (VIa) with benzoyl chloride (1 mole) at room temperature gave the *N*-benzoylhydrazide (VIi), but this did not condense with trichloromethanesulfenyl chloride, presumably due to steric reasons. With an excess of benzoyl chloride under more forcing conditions (in boiling dioxan, 2 hours), the *N,N'*-dibenzoyl derivative (VIj) was obtained. The structure is probably (VIj) since the product was insoluble in aqueous sodium hydroxide, and the sulfonamides of secondary amines are known (9) to be insoluble in sodium hydroxide, while those of primary amines are soluble. The *N,N*-dibenzoyl derivative is unlikely as it would contain the more acidic SO_2NH group. In addition, structural considerations suggest that this product is subject to greater steric hindrance. Unfortunately, attempts to prepare the *N,N'*-dibenzoylhydrazide (VIj) by the reaction of thiophene-2-sulfonyl chloride (VIc) with *N,N'*-dibenzoylhydrazine were unsuccessful.

By analogy with thiophene-2-sulfonohydrazide (VIa),

Table II

Heterocyclic Sulfonamides

Compound No.	Yield (%)	M.p. (°C)	Molecular Formula	Analysis Calcd. (%) C	H	N	Found (%) C	H	N
Ic	52 (a)	225-228	$C_9H_{11}NO_6S$	47.2	4.8	6.1	47.3	4.6	6.4
Id + IIb	70 (b)	160-166	$C_{11}H_8ClNO_5S$	43.8	2.7	4.6	43.9	2.6	4.3
Ie	65 (b)	216-217	$C_9H_{12}N_2O_5S$	41.5	4.6	10.8	41.2	4.6	10.7
IIIb	35 (c)	188-190	$C_{11}H_{11}N_3O_2S$	52.6	5.2	16.7	52.4	5.0	16.9
IIIc	55 (c)	157-159	$C_9H_{15}N_3O_3S$	44.1	6.1	17.1	44.0	6.2	17.1
IIId	40 (c)	169-170	$C_{11}H_{12}ClN_3O_2S$	46.2	4.2	14.7	46.0	4.3	14.9
IVb	80 (a)	147-148	$C_9H_{14}N_2O_4S$	43.9	5.7	11.4	44.1	5.7	11.3
IVc	60 (b)	138-139	$C_{11}H_{11}ClN_2O_3S$	46.1	3.8	9.8	46.1	4.0	9.8
Vb	65 (b)	140-142	$C_5H_8N_2O_2S_2$	31.3	4.2	14.6	31.2	4.0	14.5
Vc	67 (c)	92-93	$C_6H_{10}N_2O_2S_2$	35.0	4.9	13.6	34.8	4.8	13.7
Vd	72 (c)	93-94	$C_9H_{14}N_2O_3S_2$	46.95	6.1	12.2	46.7	6.3	12.4
Ve	50 (c)	124-125	$C_{11}H_{12}N_2O_2S_2$	49.3	4.5	10.4	49.1	4.5	10.5

(a) Recrystallised from ethanol. (b) Recrystallised from ethyl acetate-petroleum ether (60-80°, 1:1). (c) Recrystallised from toluene.

Spectroscopic Data of the Heterocyclic Sulfonamides

Compound No.	Nmr (DMSO) δ	Ir (cm^{-1})
Ic	7.24 (q), 2H, thiophene-3,5-Hs, 7.6-6.9 (a) (brs), 1H, OH, 3.73-3.0 (m), 8H (morpholino-Hs)	3000 (brOH), 1710 (CO), 1370, 1190 (SO_2)
Ie	8.46 (d), 1H, thiophene-3H, 8.0, 7.65, 2H, NH_2, 7.41 (a), 1H, thiophene 5-H, 3.76-3.0 (m), 8H, morpholino-Hs	3420, 3180 (NH_2), 1645 (CO), 1360, 1170 (SO_2)
IIIb	9.45 (a) (s), 1H, NH, 7.67 (a) (s), 1H, NH, 7.07 (s), 5H, C_6H_5, 2.26 (s), 6H, 2 × CH_3	3280, 3120 (NH), 1340, 1190 (SO_2)
IIIc	9.7 (a) (brs), 1H, NH, 3.84-3.69, 3.12-2.94 (m), 8H, morpholino-Hs, 2.48 (s), 6H, 2 × CH_3	3210 (NH), 1380, 1150 (SO_2)
IIId	9.75 (a), 1H, NH, 8.75 (a) (s), 1H, NH, 7.06, s, 4H, C_6H_4Cl; 2.27 (s), 6H, 2 × CH_3	3290, 3120 (NH), 1340, 1190 (SO_2)
IVb	3.75-3.55, 3.2-2.95 (m), 8H, morpholino-Hs, 2.6 (s), 3H, 5-CH_3, 2.43 (s), 3H, 3-CH_3	1370, 1180 (SO_2)
IVc	11.5 (a) (s), 1H, NH; 7.12 (q), 4H, C_6H_4, 2.4 (s), 3H, 5-CH_3, 2.24 (s), 3H, 3-CH_3	3250 (NH), 1370, 1180 (SO_2)
Vd	3.7-3.6, 3.02-2.82 (m), 8H, morpholino-Hs, 2.62 (s), 3H, 4-CH_3, 2.49 (s), 3H, 2-CH_3	1350, 1170 (SO_2)
Ve	9.5 (a) (s), 1H, NH, 2.58 (s), 3H, 4-CH_3, 2.6 (s), 3H, 2-CH_3	

(a) These signals were removed after shaking with deterium oxide.

Mass Spectra

Compound No.	
IIIc	245 (M^+), 158 (M-morpholino), 109, 95 (dimethylpyrazole), 75
IIId	285 (M^+), 159 (M-ClC_6H_4NH), 126 (ClC_6H_4NH), 111, 98, 90, 72, 65
IVc	286 (M^+), 160 (M-ClC_6H_4NH), 126 (ClC_6H_4NH), 117, 98

acetylation of 3,5-dimethylisoxazole-4-sulfonylhydrazide (IVd) with acetic anhydride gave the *N*-acetylhydrazide (IVk), while the reaction with acetyl chloride gave the diacetyl (IVl) and the triacetyl (IVm) derivatives. The mono (IVn) and dibenzoyl (IVo) derivatives were also obtained. 2,4-Dimethylthiazole-5-sulfonohydrazide (Vf) was similarly converted into the *N*-acetyl (Vk) and *N*-benzoyl (Vl) derivatives.

It is interesting to note that it was possible to convert thiophene-2-sulfonamide into the *N*-acetyl (VIk) and *N*-benzoyl (VIl) derivatives. The former was condensed with trichloromethanesulfenyl chloride to give the corresponding derivative (VIm); however, the condensation failed with the benzoyl (VIl) derivative, possible due to the larger steric size of the benzoyl group.

Aromatic sulfonohydrazides have been reacted with acetylacetone to give pyrazoles (10). In a previous study (3), pyrazoles were prepared by the condensation of pyridine-3-sulfonohydrazide with β-diketones. In the present work this has been extended to include pyrazoles derived from thiophene-2-sulfonohydrazide (VIIIa-e) Table VIII, 2-carboxythiophene-2-sulfonohydrazide (VIIIf), 3,5-dimethylisoxazole-4-sulfonohydrazide (VIIIg,h), 3,5-dimethyl-pyrazole-4-sulfonohydrazide (VIIIi)

Table III

Heterocyclic Sulfonohydrazides

Compound No.	Yield (%)	M.p. (°C)	Molecular Formula	Analysis Calcd. (%) C	H	N	Found (%) C	H	N
IIIe	70 (b)	171-173 (a)	$C_5H_{10}N_4O_2S$	31.6	5.3	29.5	31.3	5.3	29.6
IVd	68 (b)	92-94	$C_5H_9N_3O_3S$	31.4	4.7	22.0	31.6	4.6	21.8
Vf	60 (b)	110-111	$C_5H_9N_3O_2S_2$	29.0	4.3	20.3	29.1	4.2	20.3

(a) Decomposed at m.p. (b) Recrystallised from toluene.

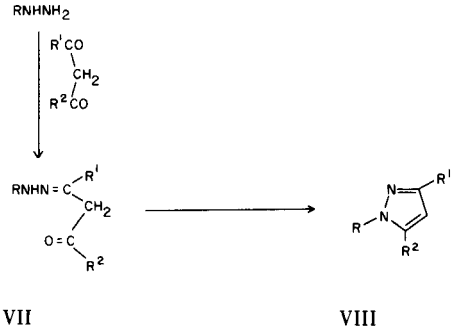
Spectroscopic Data for the Hydrazides

Compound No.	Nmr (DMSO) δ	Ir (cm^{-1})
IIIe	10.65 (a) (s), 1H, SO_2NH, 9.5 (a) (s), 1H, NH, 4.5 (a) (brs), 2H, NH_2, 2.41 (s), 6H, 2 × CH_3	3360, 3340 (NH_2), 3220, 3160, 3120 (NH), 1380, 1190 (SO_2)
IVd	10.1 (a) (s), 1H, SO_2NH, 4.5 (a) (brs), 2H, NH_2, 2.45 (s), 6H, 2 × CH_3	3380, 3300 (NH), 1370, 1160 (SO_2)
Vf	8.6 (a) (brs), 1H, NH, 4.5 (a) (brs), 2H, NH_2, 2.63, 2.52 (s), 6H, 2 × CH_3	3380, 3120 (NH), 1335, 1160 (SO_2)

(a) These signals were removed after treatment with deuterium oxide.

and *p*-toluenesulfonohydrazide (VIIIj). Acetylacetone condensed with the various heterocyclic sulfonohydrazides to give the corresponding pyrazoles (VIIIa,f,g,i), but the intermediate hydrazones were not isolated (Scheme 2).

Scheme 2



VII VIII

R = Thiophene-2-sulfonyl

VIIa R′ = CH_3, R^2 = OC_2H_5
VIIb R′ = CH_3, R^3 = CF_3
VIIc R′ = CH_3, R^2 = C_6H_5
VIId R′ = R^2 = C_6H_5
VIIe R′ = R^2 = CF_3

VIIIa R′ = R^2 = CH_3
VIIIb R′ = CH_3, R^2 = OH
VIIIc R′ = CH_3, R^2 = CF_3
VIIId R′ = CH_3, R^2 = C_6H_5
VIIIe R′ = R^2 = C_6H_5

R = 2-Carboxythiophene-4-sulfonyl

VIIIf R′ = R^2 = CH_3

R = 3,5-Dimethylisoxazole-4-sulfonyl

VIIIg R′ = R^2 = CH_3

VIIf R′ = CH_3, R^2 = C_6H_5
VIIg R′ = CH_3, R^2 = CF_3
VIIh R′ = R^2 = C_6H_5

VIIIh R′ = R^2 = C_6H_5

R = 3,5-Dimethylpyrazole-4-sulfonyl

VIIIi R′ = R^2 = CH_3

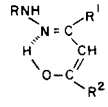
R = 2,4-Dimethylthiazole-5-sulfonyl

VIIi R′ = CH_3, R^2 = CF_3

R = *p*-Toluenesulfonyl

VIIj R′ = CH_3, R^2 = CF_3 VIIIj R′ = CH_3, R^2 = CF_3

With ethyl acetoacetate, the hydrazone (VIIe) was obtained, and this could be cyclised to the pyrazole (VIIIb), in agreement with a previous investigation (11). The sulfonohydrazones were also isolated for the compounds (VIIb-j). The hydrazones (VIIc,d) were cyclised to the corresponding pyrazoles (VIIId,e) by prolonged boiling in methanol (6 hours), but cyclisation occurred significantly faster in the presence of base (potassium carbonate) and a desiccant (sodium sulfate), conditions which were essential for the formation of the trifluoromethylpyrazoles (VIIIc,j). The increased resistance to cyclisation shown by the trifluoromethylhydrazones, notably (VIIg,i) and the hexafluorohydrazone (VIIe) can possibly be attributed to the stabilisation resulting from hydrogen bonding on enolisation (IX), under the conditions of the reaction. However, it is surprising that the methylphenylhydrazone (VIIf) could not be cyclised, particularly as the reaction was achieved with the diphenyl analogue (VIIh).



IX

Ethyl diacetylacetate with thiophene-2-sulfonohydrazide (VIa) gave the carboethoxypyrazole (XI, R = OC_2H_5).

Table IV

Heterocyclic Sulfonohydrazones

Compound No.	Yield (%)	M.p. (°C)	Molecular Formula	Analysis Calcd. (%) C	H	N	Found (%) C	H	N
IIIf	40 (b)	193-195 (a)	$C_{13}H_{16}N_4O_3S$	50.6	5.2	18.2	50.3	5.2	18.2
IIIg	83 (b)	215 (a)	$C_{14}H_{19}N_5O_2S$	52.3	5.9	21.8	52.2	6.1	21.9
IIIh	90 (b)	194-195 (a)	$C_{12}H_{13}ClN_4O_2S$	46.1	4.2	17.9	46.0	4.3	18.2
IIIi	84 (c)	170-173 (c)	$C_{12}H_{12}Cl_2N_4O_2S$	41.5	3.5	16.1	41.5	3.4	16.2
IVe	42 (b)	138-139	$C_6H_{13}N_3O_3S$	41.55	5.6	18.2	41.4	5.8	18.4
VIf	86 (b)	148-151	$C_{13}H_{15}N_3O_4S$	50.5	4.9	13.6	50.7	4.8	13.4
IVg	65 (b)	174-175 (a)	$C_{14}H_{18}N_4O_3S$	52.2	5.6	17.4	52.0	5.3	17.6
IVh	91 (c)	171-173	$C_{12}H_{12}ClN_3O_3S$	45.9	3.8	13.4	46.1	3.8	13.4
IVi	62 (c)	150-151	$C_{12}H_{11}Cl_2N_3O_3S$	41.4	3.2	12.1	51.6	3.05	11.95
Vg	42 (b)	148-150	$C_6H_{13}N_3O_2S_2$	38.9	5.3	17.0	38.8	5.4	17.0
Vh	46 (c)	150-153 (a)	$C_{12}H_{12}ClN_3O_2S_2$	43.7	3.6	12.7	43.7	3.8	12.4
Vi	50 (c)	172-175 (a)	$C_{12}H_{11}Cl_2N_3O_2S_2$	39.6	3.0	11.5	39.9	3.0	11.6

(a) Decomposed at m.p. (b) Recrystallised from ethanol. (c) Recrystallised from toluene-petroleum ether (60-80°; 1:1).

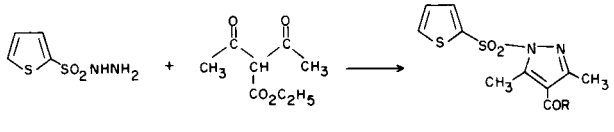
Spectroscopic Data for the Sulfonohydrazones

Compound No.	Nmr (DMSO) δ	Ir (cm^{-1})
IIIf	15.5 (a) (s), 1H, SO_2NH, 10.83 (a) (s), 1H, NH, 7.87 (s), 1H, N = CH, 7.22 (q), 4H, C_6H_4, 3.77 (s, 3H, OCH_3, 2.39 (s), 6H, 2 × CH_3	3250 (br, NH), 1380, 1190 (SO_2)
IIIg	15.33 (a) (s), 1H, SO_2NH, 10.65 (a), 1H, NH, 7.85 (s), 1H, N=CH, 7.06 (q), 4H, C_6H_4, 2.94 (s), 6H, $N(CH_3)_2$, 2.37 (s), 6H, 2 × CH_3	3210, 3160 (NH), 1360, 1190 (SO_2)
IIIh	15.42 (a) (s), 1H, SO_2NH, 11.33 (a) (s), 1H, NH, 7.57 (m), 4H, C_6H_4, 2.40 (s), 6H, 2 × CH_3	3350 (brNH), 1365, 1190 (SO_2)
IVe	10.10 (a) (s), 1H, SO_2NH, 2.60 (s), 3H, 5-CH_3, 2.36 (s), 3H, 3-CH_3, 1.84 (s), 3H, CH_3, 1.80 (s), 3H, CH_3	3250 (NH), 1380, 1190 (SO_2)
IVf	11.22 (a) (s), 1H, SO_2NH, 7.85 (s), 1H, N=CH, 7.16 (q) 4H, C_6H_4, 3.78 (s), 3H, OCH_3, 2.65 (s), 5-CH_3, 2.41 (s) 3H, 3-CH_3	3220 (NH), 1380, 1160 (SO_2)
IVg	11.13 (a) (s), 1H, SO_2NH, 7.97 (s), 1H, N=CH, 7.06 (q), 4H, C_6H_4, 3.0 (s) 6H, $N(CH_3)_2$, 2.67 (s), 3H, 5-CH_3, 2.45 (s), 3H, 3-CH_3	3150 (NH), 1370, 1180 (SO_2)
IVh	11.75 (a) (s), 1H, SO_2NH, 8.05 (s), 1H, N=CH, 7.85-7.35 (m), 4H, C_6H_4, 2.65 (s), 3H, 5-CH_3; 2.40 (s), 3H, 3-CH_3	3100 (NH), 1380, 1190 (SO_2)
IVi	11.70 (a) (brs), 1H, SO_2NH, 7.96 (s), 1H, N=CH, 7.5-7.3 (m), 3H, C_6H_3, 2.69 (s), 3H, 5-CH_3, 2.40 (s), 3H, 3-CH_3	3180 (NH), 1380, 1190 (SO_2)
Vg	9.72 (a) (s), 1H, SO_2NH, 2.64 (s), 3.5 (CH_3 × 2), 1.85, 1.92 (s), 6H, $N=C(CH_3)_2$	3070 (NH), 1345, 1170 (SO_2)
Vh	11.8 (a) (s), 1H, SO_2NH, 8.0 (s), 1H, N=CH, 7.74-7.41 (m), 4H, C_6H_4, 2.61, 2.65 (s), 6H, 2 × CH_3	2930 (NH), 1335, 1160 (SO_2)
Vi	12.0 (a) (brs), 1H, SO_2NH, 7.95 (s), 1H, N=CH, 7.80-7.58 (m), 3H, C_6H_3, 2.52, 2.49 (s), 6H, 2 × CH_3	2900 (NH), 1330, 1165 (SO_2)

(a) These signals disappeared after the addition of deuterium oxide.

Mass Spectrum

IVf 309 (M^+), 249, 148, 133, 119, 96, 81, 63



VI X XI

Attempts to replace the ethoxy group by nucleophilic attack to give the derivatives (XI, R = OH, Cl, $NHNH_2$, NHNHPh, N_3 and NH_2) were unsuccessful, possibly due to steric shielding of the carbonyl group. In an effort to obtain the acid chloride, the pyrazole (XI, R = OC_2H_5) was reacted with phosphorus pentachloride in phosphoryl chloride to give the phosphorodichloridate (XI, R = $OP(O)Cl_2$), but this did not react with morpholine to give the dimorpholidate [XI, R = $OP(O)(N\langle\rangle O)_2$].

The spectral data, particularly of the trifluoromethylhydrazones and the trifluoromethylpyrazoles, are worth

Table V

Heterocyclic Sulfonoazides

Compound No.	Yield (%)	M.p. (°C)	Molecular Formula	Analysis Calcd. % C	H	N	Found % C	H	N
IIIj	64 (c)	80-82 (b)	$C_5H_7N_5O_2S$	29.9	3.5	34.8	30.1	3.6	34.7
IVj	60 (d)	36 (b)	$C_5H_6N_4O_3S$	29.7	3.0	27.7	29.9	3.0	27.8
Vj	93	122-125 (b)	$C_5H_7ClN_4O_2S_2$	23.6	2.8	22.0	23.6	3.0	21.8

(a) Precipitated as the hydrochloride by passage of hydrogen chloride gas through an ethereal solution. (b) Decomposed at m.p. (c) Recrystallised from toluene. (d) Recrystallised from ether-petroleum ether (60-80°) (1:1).

IR Data for the Sulfonoazides (cm^{-1})

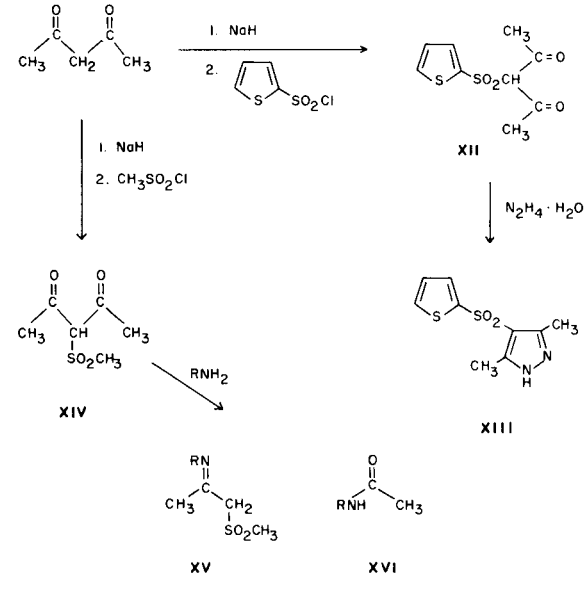
Compound No.	
IIIj	3200 (NH), 2130 (N_3), 1360, 1170
IVj	2140 (N_3), 1370, 1180
Vj	2850 (NH), 2130 (N_3), 1370, 1175

noting. The ir spectra of the hydrazones (VIIb,g) Table VII showed typical asymmetric and symmetric SO_2 stretching vibrations in the region 1380-1350 and 1180-1170 cm^{-1} respectively. It was previously reported (2) that the carbonyl absorption in the ir spectrum of pyridine-3-sulfonotrifluoromethylhydrazone was of low intensity, which indicated the predominance of the enol form.

Evidence for the enol form in the case of the trifluoromethylhydrazones (VIIb,g) came from the broad absorptions in the 3450-3160 cm^{-1} region. There was some contribution frm the keto form, as indicated by the absorptions at 1655 and 1650 cm^{-1} which can be assigned to the stetching frequencies of the carbonyl groups. The pmr spectra of the hydrazones (VIIb,g) each showed an AB quartet ($\delta \sim 3.2$, $J_{AB} \sim 18$ Hz) which could be assigned to the CH_2 group in the keto form. There was no evidence of the enol form. This non-equivalence was reported previously (2); and was attributed to the coordination of the solvent dimethyl sulfoxide at the carbonyl group. The solvent used in this study was deuteriochloroform and the non-equivalence could therefore be due to hydrogen bonding between a fluorine atom and one of the methylene protons. This is supported by the pmr spectrum of hydrazone of ethyl acetoacetate (VIIa) which gave a singlet for the methylene group. The ir spectrum of the pyrazole (VIIIb) (Table VIII) showed a carbonyl absorption band at 1660 cm^{-1}, as well as the hydroxyl stretching band at 3360 cm^{-1}, indicating that this compound existed as a mixture of the hydroxypyrazole and the pyrazolone. The SO_2 stretching vibrations in the pyrazoles (VIIIc,j) shifted to lower frequencies (1260 and 1130 cm^{-1}) compared with those of the dimethyl derivative (VIIIa), which may be due to the effects of the electron-withdrawing trifluoromethyl group.

Acetylacetone was converted to the sodio-derivative with sodium hydride, and then reaction with thiophene-2-sulfonyl chloride (VIc) gave the 3-(thiophene-2-sulfonyl)-pentane-2,4-dione (XII) which with hydrazine afforded a low yield (22%) of the 3,5-dimethylpyrazole (XIII) (Scheme 3).

Scheme 3



In constrast, the attempted reaction of XII with thiophene-2-sulfonohydrazide (VIa) failed to give the analogous 1,4-bisthiophenesulfonopyrazole. Studies (12,13) of the reaction of 3-(methanesulfonyl)pentane-2,4-dione (XIV) with primary amines resulted in low yields of the products (XV,XVI). The reaction with hydrazine allowed intramolecular cyclisation, which is not possible with

Table VI

Heterocyclic *N*-Acylsulfonohydrazides

Compound No.	Yield (%)	M.p. (°C)	Molecular Formula	Analysis Calcd. (%) C	H	N	Found (%) C	H	N
VIb	85	140-141	$C_6H_8N_2O_3S_2$	32.7	3.6	12.7	32.6	3.7	12.6
VId	56	191-192	$C_7H_7Cl_3N_2O_3S_3$	22.7	1.9	7.6	22.8	1.9	7.65
VIe	70	143-144	$C_8H_{10}N_2O_4S_2$	36.6	3.8	10.7	36.4	3.8	10.5
VIf	30	129	$C_9H_9Cl_3N_2O_4S_3$	26.2	2.2	6.8	26.4	2.1	6.9
VIg	92	112-113	$C_{10}H_{12}N_2O_5S_2$	39.5	4.0	9.2	39.2	3.95	9.3
VIh	42	152-156	$C_6H_8N_2O_3S_2$	32.7	3.6	12.7	32.6	3.6	12.3
VIi	60	233-234	$C_{11}H_{10}N_2O_3S_2$	46.8	3.5	9.9	46.5	3.7	97.
VIj	55	171-173	$C_{18}H_{14}N_2O_4S_2$	55.9	3.6	7.3	55.7	3.5	7.4
IVk	60	146	$C_7H_{11}N_3O_4S$	36.1	4.7	18.0	36.2	4.85	17.8
IVl	90	146	$C_9H_{13}N_3O_5S$	39.3	4.7	15.3	39.3	4.8	15.4
IVm	80	104-105	$C_{11}H_{15}N_3O_6S$	41.6	4.7	13.2	41.5	4.8	13.0
IVn	65	194-196	$C_{12}H_{13}N_3O_4S$	48.8	4.4	14.2	48.5	4.5	14.4
IVo	70	190-191	$C_{19}H_{17}N_3O_5S$	57.1	4.3	10.5	56.9	4.4	10.6
Vk	70	164-166	$C_7H_{11}N_3O_3S_2$	33.7	4.4	16.9	33.5	4.5	16.7
Vl	55	140-142	$C_{12}H_{13}N_3O_3S_2$	46.3	4.2	13.5	46.3	4.1	13.6

Spectroscopic Data for the *N*-Acylsulfonohydrazides

Compound No.	NMR (DMSO) δ	IR (cm^{-1})
VIb	10.07 (a), 9.90 (a) (s), 2H, 2NH, 8.66-8.54 (m), 1H, thiophene-3-H, 8.0-7.88 (m), thiophene-5-H, 7.25-7.0 (m), 1H, thiophene-4-H, 1.77 (s), 3H, $COCH_3$	3330, 3000 (NH), 1675 (CO), 1350, 1160 (SO_2)
VId	11.7 (a) (s), 1H, NH, 8.18-8.0 (m), 1H, 3-H, 7.75-7.63 (m), 1H, 5-H, 7.25-7.05 (m), 1H, 4-H, 1.80 (s), 3H, $COCH_3$	3160 (NH), 3100 (thiophene CH), 1680 (CO), 1375, 1175 (SO_2)
VIe	11.15 (a) (s), 1H, NH, 8.22-8.12 (m), 1H, 3-H, 8.01-7.92 (m), 1H, 5-H, 7.36-7.22 (m), 1H, 4-H, 2.09, 2.08 (s), 6H, s × $COCH_3$	3340 (NH), 3100 (thiophene CH), 1730, 1710 (CO), 1370, 1175 (SO_2)
VIf	8.3-8.15 (m), 1H, 3-H, 8.02-7.88 (m), 1H, 5-H, 7.35-7.15 (m), 1H, 4-H, 2.6, 2.28 (s), 6H, 2 × $COCH_3$	3100 (thiophene CH), 1740, 1720 (CO), 1370, 1170 (SO_2)
VIg	7.95-7.9 (m), 1H, 3-H, 7.82-7.78 (m), 1H, 5-H, 7.2-7.1 (m) 1H, 4-H, 2.52 (s), 6H, 2 × $COCH_3$, 2.2 (s), 3H, $COCH_3$	3110 (thiophene CH), 1730 (CO), 1380, 1175 (SO_2)
VIi	10.75 (a), 11.10 (a) (s), 2H, 2 × NH, 7.98-7.4, 7.2-7.0 (m), 8H, C_6H_5, C_4H_3S	3320, 3130 (NH), 1675 (CO), 1350, 1170 (SO_2)
VIj	11.93 (a) (brs), 1H, NH, 8.23-7.92 (m), 2H, 3,5-H's, 7.8-7.2 (m), 11H, 2 × C_6H_5, 4-H	3300 (NH), 1700, 1660 (CO), 1380, 1170 (SO_2)
IVk		3340, 3100 (NH), 1660 (CO), 1370, 1190 (SO_2)
Vl		3350, 3290 (NH), 1670 (CO), 1350, 1160 (SO_2)

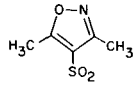
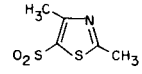
(a) These signals disappeared after the addition of deuterium oxide.

Mass Spectra

VIb	220 (M^+), 178, 163, 142, 131, 111, 99, 84, 45
VId	368 (M^+), 221 (M^+-thiophene SO_2), 179, 166, 147, 131, 126, 124, 99, 84, 81, 80, 72, 70, 64, 58
VIe	262 (M^+), 220, 178, 168, 156, 149, 147, 142, 131, 123, 99, 84
VIf	4[illegible] ($M^+ + 1$), 368 (M-$COCH_3$), 326, 304, 263 (M-$C_4H_3SO_2H$), 247, 221 ($CH_3CONSCCl_3$), 179, 166, 147, 142, 131, 116, 114 ($NN(COCH_3)_2$), 111, 99, 84 (C_4H_4S), 79
VIg	304 (M^+), 262, 245, 220, 178, 149, 147, 142, 131, 99, 84, 73
VIi	282 (M^+), 147, 122, 105, 84, 78
VIj	386 (M^+), 165, 148, 105, 84, 78
IVk	233 (M^+), 191, 162, 161, 160, 128, 97, 82, 54

Table VII

Heterocyclic β-Ketosulfonohydrazones

Compound No.	R	R^1	R^2	Yield (%)	M.p. (°C)	Molecular Formula	Calcd. (%) C	H	N	Found (%) C	H	N
VIIa		CH_3	OC_2H_5	86	117-118	$C_{10}H_{14}N_2O_4S_2$	41.4	4.3	9.7	41.34	4.85	9.8
VIIb	"	CH_3	CF_3	63	104-107	$C_9H_9F_3N_2O_3S_2$	34.4	2.9	8.9	34.7	3.0	9.1
VIIc	"	CH_3	C_6H_5	78	126-128	$C_{14}H_{14}N_2O_3S_2$	52.1	4.2	8.7	52.0	4.3	8.8
VIId	"	C_6H_5	C_6H_5	82	107-110	$C_{19}H_{16}N_2O_3S_2$	59.4	4.2	7.3	59.4	4.3	7.1
VIIe	"	CF_3	CF_3	70	120	$C_9H_6F_6N_2O$	29.3	1.6	7.6	29.0	1.7	7.8
VIIf		CH_3	C_6H_5	67	173-175	$C_{15}H_{17}N_3O_4S$	53.7	5.1	12.5	53.5	5.1	12.5
VIIg	"	CH_3	CF_3	72	112-114	$C_{10}H_{12}F_3N_3O_4S$	36.7	3.7	12.8	36.7	3.6	13.0
VIIh	"	C_6H_5	C_6H_5	71	168-170	$C_{20}H_{19}N_3O_4S$	60.5	4.8	10.6	60.1	4.8	10.7
VIIi		CH_3	CF_3	85	160-161	$C_{10}H_{12}F_3N_3O_3S_2$	35.0	3.5	12.2	35.1	3.5	11.9
VIIj	p-$CH_3C_6H_4SO_2$	CH_3	CF_3	80	126-128	$C_{12}H_{13}F_3N_2O_3S$	44.7	4.0	8.7	44.7	4.0	8.5

Spectroscopic Data for the β-Ketosulfonohydrazones

Compound No.	NMR (deuteriochloroform) δ	IR (cm^{-1})
VIIa	10.59 (a) (s), 1H, NH, 8.15-8.0 (m), 1H, thiophene-3H, 7.8-7.65 (m), 1H, 5-H, 7.4-7.17 (m), 1H, 4-H, 4.12 (q), 2H, OCH_2, 3.3 (s), 2H, CH_2, 1.9 (s), 3H, N-C-CH_3, 1.1 (t), 3H, CH_3	3200 (NH), 3100 (thiophene CH), 1715 (CO), 1370, 1190 (SO_2)
VIIb	7.84-7.67 (m), 2H, 3,5-H, 7.17-7.08 (m), 1H, 4-H, 6.40 (a) (brs), 1H, NH, 3.16 (q), 2H, CH_2, 2.0 (s), 3H, CH_3)	3450 (br, NH, OH), 3120, 3100, 3090 (thiophene CH), 1650 (CO), 1350, 1170 (SO_2)
VIIc	11.7 (a) (s), 1H, NH, 8.9 (a) (s), 1H, OH, 7.8-7.66, 7.5-7.08 (m), 8H, C_6H_5, C_4H_3S, 4.8, 1H, CH, 1.58 (s), 3H, CH_3	3260 (NH), 3110 (thiophene CH), 2950 (br OH), 1350, 1160 (SO_2)
VIIg	8.16 (a) (s), 1H, NH, 3.16 (q), 2H, CH_2, 2.6 (s), 3H, 5-CH_3, 2.37 (s), 3H, 3-CH_3, 2.04 (s), N=C-CH_3	3260-3160 (NH, OH), 1655 (CO), 1380, 1180 (SO_2)

(a) These signals disappeared after the addition of deuterium oxide.

Mass Spectra

VIIb	314 (M^+), 296, 250 (M^+-SO_2), 245, 180, 166, 148, 146, 130, 98, 82, 69
VIIc	322 (M^+), 304 (M^+-H_2O), 240 (M^+-H_2O -SO_2), 178, 158, 157, 149, 148, 147, 129, 110, 99, 82
VIId	384 (M^+), 366, 302 (M^+-H_2O -SO_2), 219, 191, 165, 147, 105, 91, 89, 77, 83
VIIf	335 (M^+), 317 (M^+-H_2O), 253 (M^+-H_2O -SO_2), 175, 165, 159, 158, 130, 129, 119, 96, 78
VIIg	327 (M^+), 258, 167, 117, 98, 78, 69
VIIi	343 (M^+), 274, 210, 176, 113, 72, 69, 64

the primary amine. However, the low yield suggested that competitive side-reactions were present.

EXPERIMENTAL

Melting points were determined with a Kofler hot-stage apparatus and are uncorrected. Ir spectra were measured as Nujol mulls or liquid films with a Perkin Elmer 257 spectrophotometer. Nmr spectra were recorded with a Varian HA 100 spectrometer using tetramethylsilane as internal standard. Microanalyses were by Butterworth's Microanalytical Consultancy Ltd., Teddington, England. Mass spectra were determined with an AEI MS 10 spectrometer operating at 70 eV.

N-Acetyl-*N'*-thiophene-2-sulfonohydrazide (VIb) (Table VI).

Method 1.

Thiophene-2-sulfonohydrazide (VIa) (1.8 g.) was boiled under reflux with acetic anhydride (10 ml.) and acetic acid (10 ml.) for 1 hour. The solution was left overnight at room temperature and poured onto ice, and extracted with ethyl acetate (3 × 40 ml.). The extract was washed with water, dried (magnesium sulfate) and evaporated. Recrystallisation of the residue from toluene gave the mono-acetate (VIb) (85%).

Method 2.

Thiophene-2-sulfonyl chloride (VIc) (1.8 g.) was reacted with acetylhydrazine (1.7 g.) in tetrahydrofuran at room temperature for 24 hours. The solvent was evaporated and the residue recrystallised (toluene) to give the *N*-acetyl sulfonohydrazide (VIb) (1.1 g., 50%).

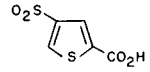
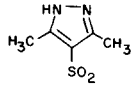
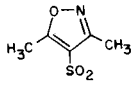
The *N*-acetyl compounds (IVk,Vk) (Table VI) were similarly prepared by Method 1.

N,N-Diacetyl-*N'*-thiophene-2-sulfonohydrazide (VIe).

Thiophene-2-sulfonohydrazide (VIa) (1.8 g.) was reacted with acetyl chloride (5 ml.)-acetic acid (5 ml.) at room temperature for 24 hours.

Table VIII

Pyrazoles

Compound No.	R	R^1	R^2	Yield (%)	M.p. (°C)	Molecular Formula	Calcd. (%) C	H	N	Found (%) C	H	N
VIIIa		CH_3	CH_3	70	65	$C_9H_{10}N_2O_2S_2$	44.6	4.1	11.6	44.4	4.2	11.8
VIIIb	"	CH_3	OH	50	185-188	$C_8H_8N_2O_3S_2$	39.3	3.3	11.5	39.5	3.6	11.3
VIIIc	"	CH_3	CF_3	50	199-201	$C_9H_7F_3N_2O_2S_2$	36.5	2.4	9.5	36.8	2.3	9.4
VIIId	"	CH_3	C_6H_5	65	83-85	$C_{14}H_{12}N_2O_2S_2$	55.3	3.9	9.2	54.9	3.8	9.25
VIIIe	"	C_6H_5	C_6H_5	63	141-142	$C_{19}H_{14}N_2O_2S_2$	62.3	3.8	7.7	62.0	3.9	7.7
VIIIf		CH_3	CH_3	50	154-156	$C_{10}H_{10}N_2O_4S_2$	42.0	3.5	9.8	42.0	3.6	9.9
VIIIj	p-$CH_3C_6H_4SO_2$	CH_3	CF_3	85	188-192	$C_{12}H_{11}F_3N_2O_2S$	47.4	3.6	9.2	47.2	3.6	9.1
VIIIi		CH_3	CH_3	85	164-167	$C_{10}H_{14}N_4O_2S$	47.2	5.5	22.0	47.0	5.5	22.2
VIIIg		CH_3	CH_3	90	59-60	$C_{10}H_{13}N_3O_3S$	47.0	5.1	16.5	46.8	5.0	16.6
VIIIh	"	C_6H_5	C_6H_5	71	132-134	$C_{20}H_{17}N_3O_3S$	63.3	4.5	11.1	63.1	4.5	11.2

Spectroscopic Data for the Pyrazoles

Compound No.	NMR (DMSO) δ	IR (cm^{-1})
VIIIa	8.16-1.08 (m), 1H, 3-H, 7.90-7.85 (m), 1H, 5-H, 7.28-8.18 (m), 1H, 4-H, 6.14 (s), 1H, pyrazole-H, 2.16, 2.47 (s), 6H, 2 × CH_3	3105, 3090 (thiophene CH), 1340, 1180 (SO_2)
VIIIb	12.3 (a) (brs), ⅓H, OH, 8.22-8.0 (m), 1H, 3-H, 7.8-7.69 (m), 1H, 5-H, 7.30-7.13 (m), 1H, 4-H, 5.74 (s), ⅓H, pyrazole-H, 5.0 (s), 1⅓H, $C_3H_2N_2$, 2.18 (s), 1H, ⅓CH_3-C_3HN_2, 2.07 (s), ⅔CH_3-$C_3H_2N_2$	3360 (OH), 3120, 3100 (CH), 1660 (CO), 1380, 1175 (SO_2)
VIIIc	7.6-7.46 (m), 1H, 3-H, 7.25-7.15 (m), 1H, 5-H, 7.03-6.96 (m), 1H, 4-H, 4.98 (s), 1H, CH, 1.9 (s), 3H, CH_3	1260, 1130 (SO_2)
VIIIj	7.35 (q), 4H, C_6H_4, 4.95 (s), 1H, CH, 2.37 (s), 3H, $CH_3C_6H_4$, 1.98 (s), 3H, CH_3-pyrazole	1260, 1130 (SO_2)
VIIIi	15.6 (a) (s), 1H, NH, 5.89 (s), 1H, pyrazole H, 2.39 (s), 6H, 2 × CH_3-C-SO_2, 2.13 (s), 6H, 2 × CH_3-CH	3200 (NH), 3100 (pyrazole CH), 1360, 1150 (SO_2)
VIIIg	5.93 (s), 1H, pyrazole CH, 2.72 (s), 3H, 5-CH_3-N-O, 2.40 (s) 3H, 3-CH_3-O-N, 2.51, 2.18 (s), 6H, 2 = CH_3-N-N	3120 (CH), 1360, 1160 (SO_2)

(a) These signals disappeared after the addition of deuterium oxide.

Mass Spectrum

Compound No.	
VIIIh	379 (M^+), 315 (M-SO_2), 232, 219, 191, 165, 89, 68

Acetyl chloride and acetic acid were evaporated off under reduced pressure; the residue was washed with water and recrystallised (ethyl acetate-toluene 1:1) to give the *N,N*-diacetate (VIe). The *N,N'*-diacetate (IVl) (Table VI) was similarly prepared.

N,N,N'-Triacetyl-*N'*-thiophene-2-sulfonohydrazide (VIg).

Thiophene-2-sulfonohydrazide (VIa) (1.8 g.) was refluxed with acetic acid (10 ml.) with acetyl chloride (5 ml.) for 4 hours. Excess acetyl chloride and acetic acid were evaporated; the residue was washed with water and recrystallised (toluene) to give the *N,N,N'*-triacetate (VIg).

The *N,N,N'*-triacetate (IVm) (Table VI) was similarly prepared.

N-Acetyl-*N*-thiophene-2-sulfonohydrazide (VIh).

A solution of *N,N,N'*-triacetyl-*N'*-thiophene-2-sulfonohydrazide (VIg) (0.5 g.) in ethanol (5 ml.) and 2*N* sodium hydroxide (5 ml.) was stirred at room temperature for 18 hours. Ethanol was evaporated in vacuo and the aqueous mixture extracted with ethyl acetate (3 × 15 ml.), dried (magnesium sulfate) and evaporated. Recrystallisation of the residue from ethyl acetate-light petroleum (60-80°) gave the monoacetate (VIh) (42%).

N-Benzoyl *N'*-thiophene-2-sulfonohydrazide (VIi).

Thiophene-2-sulfonohydrazide (VIa) (2 g.) was treated with benzoyl

chloride (10 ml.) at room temperature for 24 hours. The excess benzoyl chloride was evaporated off under reduced pressure and the residue washed with water. Recrystallization from toluene-light petroleum (60-80°) (1:1) gave the *N*-benzoate (VIi).

The *N*-benzoates (IVn, Vl) (Table VI) were similarly prepared.

N,N'-Dibenzoyl *N'*-thiophene-2-sulfonohydrazide (VIj).

Thiophene-2-sulfonohydrazide (VIa) (1 g.) was refluxed with benzoyl chloride (4 g.) in dioxan (20 ml.) for 2 hours. Benzoyl chloride and dioxan were evaporated off under reduced pressure. The residue was triturated with water and the mixture extracted with ethyl acetate (3 × 25 ml.); the extract was washed with 10% potassium carbonate solution (10 ml.), water (10 ml.) and dried (magnesium sulfate). Evaporation, and recrystallisation of the residue from toluene gave *N,N'*-dibenzoate (VIj).

The *N,N'*-dibenzoate (IVo) (Table VI) was similarly prepared.

N-Acetylthiophene-2-sulfonoamide (VIk).

Thiophene-2-sulfonamide (1.6 g.) was refluxed with acetyl chloride (5 ml.)-acetic acid (5 ml.) for 30 minutes. Evaporation under reduced pressure gave a residue which was washed with water and recrystallised (toluene) to give the *N*-acetylsulfonamide (VIk) (1.2 g., 60%), m.p. 98-100°; ir: ν max 3150 (NH), 1700 (CO), 1350, 1160 (SO_2) cm^{-1}; ms: 205 (M^+), 162, 147, 100, 99, 83, 57, 44.

Anal. Calcd. for $C_6H_7NO_3S_2$: C, 35.1; H, 3.4; N, 6.8. Found: C, 35.4; H, 3.5; N, 7.0.

N-Benzoylthiophene-2-sulfonamide (VIl).

Thiophene-2-sulfonamide (1 g.) was refluxed with benzoyl chloride (1 g.) in dioxan (10 ml.) for 2 hours. Evaporation (reduced pressure) gave a solid residue which was shaken with water and 10% potassium carbonate solution. Recrystallisation (toluene-light petroleum 60-80°) (1:1) gave the *N*-benzoate (VII) (0.9 g., 56%), m.p. 108-110°; ir: ν max 3190 (NH), 1685 (CO), 1360, 1170 (SO_2) cm^{-1}.

N-Acetyl-*N*-trichloromethanesulfenylthiophene-2-sulfonamide (VIm).

A solution of *N*-acetylthiophene-2-sulfonamide (VIk) (2 g.) in ether (15 ml.) was added dropwise to a stirred solution of trichloromethanesulfenyl chloride (2.1 g.) and 10% sodium hydroxide solution (4 ml.) at 0°. The mixture was stirred for 24 hours at room temperature, and the precipitate collected and recrystallised from toluene to give *N*-trichloromethanesulfenyl derivative (VIm) (1.8 g., 50%), m.p. 95-96°; ir: ν max 1730 (CO), 1370, 1170 (SO_2) cm^{-1}; ms: 353 (M^+), 311 (M-$COCH_3$), 276, 247, 190, 163, 147, 131, 100, 44.

The following *N*-acyl-*N*-trichloromethanesulfenylthiophene-2-sulfonohydrazides were similarly prepared (VId,VIf).

Trifluoromethylpentane-2,4-dione Thiophene-2-sulfonohydrazone (VIIb) (Table VII).

Thiophene-2-sulfonohydrazide (VIa) (2 g.) was boiled under reflux with trifluoroacetylacetone (1.75 g.) in methanol (25 ml.) for 24 hours. Evaporation and crystallisation gave the hydrazone (VIIb).

3-Trifluoromethyl-5-methylthiophene-2-sulfonylpyrazole (VIIIc) (Table VIII).

Trifluoromethylpentane-2,4-dione thiophenesulfonohydrazone (VIIb) (1 g.), sodium sulfate (4 g.) and potassium carbonate (2 g.) suspended in toluene (25 ml.) was boiled under reflux for 3 days. The inorganic compounds were filtered off and the solid washed with ethyl acetate. The filtrate and washings were evaporated to dryness and the residue recrystallised from toluene to give the pyrazole (VIIIc).

4-Carbethoxy-3,5-dimethyl-1-(thiophene-2'-sulfonyl)pyrazole (XI, R = OC_2H_5).

A solution of thiophene-2-sulfonohydrazide (VIa) (2 g.) and ethyl diacetylacetate (X) (2 g.) (14) in ethanol (30 ml.) was boiled under reflux for 2 hours. Concentration and cooling afforded the carbethoxypyrazole (XI) (2.8 g., 80%), m.p. 131-132°; nmr (deuteriochloroform): δ 7.96-7.9 (1H, m, thiophene-3H); 7.86-7.80 (1H, m, thiophene-5H); 7.25-7.15 (1H, m, thiophene-4H); 4.36 (2H, q, CH_2); 2.9-2.48 (6H, 2 xs, 3,5-$(CH_3)_2$); 1.39 (3H, t, CH_2CH_3); ir: ν max 3110 (thiophene CH), 1710 (CO), 1380, 1190 (SO_2) cm^{-1}.

Anal. Calcd. for $C_{12}H_{14}N_2O_4S_2$: C, 45.85; H, 4.5; N, 8.9. Found: C, 46.0; H, 4.5; N, 8.9.

This was converted to the 4-carboxyphosphorodichloridate (XI, R = $OP(O)Cl_2$) by refluxing the pyrazole (X, R = OC_2H_5) (1.8 g.) with phosphoryl chloride (5 ml.) for 1 hour. Removal of the excess phosphoryl chloride under reduced pressure gave the phosphorodichloridate as an oil (2.1 g., 90%). The compound darkened on standing and decomposed on attempted vacuum distillation; ir: ν max 3100 (thiophene CH), 1670 (CO), 1350, 1160 (SO_2), 1260 (PO) cm^{-1}; ms: 402 (M^+), 285, 241, 182 ($C_4H_3SSO_2Cl$), 147 ($C_4H_3SSO_2$), 117, 100, 83.

3-(Thiophene-2'-sulfonyl)pentane-2,4-dione (XII).

A mixture of acetylacetone (5 g.) and sodium hydride (1.2 g.) was refluxed in tetrahydrofuran (30 ml.) for 30 minutes. Thiophene-2-sulfonyl chloride (VIc) (9.2 g.) was added and the mixture stirred for 12 hours at room temperature. The solvent was evaporated off under reduced pressure, the oily residue was diluted with water (10 ml.) and extracted with ether (3 × 25 ml.). The extract was dried (magnesium sulfate) and the ether distilled off to give the sulfone (XI) as an oil (9.5 g., 78%); ir: ν max 3100 (thiophene CH), 3040 (br, OH), 1670 (CO), 1370, 1180 (SO_2) cm^{-1}; the Beilstein test for Cl was negative. The sulfone was characterised by the preparation of the pyrazole (XIII).

3,5-Dimethyl-4-(thiophene-2'-sulfonyl)pyrazole (XIII).

3-(Thiophene-2'-sulfonyl)pentane-2,4-dione (XII) (1 g.) in ether (15 ml.) was gradually added to hydrazine hydrate (2 ml.) at 0°. After 12 hours at room temperature water (10 ml.) was added, the ether layer was separated and the aqueous solution further extracted with ether (2 × 20 ml.). The combined ether extract was dried (magnesium sulfate) and evaporated; the residue was crystallised from light petroleum (b.p. 60-80°) to give the pyrazole (0.6 g., 60%), m.p. 73°; ir: ν max 3420 (NH), 3110 (thiophene CH), 1380, 1180 (SO_2) cm^{-1}; ms: 243 (M^+ + 1), 178 (M-SO_2), 147 (C_4H_3S-SO_2), 110, 99, 95, 83 (C_4H_3S).

Anal. Calcd. for $C_9H_{10}N_2O_2S_2$: C, 44.6; H, 4.15; N, 11.6. Found: C, 44.7; H, 4.1; N, 11.9.

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