The Reaction of Diazoalkanes with Thiophen

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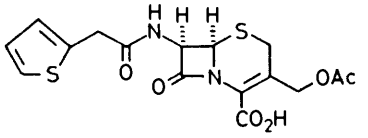
During the rhodium-catalysed reaction of thiophen with diazoalkanes, three types of product are observed depending on the nature of the diazoalkane. With diazomalonic esters stable ylides are formed. Simple diazoketones such as diazoacetophenone result in 2-substitution of the thiophen ring whereas diazoacetic esters react to give 2-thiabicyclo[3.1.0]hex-3-ene derivatives. Diazoacetoacetic esters give mixed 2-substitution–cyclopropanation, with the former predominating.

OVER the last twenty years there has been a growing interest in the use of thiophen and its derivatives in medicinal chemistry [1] and in particular 2-thienylacetic acid and 3-thienylmalonic acid have found use in the production of the semisynthetic β-lactam antibiotics cephalothin (1) and ticarcillin (2).



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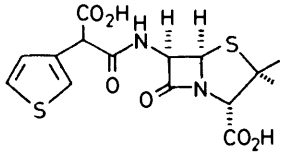

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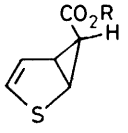

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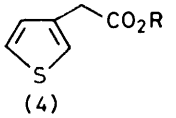

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Although 2-thienylacetic acid is readily available by a number of routes,[2] existing methods for the production of 3-thienylmalonic acid are circuitous and as such very costly.

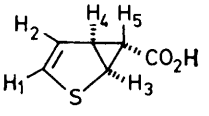
The reactions of thiophen with diazoacetic esters under thermal [3] and photochemical conditions are well established and the resultant cyclopropanated derivatives (3) are stable and may be transformed into 3-thienylacetates [4] (4) by acid-catalysed rearrangement, although a number of points about these reactions need to be clarified. The available microanalytical data and general chemistry of the addition products of diazoacetic esters and thiophen suggest structure (3); however no evidence exists to indicate whether (3) is formed as a mixture of *exo*- and *endo*-isomers or whether there is any preference for the formation of a single product.

Attempts to analyse the ^{1}H n.m.r. spectrum of (3; R = Et) were fraught with difficulty due to overlapping signals and (3) was hydrolysed to the corresponding acid (5). The acid (5) showed a virtually identical n.m.r. spectrum to that of the ester (3; R = Et) with the exception that the high-field ethyl triplet (which formerly obscured a one-proton triplet at τ 8.9) and the methylene quartet at τ 6.10 were removed, thus simplifying the spectrum. The spectrum was first order and decoupling permitted assignment of all protons and the determination of the coupling constants (Table 1). A number of points are worth comment: the two low-field multiplets centred at τ 6.4 and 6.87 correspond to two AB quartets (δ_{AB} 41 and 27 Hz, respectively) in which each half of the quartet is split due to further couplings. The large (1.7 Hz) four-bond coupling between 1- and 3-H almost certainly arises from the W (molecular models) arrangement of these two protons. The appearance of 5-H as a triplet rather than the expected doublet of doublets is a consequence of the identical coupling constants $J_{4,5}$ and $J_{3,5}$. Furthermore the small coupling constants (3.2 Hz) for $J_{4,5}$ and $J_{3,5}$ are consistent [5] with a *trans*-arrangement of these protons in the cyclopropane ring, confirming that the adduct has *exo*-stereochemistry.

The reaction of diazoacetic esters with thiophen is remarkably susceptible to variations in conditions and the yield of cyclopropanated product is usually low (20%).[3,4] Clearly, for this method to represent a practical synthesis of 3-thienylacetates, a higher yield at the cyclopropanation step is desirable and we have examined the effect of temperature and catalyst on this reaction. Conventionally copper catalysts [6] have been used, but the recent report of Hubert and his co-workers [7] that rhodium(II) acetate catalyses carbenoid formation from diazoalkanes prompted us to examine the use of this catalyst. We also decided that it was desirable to

TABLE 1

N.m.r. data for compound (5)



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Proton	Chemical shift (τ) [a]	Coupling constants (J/Hz)
1-H	3.8	$J_{1,2}$ 5.8, $J_{1,3}$ 1.7, $J_{1,4}$ 0
2-H	4.1	$J_{1,2}$ 5.8, $J_{2,4}$ 2.8
3-H	6.4	$J_{3,4}$ 7.5, $J_{3,5}$ 3.2, $J_{1,3}$ 1.7
4-H	6.87	$J_{4,3}$ 7.5, $J_{4,5}$ 3.2, $J_{4,2}$ 2.8, $J_{4,1}$ 0
5-H	8.9	$J_{5,4} = J_{5,3} = 3.2$

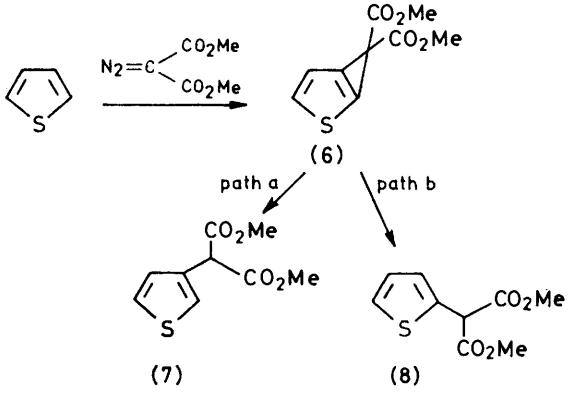
[a] Recorded at 90 MHz on a Perkin-Elmer R32 as 10% w/v solutions in $CDCl_3$, with tetramethylsilane as an internal standard.

use the relatively stable n-butyl diazoacetate rather than the ethyl ester and Table 2 shows the effect of copper(I) and rhodium(II) catalysts on the reaction. The most obvious conclusion which may be drawn is that rhodium(II) catalysis is far superior to copper(I) catalysis. In the case of copper(I) catalysts most of the diazoester is converted to di-n-butyl fumarate.

Although these results were quite reproducible on a small scale we found that when we attempted to scale up the reactions, although the times taken for the reactions to go to completion were the same, lower yields of distilled products were obtained. In all cases we obtained large distillation residues which led us to the conclusion that the 2-thiabicyclo[3.1.0]hex-3-enecarboxylates (3) are thermally labile and prolonged heating during distillation causes decomposition.

Treatment of the cyclopropane (3; R = Bu^n) with 5% ethanolic HCl at 40 °C over 3 days results in a smooth rearrangement to ethyl 2-(3-thienyl)acetate in 76% yield, which corresponds to an overall conversion of thiophen to the 3-acetate of 54%.

The facility with which (3) undergoes rearrangement to 3-thienylacetates (4) prompted us to consider the possible consequences of the addition of diazomalonic ester * to thiophen. Thus if addition occurs by a similar mechanism to give the cyclopropane (6), then under suitable conditions (6) might be induced to yield 3-thienylmalonic esters (7) (Scheme, path a) or possibly 2-thienylmalonic esters (8) (Scheme, path b) and this



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route would offer distinct advantages over existing methodology in that both (7) and (8) would be available through a single intermediate.

The reaction of thiophen with diazomalonic ester proved to be impractically slow in the presence of copper catalysts and even after 8 days at reflux some of the diazo-ester remained unchanged. When the reaction was worked up the major product was found to be 2-thienylmalonate (8) formed in 36% yield, with significant quantities of the carbene dimer (9) also being present. With rhodium acetate the reaction became significantly faster; thus heating a mixture of diazomalonic ester and thiophen in the presence of a catalytic quantity of rhodium(II) acetate † resulted in a violent reaction and i.r. examination after the initial reaction subsided showed that no diazo-ester remained. On removal of the excess of thiophen the only product was the dimer (9) formed in quantitative yield.

When the diazo-ester was added to a solution of the rhodium catalyst in thiophen, the slow deposition of a crystalline solid occurred and this product was characterised as the ylide (10) by an *X*-ray crystal structure determination.[8] Recently Ando and his co-workers [9] have reported that (10) may be prepared by a photochemically induced fragmentation of diazomalonic ester

TABLE 2

Reaction of n-butyl diazoacetoacetate with thiophen

Catalyst	Temp. (°C)	Reaction time [a]	Yield of (3; R = Bu^n) (%)
Cu^I [e]	25	4 h	0 [b]
Cu^I [e]	85	15 min	0 [b]
CuCl	85	15 min	17.2 [c]
	25	No reaction	
	85	120 h	10.6
Rh^{II}	32	73 h	60 [d]
Rh^{II}	42	3 h	58 [d]
Rh^{II}	52	2.5 h	62 [d]
Rh^{II}	62	30 min	62 [d]
Rh^{II}	85	15 min	71 [d]

[a] Monitored by the disappearance of the diazo-band in the i.r. spectrum. [b] No product detected. [c] Isolated by preparative t.l.c. [d] Isolated by distillation. [e] See ref. 6.

in thiophen, and aside from minor differences in the spectroscopic properties, our data are in close agreement with those of Ando.

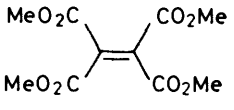
Substituted thiophens might also be expected to undergo similar reactions with diazomalonic esters and an examination of substituent effects has been carried out. Simple alkyl thiophens, *e.g.* 2-methylthiophen, react readily giving high yields of the corresponding ylides. Similarly halogenothiophens also give high yields of ylides, but when cyano, formyl, acetyl, or alkoxycarbonyl substituents are present in the ring, no ylide formation occurs presumably due to the reduced availability of the lone pair of electrons on the ring sulphur atom as a consequence of mesomeric interaction with the substituent. Benzo[*b*]thiophen also reacts to give a high yield of the corresponding ylide (11). Clearly the formation of a large number of ylides indicates that they are relatively stable and further examination of factors other than ring substitution, which might serve to stabilise the thiophenium ylides, was undertaken.

Diethyl diazomalonate also appears to give stable ylides and we turned our attention to Meldrum's diazo (12) since this compound might be expected to exhibit similar behaviour [10] to diazomalonic esters. Somewhat surprisingly the rhodium(II)-catalysed reaction of Meldrum's diazo with thiophen proved to be exception-

* Diazomalonic ester refers to dimethyl diazomalonate unless otherwise specified.

† Solutions of rhodium(II) acetate in thiophen are usually blue-green in colour. However, when the thiophen is impure a purple colour develops and under these conditions the catalyst is less effective.

ally slow. After 3 days at room temperature the diazo-band in the i.r. spectrum showed no diminution in intensity and the reaction mixture was heated at 50 °C for 3 days with no effect. Higher temperatures although increasing the rate of decomposition of the diazo-ester, did not provide a clean reaction and dark brown polymeric products were obtained. The failure of Meldrum's diazo to undergo reaction under these conditions must reflect the reduced reactivity of (12) with the rhodium salt to give a carbenoid intermediate. At elevated temperatures when the carbenoid is formed



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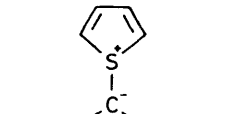

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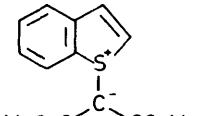

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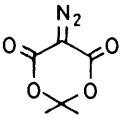

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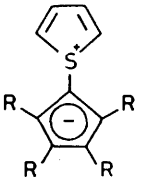

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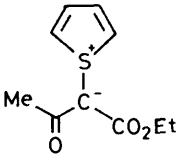

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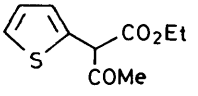

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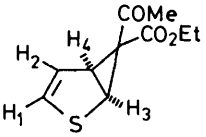

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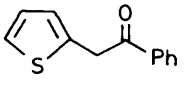

(17)

then the Wolff rearrangement [10] and subsequent decomposition to by-products must represent a more attractive reaction pathway than ylide formation, which is only favourable at ambient temperature.[8]

Durr and his co-workers have previously reported [11] that diazotetraphenylcyclopentadiene reacts with thiophen under photochemical conditions although the yield of product (13; R = Ph) was not specified. In an attempt to prepare (13; R = H) we set out to prepare diazocyclopentadiene [12] but an explosion occurred during the distillation of the diazo-compound and this aspect of the work was not continued further. The observation of compounds such as (13; R = Ph) does, however, provide further evidence of the stability of thiophenium ylides.

In view of the fact that diazomalonic esters give rise to the ylides (10) whereas diazoacetic esters and diazomethane [13] give rise to cyclopropanated products, then systems capable of delocalisation of the negative charge on the ylide carbon atom might also stabilise the ylide structure. Thus, diazo-ketones or diazoacetoacetic esters might be expected to be ideal substrates for ylide formation.

The synthesis of ethyl diazoacetoacetate was readily accomplished by a standard diazo-transfer reaction using tosyl azide [6] and the rhodium-catalysed addition to thiophen was complete in 20 h at room temperature. However, on removal of the excess of thiophen the ylide (14) was not obtained; instead an oily residue remained which was shown to be a mixture of two products by t.l.c. The two products were readily separated by column chromatography and they, 60 and 5% yield, respectively, were both shown by mass spectrometry and microanalysis to be 1 : 1 adducts of the carbenoid and thiophen.

The i.r. spectrum of the major product showed absorptions at 1 720 and 1 640 cm^{-1} typical of a β-keto-ester, but the ^1H n.m.r. spectrum was more informative, showing thiophen ring protons at τ 2.9 (1 H) and 3.2 (2 H), a methine proton at 5.2, and two signals at 7.9 and 8.1, integrating for three protons, which are readily assignable to the keto and enol forms of the 2-substitution product (15). The D_2O exchange of the signal appearing at τ −3.3 and the methine proton at 5.2 serve as further evidence in support of this assignment.

The minor product again showed typical β-keto-ester carbonyl absorptions. The ^1H n.m.r. spectrum bears a striking resemblance to that of the ester (3; R = Et) with one-proton multiplets at τ 3.45, 4.03, 4.4, and 4.7, two overlapping methylene quartets at 5.83, two sharp singlets at 7.7 and 7.71, and two overlapping ethyl triplets at 8.85. Decoupling experiments were fraught with difficulty, thus the presence of two ethyl and two acetyl signals indicates that although the product is chromatographically homogeneous, it is a mixture of two products [*exo*- and *endo*-isomers of (16)]. Clearly, any small chemical shift difference between the equivalent protons in the *exo*- and *endo*-isomers will result in broadening the spectral lines. The appearance of a number of strongly coupled signals in a narrow range of the spectrum means that when the second radiofrequency signal is applied to bring about decoupling, there is usually a significant amount of line broadening, particularly in those peaks closest to the frequency of irradiation. This has the effect of precluding the decoupling of any signal within *ca.* 50 Hz of the decoupling frequency. However, it was possible by direct measurements from scale-expanded spectra and with the aid of a limited number of decoupling experiments to make proton assignments and to obtain coupling constants (Table 3), confirming that the minor product was a mixture of the cyclopropanes (16).

When the reaction of ethyl diazoacetoacetate with thiophen was carried out by the dropwise addition of the diazoester to a refluxing solution of the rhodium catalyst

in thiophen, the reaction was complete within a matter of minutes and (15) and (16) were obtained in yields of 67 and 13% respectively.

The reaction with diazoacetophenone was not clean and the only product which was isolated was the 2-substitution product (17) formed in *ca.* 20% yield.

From these observations it can be seen that three types of product may arise during the reaction of thiophen with diazoalkanes. In the case of diazomalonic esters and diazocyclopentadienes, stable thiophenium ylides are formed. Other diazoalkanes result in cyclopropanation or 2-substitution of the thiophen ring. It seems probable that these products can be rationalised in terms of a single mechanistic scheme involving initial ylide formation in all cases. and further work is in hand to confirm this point.

TABLE 3

N.m.r. data for compound (16)

Chemical shift (τ) [a]	Assignment	Coupling constants (J/Hz) [b]
3.45	1-H	$J_{1.2}$ 6, $J_{1.4}$ 1
4.03	4-H	$J_{4.3}$ 10, $J_{4.2}$ 3, $J_{4.1}$ 1
4.4	2-H	$J_{2.1}$ 6, $J_{2.4}$ 3
4.7	3-H	$J_{3.4}$ 10 [c]
5.83	CH_2CH_3	J 7
7.70, 7.71	$COCH_3$	
8.85	CH_2CH_3	J 7

[a] 10% w/v solutions in $CDCl_3$ with tetramethylsilane as an internal standard. [b] All couplings quoted to the nearest whole number. [c] The difference in chemical shift of 3-H in the *exo*- and *endo*-isomers prevented the determination of other small couplings which broaden the signal.

EXPERIMENTAL

M.p.s were determined on a Kofler block and are uncorrected. N.m.r. spectra were recorded on Perkin-Elmer R24 (60 MHz) or R32 (90 MHz) instruments. Ethyl and butyl diazoacetate were prepared by the method of Searle.[14] Diazomalonic esters and ethyl diazoacetoacetate were prepared by the method of Wulfman *et al.*[6] and diazoacetophenone was prepared by the method of Bridson and Hooz.[15] Column chromatography was carried out using Merck Kieselgel HF_{254}.

2-Thiabicyclo[3.1.0]*hex-3-ene-6-carboxylic Acid* (5).—Thiophen (10 g) and ethyl diazoacetate (1.14 g, 10 mmol) were stirred together in the presence of $[CuP(OEt)_3]^+I^-$ (ref. 6) (10 mg) at room temperature for 2 h, after which the diazo-band was no longer present in the i.r. spectrum. The excess of thiophen was removed on a rotary evaporator and the crude product was subjected to preparative t.l.c. (SiO_2–$CHCl_3$). The major product was removed and eluted to yield 6-ethoxycarbonyl-2-thiabicyclo[3.1.0]hex-3-ene [4] (3; R = Et) (0.34 g, 20%) as a pale yellow oil, $\nu_{max.}$ ($CHCl_3$) 2 850, 1 710, 1 460, 1 365, and 1 280 cm^{-1}; τ($CDCl_3$) 8.9 (4 H, m), 6.87 (1 H, m), 6.42 (1 H, m), 6.10 (2 H, q), 4.8 (1 H, m), and 3.1 (1 H, m).

This product was dissolved in 20% aqueous methanol (10 ml) and sodium (0.1 g) was added. When the sodium had dissolved the mixture was heated under reflux for 2 days, cooled, and reduced in volume. The residue was dissolved in water (20 ml) and the aqueous solution extracted with ether. The ether was discarded and the aqueous phase acidified and extracted with chloroform (2 × 10 ml), and the combined chloroform extracts dried ($MgSO_4$), filtered, and evaporated to yield a brown solid. The product was purified by passage through a silica column with $CHCl_3$–MeOH (9 : 1) and gave the title compound (5) (0.2 g) as a crystalline solid, m.p. 110—111.5 °C; $\nu_{max.}$ ($CHCl_3$) 3 300—2 500, 3 010, 1 690, 1 555, 1 440, 1 325, 1 287, and 1 230—1 205 cm^{-1}; τ($CDCl_3$) 8.9 (1 H, t), 6.87 (1 H, m), 3.8 (1 H, m), and −2.0br (1 H, s, exchangeable with D_2O) (Found: C, 50.7; H, 4.4; S, 22.55. $C_6H_6O_2S$ requires C, 50.7; H, 4.25; S, 22.55%).

General Conditions for the Catalysed Addition of n-Butyl Diazoacetate to Thiophen (*Table* 2).—To a solution of the catalyst (5 mg) in thiophen (10 ml) at the required temperature was added dropwise over 1.5 h, butyl diazoacetate (1.42 g, 10 mmol) in thiophen (5 ml). Evolution of nitrogen was normally observed. When the reaction was complete thiophen was removed under reduced pressure and the resultant brown liquid distilled to yield the product 6-n-butoxycarbonyl-2-thiabicyclo[3.1.0]hex-3-ene (3; R = Bu^n), b.p. 85—95 °C at 0.1 Torr, as a pale yellow liquid; $\nu_{max.}$ ($CHCl_3$) 2 850, 1 710, 1 460, 1 400, 1 365, 1 280, 1 170, 1 070, 1 030, 945, and 695 cm^{-1}; τ($CDCl_3$) 3.9 (1 H, m), 4.2 (1 H, m), 5.95 (2 H, m), 6.55 (1 H, m), 7.05 (1 H, m), 8.50 (4 H, m), and 9.05 (4 H, m).

Ethyl 3-Thienylacetate (4; R = Et).—6-n-Butoxycarbonyl-2-thiabicyclo[3.1.0]hex-3-ene (3; R = Bu^n) (7.92 g, 40 mmol) was added to a solution of HCl in ethanol (100 ml, 5% w/v) and stirred at 40 °C for 3 days after which time t.l.c. indicated that no starting material remained. The solution was evaporated to dryness to yield an orange oil which was distilled, b.p. 87 °C at 0.15 Torr (lit.,[16] 107—115 °C at 6 Torr); τ($CDCl_3$) 2.95 (1 H, m), 3.05 (2 H, m), 5.95 (2 H, q), 4.30 (2 H, s), and 8.85 (3 H, t).

Copper(I)*-catalysed Addition of Dimethyl Diazomalonate to Thiophen.*—To a solution of $[CuP(OEt)_3]^+I^-$ (25 mg) in thiophen (100 ml) was aded a solution of dimethyl diazomalonate (12.72 g, 0.08 mol) in thiophen (10 ml). The mixture was heated under reflux for 8 days. Filtration followed by evaporation of the excess of thiophen yielded a brown oil which was fractionally distilled to yield 2-thienylmalonate (8) (6.2 g), b.p. 89—94 °C at 0.06 Torr; $\nu_{max.}$ (film) 2 955, 1 735, 1 432, and 1 240 cm^{-1}; τ($CDCl_3$) 2.9 (3 H, m), 5.0 (1 H, s), and 6.3 (6 H, s) (Found: C, 50.2; H, 4.7; S, 15.05. Calc. for $C_9H_{10}O_4S$: C, 50.45; H, 4.7; S, 14.95%).

Rhodium(II) *Acetate-catalysed Addition of Diazomalonic Esters to Thiophen Derivatives. General Conditions.*—The diazo-compound (10 mmol) was added dropwise over 1 h to a solution of $Rh_2(OAc)_4$ (5 mg) in the thiophen derivative (10 ml). Stirring at room temperature was continued until the diazo-band was no longer present in the i.r. spectrum. In most cases filtration of the mixture gave the ylide as a solid. Thus prepared were *thiophenium bis(methoxycarbonyl)methylide* (93%), m.p. (acetonitrile) 145—146 °C; $\nu_{max.}$ ($CHCl_3$) 1 650, 1 435, 1 330, 1 230, and 1 090 cm^{-1}; τ($CDCl_3$) 2.9 (4 H, m) and 6.35 (6 H, s) (Found: C, 50.5; H, 4.5. $C_9H_{10}O_4S$ requires C, 50.45; H, 4.7%): *2,5-dichlorothiophenium bis(methoxycarbonyl)methylide* (90%), m.p. (acetonitrile) 174—174.5 °C; $\nu_{max.}$ ($CHCl_3$) 1 690, 1 660, 1 440, 1 330, and 1 095 cm^{-1}; τ($CDCl_3$) 3.10 (2 H, s) and 6.30 (6 H, s) (Found: C, 38.2; H, 2.8; S, 11.9; Cl, 25.3. $C_9H_8Cl_2O_4S$ requires C, 38.2; H, 2.85; S, 11.65; Cl, 25.05%): *thiophenium bis(ethoxycarbonyl)methylide* (90%), m.p. (acetonitrile) 111—111.5 °C; $\nu_{max.}$ ($CHCl_3$) 1 675, 1 640, 1 370, 1 310, 1 205—1 240br, and 1 085 cm^{-1}; τ($CDCl_3$) 2.90 (4 H, m), 5.95 (4 H, q), and 8.80 (6 H, t) (Found: C, 54.8; H,

5.8; S, 13.4. $C_{11}H_{14}O_4S$ requires C, 54.55; H, 5.8; S, 13.25%): 2,5-*dichlorothiophenium bis(ethoxycarbonyl)-methylide* (60%), isolated by column chromatography (SiO_2; $CHCl_3$–methanol, 97.5 : 2.5), m.p. (acetonitrile) 82.5—83 °C; $\nu_{max.}$ ($CHCl_3$) 1 690, 1 650, 1 370, 1 310, 1 205—1 240br, and 1 085 cm^{-1}; τ($CDCl_3$) 3.10 (2 H, s), 5.85 (4 H, q), and 8.75 (6 H, t) (Found: C, 42.4; H, 3.9; S, 10.5; Cl, 22.9. $C_{11}H_{12}Cl_2O_4S$ requires C, 42.45; H, 3.9; S, 10.3; Cl, 22.8%): 2-*methylthiophenium bis(methoxycarbonyl)-methylide* (92%), m.p. (ethyl acetate) 146—146.5 °C; $\nu_{max.}$ ($CHCl_3$) 1 680, 1 650, 1 435, 1 330, 1 210—1 240br, and 1 090 cm^{-1}; τ($CDCl_3$) 2.90 (1 H, m), 3.15 (2 H, m), 6.33 (6 H, s), and 7.75 (3 H, s) (Found: C, 52.3; H, 5.3; S, 14.4. $C_{10}H_{12}O_4S$ requires C, 52.65; H, 5.3; S, 14.05%): 2-*bromothiophenium bis(methoxycarbonyl)methylide* (73%), isolated by evaporation of the reaction mixture, m.p. (acetonitrile) 138—140 °C; $\nu_{max.}$ ($CHCl_3$) 1 680, 1 660, 1 435, 1 330, 1 245br, and 1 090 cm^{-1}; τ($CDCl_3$) 2.80 (1 H, m), 2.95 (2 H, m), and 6.30 (6 H, s) (Found: C, 37.0; H, 3.2; S, 11.1; Br, 27.6. $C_9H_9BrO_4S$ requires C, 36.85; H, 3.1; S, 10.95; Br, 27.3%): 2-*hydroxymethylthiophenium bis(methoxycarbonyl)methylide* (54%), isolated by evaporation of the reaction mixture, m.p. ($CHCl_3$) 133—133.5 °C; $\nu_{max.}$ ($CHCl_3$) 3 400br, 1 675, 1 630, 1 435, 1 330, 1 245, and 1 090 cm^{-1}; τ($CDCl_3$) 3.00 (2 H, m), 3.15 (1 H, m), 5.45 (2 H, d, *J* 6 Hz), 6.35 (6 H, s), 6.55 (1 H, t, *J* 6 Hz, exchanges with D_2O) (Found: C, 48.9; H, 5.0; S, 13.4. $C_{10}H_{12}O_5S$ requires C, 49.15; H, 4.95; S, 13.15%): 2-*bromo*-3-*methyl-thiophenium bis(methoxycarbonyl)methylide* (86%), m.p. (acetonitrile) 128.5—129 °C; $\nu_{max.}$ ($CHCl_3$) 1 680, 1 645, 1 440, 1 330, 1 225br, and 1 090 cm^{-1}; τ($CDCl_3$) 3.05 (2 H, s), 6.35 (6 H, s), and 7.80 (3 H, s) (Found: C, 39.1; H, 3.7; S, 10.0; Br, 26.2. $C_{10}H_{11}BrO_4S$ requires C, 39.1; H, 3.6; S, 10.45; Br, 26.0%): *benzo*[b]*thiophenium bis(methoxy-carbonyl)methylide* (97%), m.p. (acetonitrile) 177—177.5 °C; $\nu_{max.}$ ($CHCl_3$) 1 680, 1 650, 1 435, 1 330, 1 245br, and 1 090 cm^{-1}; τ($CDCl_3$) 2.45 (5 H, m), 3.25 (1 H, d), and 6.40 (6 H, s) (Found: C, 59.1; H, 4.7; S, 12.1. $C_{13}H_{12}O_4S$ requires C, 59.05; H, 4.6; S, 12.15%): 2,5-*dibromothiophenium bis-(methoxycarbonyl)methylide* (55%), m.p. (acetonitrile) 190—190.5 °C; $\nu_{max.}$ ($CHCl_3$) 1 690, 1 660, 1 440, 1 330, 1 250, and 1 095 cm^{-1}; τ($CDCl_3$) 2.90 (2 H, s) and 6.25 (6 H, s) (Found: C, 29.05; H, 2.15; S, 8.4; Br, 43.05. $C_9H_8Br_2O_4S$ requires C, 29.05; H, 2.15; S, 8.6; Br, 42.95%).

Reaction of Thiophen with Ethyl Diazoacetoacetate.—To a solution of $Rh_2(OAc)_4$ (5.5 mg) in thiophen (10 ml) was added dropwise over 30 min a solution of ethyl diazo-acetoacetate (1.56 g, 10 mmol) and the mixture stirred at room temperature for 20 h, after which time the i.r. spectrum contained no diazo-absorption band. The solvent was removed under reduced pressure and the residual oil examined by t.l.c. (light petroleum–ether, 4 : 1) which indicated that two products were present. The products were separated on a silica column eluting with light petroleum–ether (85 : 15) to yield *ethyl*-3-*oxo*-2-(2-*thienyl*)*butanoate* (15) (1.28 g, 60.5%); $\nu_{max.}$ ($CHCl_3$) 3 000, 2 990, 1 720, 1 640, 1 340, 1 260, 1 060, 920, 850, and 695 cm^{-1}; τ(CCl_4) 2.9 (1 H, d), 3.2 (2 H, m), 5.2 (s, exchanges with D_2O), 5.9 (2 H, q), 7.9 (s) and 8.1 (s) (total 3 H), 8.9 (3 H, dt, Et in the keto and enol forms), and −3.3 (s, exchanges with D_2O) (Found: C, 56.8; H, 5.8; S, 15.0. $C_{10}H_{12}O_3S$ requires C, 56.6; H, 5.7; S, 15.1%).

The minor product 6-*acetyl*-6-*ethoxycarbonyl*-2-*thiabi-cyclo*[3.1.0]*hex*-3-*ene* (16) (0.11 g, 5.2%) exhibited the following spectroscopic properties: $\nu_{max.}$ (CCl_4) 2 940—2 990, 1 705, 1 640, 1 210, 1 085, 970, and 715 cm^{-1}; τ($CDCl_3$) 3.45 (1 H, m), 4.03 (1 H, m), 4.7 (1 H, m), 5.83 (2 H, overlapping q), 7.70 and 7.71 (3 H, overlapping s), and 8.85 (3 H, overlapping t) (see Table 3) (Found: M^+, 212.052 4. $C_{10}H_{12}O_3S$ requires *M*, 212.050 8).

Reaction of Ethyl Diazoacetoacetate with Thiophen at Reflux.—To a refluxing solution of $Rh_2(OAc)_4$ (5 mg) in thiophen (10 ml) was added dropwise over 30 min ethyl diazoacetoacetate (1.72 g, 10 mmol). A vigorous reaction occurred, with the evolution of nitrogen being clearly visible. The reaction was complete almost immediately to yield a red solution which was evaporated to dryness to yield a red oil. The mixture of products was separated by column chromatography over silica to yield (15) (1.42 g, 67%) and (16) (0.28 g, 13%). These products exhibited identical spectroscopic properties to those described above.

Reaction of Diazoacetophenone with Thiophen.—To a stirred solution of $Rh_2(OAc)_4$ (5 mg) in thiophen (5 ml) was added dropwise, under nitrogen, diazoacetophenone (0.438 g, 3 mmol) in thiophen (5 ml). Nitrogen evolution occurred and the initially green solution became brown. The reaction was complete in 3 h at room temperature. Thiophen was evaporated and the resultant brown oil subjected to preparative t.l.c. (SiO_2; $CHCl_3$) to yield *phenyl* 2-*thienyl ketone* (17) (0.12 g, 22.6%) as a yellow oil. $\nu_{max.}$ (film) 3 015, 1 680, 1 595, 1 580, 1 440, 1 320, and 1 280 cm^{-1}; τ($CDCl_3$) 2.15 (2 H, m), 2.55 (3 H, m), 2.97 (1 H, m), 3.22 (2 H, m), and 5.73 (2 H, s) (Found: M^+, 202.046 6. $C_{12}H_{10}OS$ requires *M*, 202.045 3).

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