1,3-Dipolar Character of Six-Membered Aromatic Rings. Part XVIII.[1] Adducts from 3-Oxido-1-phenylpyridinium and their Quaternisation and Conversion into Tropone Derivatives

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3-Oxido-1-phenylpyridinium forms adducts with diethyl maleate, diethyl fumarate, styrene, *p*-substituted styrenes, and phenylacetylene. The concerted character of the cycloaddition is demonstrated by the preservation of the addend stereochemistry in the adducts. The adducts are quaternised under vigorous conditions: the methylation occurs with equatorial approach. Attempted Hofmann degradation of the quaternary salts frequently leads to demethylation, but the methyl acrylate adduct affords an isolable dihydrotropone which has been converted into the corresponding tropolone.

We have developed a synthesis of tropones by the quaternisation and subsequent Hofmann elimination of cycloadducts from 1-methyl-3-oxidopyridinium and 2π-electron dipolarophiles.[2] 3-Oxido-1-phenylpyridinium (2) is easier to prepare and handle,[3] and more reactive (see later), than its 1-methyl analogue. We have therefore examined it as a precursor for tropone synthesis and now report our results.

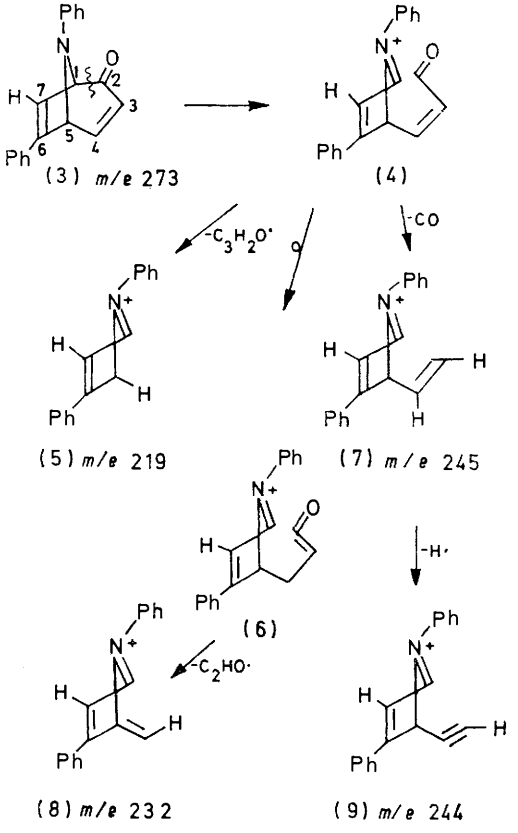
(1) (2)

Adduct Formation with 3-Oxido-1-phenylpyridinium.—Previous work[3] with this betaine has involved its isolation and reaction with electron-deficient olefins. We now find that it can be conveniently generated from the readily accessible[4] chloride (1) *in situ* with triethylamine and that it reacts readily with phenylacetylene and with styrenes.

The chloride (1) with phenylacetylene and triethylamine gave the adduct (3). This reaction demonstrates the superior reactivity of the betaine (2) in comparison with the 1-methyl analogue, which does not react with phenylacetylene. The structure of the cycloadduct (3) was confirmed by spectral data [ν(C=O) 1 680, ν(C=C) 1 640 cm^{-1}, and aromatic (1 600 cm^{-1}) bands; $\lambda_{max.}$ 246 nm (*cf.* styrene,[5] 247 nm); n.m.r. and mass spectra are discussed later].

The betaine (2), liberated *in situ* from the salt (1), also reacted with styrene, *p*-substituted styrenes, and 4-vinylpyridine, to give in each case a single yellow crystalline *endo*-adduct (10)—(13). These structures were supported by their i.r. and u.v. spectra (see Experimental section). Methyl acrylate and acrylonitrile similarly gave mixtures of *endo*-[(14) and (15)] and the corresponding *exo*-adducts, identical with the compounds previously[3] but less conveniently prepared from the isolated betaine (2).

Diethyl fumarate reacts with either the isolated betaine (2) or the betaine (2) prepared *in situ* with

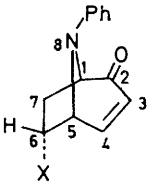


SCHEME 1

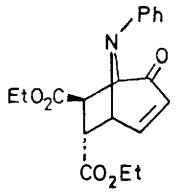
triethylamine to yield a mixture of the expected cycloadducts (16) and (17) (Table 1). Diethyl maleate reacts with the isolated betaine (2) to produce mainly the expected cycloadducts (18) and (19), together with small quantities of the isomeric adducts (16) and (17). However in the presence of triethylamine the isomers (16) and (17) were obtained in high yield, while the expected maleate cycloadducts (18) and (19) were present in low

[1] Part XVII, A. R. Katritzky, N. Dennis, and Y. Takeuchi, *Angew. Chem. Internat. Edn.*, 1976, **15**, 1.
[2] A. R. Katritzky and Y. Takeuchi, *J. Chem. Soc.* (*C*), 1971, 878.
[3] N. Dennis, A. R. Katritzky, T. Matsuo, S. K. Parton, and Y. Takeuchi, *J.C.S. Perkin I*, 1974, 746.
[4] C. F. Koelsch and J. J. Carney, *J. Amer. Chem. Soc.*, 1950, **72**, 2285.
[5] J. C. P. Schwarz, 'Physical Methods in Organic Chemistry,' Oliver and Boyd, Edinburgh and London, 1964, p. 147.

yield (Table 1). The presence of the fumarate cycloadducts (16) and (17) in the product from the diethyl maleate reaction is due to either base-catalysed *cis–trans*-isomerisation of the diethyl maleate or base-catalysed epimerisation of the initially formed maleate cycloadducts at C-7, or both.



(10) X = Ph
(11) X = *p*-BrPh
(12) X = *p*-ClPh
(13) X = 4-pyridyl
(14) X = CO_2Me
(15) X = CN



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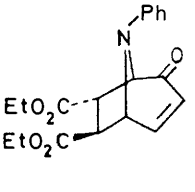

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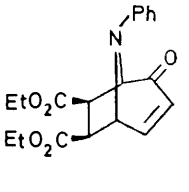

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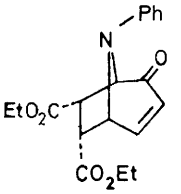

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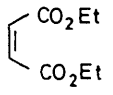

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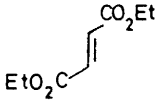


(21)

TABLE 1

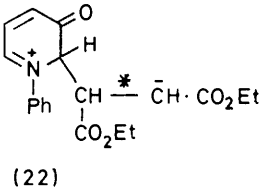
Reaction of betaine (2) with diethyl maleate and fumarate

Method	Ester	Yields of adducts (16)	(17)	(18)	(19)
Isolated betaine	Maleate	1.8	2.0	9.6	7.7
Isolated betaine	Fumarate	17	27		
Presence of NEt_3	Maleate	20	17	1.4	0.4
Presence of NEt_3	Fumarate	31	19	0.6	

We found that diethyl maleate (20) was partially isomerised to diethyl fumarate (21) by heating with triethylamine in acetonitrile, but that the latter (21) was stable under these conditions. Similar treatment of the adducts showed that (18) was isomerised to (17) and (19) to (16), evidently by epimerisation at C-7.

Stereospecificity of Adduct Formation.—The stereochemistry of the reactions with diethyl fumarate and maleate shows clearly that these reactions are concerted cycloadditions; specifically, the lifetime of any intermediate of type (22) is insufficient to allow free rotation about the asterisked C–C bond. We have previously demonstrated [6] such a situation for the reaction of the betaine (23) with dimethyl maleate or fumarate. The present work provides confirmation for a less reactive betaine. In the 2-(2,4-dinitrophenyl)-isoquinolinium series, reaction with dimethyl maleate did not proceed stereospecifically, which we attributed [7] to subsequent epimerisation of the adduct: the present work supports this explanation.

N.m.r. and Mass Spectra of Adducts.—The n.m.r. spectra of the new *endo*-adducts (10)—(13) showed the expected characteristic features.[3] The *endo*-stereochemistry is proved by the doublet for H-1 (coupling with H-7-*exo*) and triplet for H-5 (coupling with H-6-*exo* and H-4). The H-4 signal appears as a quartet (coupling with H-3 and -5) and H-3 gives a double doublet (Table 2). The assignments were confirmed by double irradiation studies: *e.g.* irradiation at the frequency of H-5 caused collapse of the H-4 quartet of each of the cycloadducts to a doublet, allowing the signal to be distinguished from the complex aromatic multiplet in which region it occurs. For the cycloadducts (16)—(19) derived from diethyl maleate and diethyl fumarate the stereochemistry of each isomer follows from the splitting of the H-1 and -5 signals. Thus, if the splitting due to W-type long-range coupling with H-3 ($J_{1,3}$ 1.5 Hz) is neglected, the H-1 signal appears as a singlet when H-7 is *endo* [(16) and (18)] ($J_{1,7\text{-}endo} < 1$ Hz) whereas it is a doublet if H-7 is *exo* [(17) and (19)] ($J_{1,7\text{-}exo}$ *ca.* 8 Hz). Further, the H-5 signal is a doublet if H-6 is *endo* [(17) and (18)] ($J_{4,5}$ *ca.* 5, $J_{5,6\text{-}endo} < 1$ Hz) but a double doublet if H-6 is *exo* [(16) and (19)] ($J_{4,5}$ *ca.* 5, $J_{5,6\text{-}exo}$ *ca.* 6 Hz) (Table 2). The assignment of the other peaks is based on the splitting patterns and comparisons with similar compounds. In the case of the phenylacetylene cycloadduct (3) the signals for the bridgehead protons H-5 and -1 appear as a triplet and a broad doublet, respectively. The lanthanide shift reagent $Pr(fod)_3$ [8] shifted upfield the H-1 and -3 signals to the greatest extent and those of H-7, -4, and -5 to the least extent; the shift reagent thus complexes preferentially with the ketonic carbonyl group, as expected.[9]



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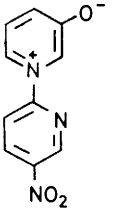


(23)

The mass spectra of the styrene cycloadducts (10)—(13) showed typical retro-1,3-dipolar cycloadditions [10] to give base peaks (*m/e* 171) corresponding to the 1-phenylpyridinium betaine (2). This ion (*m/e* 171) then fragments as expected [11] to give *m/e* 143 (loss of CO), 116, and 104. No retro-1,3-dipolar cycloaddition was

[6] N. Dennis, B. Ibrahim, and A. R. Katritzky, *J.C.S. Chem. Comm.*, 1974, 500.
[7] N. Dennis, A. R. Katritzky, and S. K. Parton, *Chem. and Pharm. Bull. (Japan)*, 1975, **23**, 2899.
[8] R. E. Rondeau and R. E. Sievers, *J. Amer. Chem. Soc.*, 1971, **93**, 1522.
[9] Z. W. Wolkowski, *Tetrahedron Letters*, 1971, 821.
[10] Y. Nomura, F. Furusaki, and Y. Takeuchi, *J. Org. Chem.*, 1972, **37**, 502.
[11] K. Undheim and G. Hvistendahl, *Org. Mass. Spectrometry*, 1970, **3**, 1423.

TABLE 2

Proton n.m.r. spectra [a] of cycloadducts derived from the betaine (2)

(a) With olefins and acetylenes

Chemical shifts (δ)

	(3) [b]	(10) [b]	(11) [b]	(12) [b]	(13) [b]	(14) [b,c]	(15) [b,c]
H-1	4.89 [d]	4.54 [d]	4.52 [d]	4.54 [d]	4.56	4.48 [d]	4.55 [d]
H-3	5.51 [e]	5.96 [e]	5.97 [e]	5.98 [e]	5.98 [e]	5.93 [e]	5.99 [e]
H-4	6.80 [f]	6.63 [f]	6.62 [f]	6.63 [f]	6.64 [f]	7.13 [f]	7.98 [f]
H-5	5.29 [g]	4.86 [g]	4.83 [g]	4.83 [g]	4.91 [g]	5.09 [h]	4.91 [h]
H-6-*exo*		4.05 [h]	4.00 [h]	4.03 [h]	4.04 [h]		
H-6-*endo*						3.07 [f]	3.12 [f]
H-7-*exo*		2.94 [i]	2.95 [i]	2.96 [i]	2.98 [i]	3.02 [i]	2.88 [i]
(7)	6.58 [d]						
H-7-*endo*		2.06 [f]	1.99 [f]	2.02 [f]	2.07	2.11 [j]	2.21
CO_2Me						3.74 [k]	

Coupling constants (Hz)

1,3	1.5	1.5	1.4	1.5	1.4	1.5	1.5
1,7-*endo*		1.0	1.0	1.0	1.5	0.8	1.0
(1,7)	3.5						
1,7-*exo*		8.0	7.8	8.0	8.0	7.8	8.0
3,4	10.0	10.0	9.8	10.0	10.0	9.8	10.0
4,5	5.0	5.0	4.8	5.0	4.8	4.8	5.0
5,6-*exo*		6.0	6.0	6.0	6.0		
5,6-*endo*						0.4	0.8
6-*exo*,7-*endo*		6.0	6.0	6.0	6.0		
6-*endo*,7-*endo*						9.4	9.4
6-*exo*,7-*exo*		10.0	9.8	10.0	10.0		
6-*endo*,7-*exo*						3.4	3.4
7-*exo*,7-*endo*		13.8	13.8	13.8	13.8	13.8	13.8

(b) With diethyl maleate and fumarate

Chemical shifts (δ)

	(16) [b]	(16)	(17) [b]	(17) [l]	(18) [b]	(18) [l]	(19) [b]	(19) [l]
H-1	4.75 [k]	4.92 [k]	4.79 [d]	4.72 [d]	4.87 [k]	5.07 [k]	4.72 [d]	4.53 [d]
H-3	5.93 [e]	5.70 [e]	5.97 [e]	5.68 [e]	5.98 [e]	5.52 [e]	6.05 [e]	5.30 [e]
H-4	7.07 [e]	6.4 [m]	7.2 [m]	6.35 [e]	7.14 [e]	6.16 [e]	7.56 [e]	*m*
H-5	5.03 [e]	4.68 [e]	5.09 [d]	4.86 [d]	5.03 [d]	4.66 [d]	4.86 [e]	4.32 [e]
H-6-*exo*	4.2 [m]	4.15 [g]					3.86 [e]	3.25 [e]
H-6-*endo*			3.63 [d]	3.64 [d]	3.45 [d]	3.8 [m]		
H-7-*exo*			4.2 [m]	4.23 [e]			4.3 [m]	3.7 [m]
H-7-*endo*	3.43 [d]	3.59 [d]			3.29 [d]	3.00 [d]		
OCH_2CH_3	4.25 [f]	3.85 [f]	4.14 [f]	3.89 [f]	4.20 [f]	3.88 [f]	4.2 [f]	3.89 [f]
	4.30 [f]	3.89 [f]	4.22 [f]		4.23 [f]	3.92 [f]		3.91 [f]
OCH_3CH_3	1.25 [g]	0.90 [g]	1.26 [g]	0.90 [g]	1.30 [g]	0.92 [g]	1.26 [g]	0.94 [g]
	1.28 [g]	0.92 [g]	1.29 [g]			0.96 [g]		0.98 [g]
Ph	6.9—7.3	6.6—7.0	6.8—7.2	6.6—7.0	6.9—7.2	6.7—7.0	6.9—7.3	6.7—7.0

Coupling constants (Hz)

1,3	1.4	1.5	1.3	1.5	1.5	1.5	1.4	1.3
1,7-*endo*	0.6	0.8			0.7	0.8		
1,7-*exo*			7.7	7.7	8.0	7.4	7.7	8.0
3,4	9.8	9.7	9.8	9.8	9.6	9.7	9.7	9.8
4,5	4.7	4.8	4.8	4.8	4.7	4.7	5.0	4.6
5,6-*endo*			0.4	0.4	0.4	0.4		
5,6-*exo*	6.2	6.2					5.5	5.8
6-*endo*,7-*endo*					9.5	9.2		
6-*endo*,7-*exo*			4.5	4.7				
6-*exo*,7-*endo*	6.1	6.0						
6-*exo*,7-*exo*							10.8	11.0

[a] In p.p.m. relative to Me_4Si as internal standard. [b] In $CDCl_3$. [c] *Cf.* N. Dennis, A. R. Katritzky, T. Matsuo, S. K. Parton, and Y. Takeuchi, *J.C.S. Perkin I*, 1974, 746. [d] Doublet. [e] Double doublet. [f] Quartet. [g] Triplet. [h] Sextet. [i] Octet. [j] Doublet of quartets. [k] Singlet. [l] In C_6D_6. [m] Obscured by other peaks.

observed in the mass spectrum of the adduct (3). Rupture of the 1,2-bond leads to (4), which fragments further by expulsion of carbon monoxide [to (7) (*m/e* 245)] and then loss of a hydrogen atom to give the base peak (9) (*m/e* 244). Alternatively, the 3,4-bond is cleaved (Scheme 1) with loss of $C_2HO\cdot$ to give species (8) (*m/e* 232). Species (4) also fragments by loss of $C_3H_2O\cdot$ [to (5) (*m/e* 219)]. A similar fragmentation pattern is found for related tropinones.[12]

Quaternisation of the Cycloadducts.—The *N*-methyl analogues [13] are quaternised easily by methyl iodide, but the *N*-phenyl adducts (10)—(13) are less reactive: mesomerism (p–π interaction) with the aromatic ring as in aniline [14] reduces the availability of the nitrogen lone pair. Kricka and Vernon [15] observed reduced nucleophilicity of a bridged nitrogen atom attached to phenyl. Milder alkylating reagents were unsuccessful, but stirring the cycloadducts (10)—(14) in dry dichloroethane at

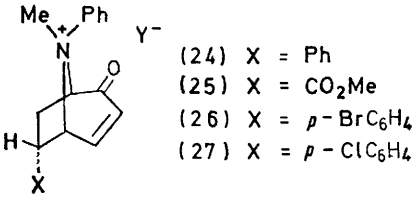
[12] E. C. Blossey, H. Budzikiewicz, M. Ohashi, G. Fodor, and C. Djerassi, *Tetrahedron*, 1964, **20**, 585.

[13] A. R. Katritzky and Y. Takeuchi, *J. Chem. Soc.* (*C*), 1971, 874.

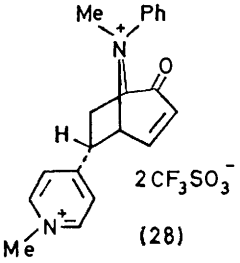
[14] J. D. Roberts and M. C. Caserio, 'Basic Principles of Organic Chemistry,' Benjamin, New York, 1964, p. 879.

[15] L. J. Kricka and J. M. Vernon, *J.C.S. Perkin I*, 1973, 766.

room temperature, with methyl fluorosulphonate [16] and with methyl trifluoromethanesulphonate [17] gave the respective quaternary salts (24)—(28). Methylation of the vinylpyridine cycloadduct (13) occurs simultaneously at the pyridine nitrogen atom to give the bis-salt (28).



(24) X = Ph
(25) X = CO_2Me
(26) X = p-BrC_6H_4
(27) X = p-ClC_6H_4



(28)

The i.r. spectra of the cycloadduct salts (24)—(28) all showed αβ-unsaturated ν(C=O) (1 700) and aromatic (1 600 cm^{-1}) bands. Their n.m.r. spectra reflect deshielding of the ring protons H-3, -4, -6, and -7, and especially the bridgehead protons H-1 and -5 due to the quaternary nitrogen atom; for quaternary ammonium salts the charge on the nitrogen reduces the electron density decreasingly with distance.[18] The proton n.m.r. spectral assignments (Table 3) were determined by their multiplicities and chemical shifts relative to the original cycloadducts (10)—(14).

TABLE 3

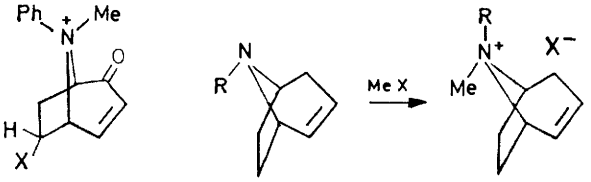
Proton n.m.r. spectra of cycloadduct fluorosulphonate and trifluoromethanesulphonate salts [a]

Chemical shifts (δ)					
	(24) [b]	(25) [b]	(26) [c]	(27) [c]	(28) [c]
H-1	5.66 [d]	5.51 [d]	5.93 [d]	5.94 [d]	6.08 [d]
H-3	6.10 [e]	6.19 [e]	6.30 [e]	6.32 [e]	6.35 [e]
H-4	6.88 [f]	7.43 [f]	7.17 [f]	7.21 [f]	7.35 [f]
H-5	6.16 [g]	6.05 [g]	6.57 [g]	6.60 [g]	6.79 [g]
H-6-*exo*	4.95 [h]	4.52 [h]	5.19 [h]	5.24 [h]	5.61 [h]
H-7-*exo*	3.53 [i]	3.34 [i]	3.78 [i]	3.79 [i]	3.98 [i]
H-7-*endo*	2.65 [f]	2.77 [f]	2.74 [f]	2.83 [f]	3.06 [f]
NMe	3.84 [j]	3.78 [j]	4.09 [j]	4.07 [e]	4.13 [j]
					4.70 [j]
CO_2Me		3.62			
NPh	7.8—7.3 [k]	7.8—7.3 [k]	7.5—8.1 [k]	7.4—8.1 [k]	7.6—9.3 [k]
Coupling constants (Hz)					
1,3	1.5	1.5	1.4	1.5	1.4
1,7-*endo*	1.0	1.5	1.5	1.0	1.5
1,7-*exo*	8.0	8.0	7.8	8.0	8.0
3,4	10.0	10.0	9.8	10.0	10.0
4,5	5.0	4.8	4.8	5.0	4.8
5,6-*exo*	6.0	6.0	6.0	6.0	6.0
6-*exo*,7-*endo*	6.0	6.1	6.0	6.0	6.0
6-*exo*,7-*exo*	10.0	10.0	9.8	10.0	10.0
7-*endo*,7-*exo*	13.8	13.8	13.8	13.8	13.8

[a] In p.p.m. relative to Me_4Si as internal standard. [b] In D_2O. [c] In $(CD_3)_2CO$. [d] Doublet. [e] Double doublet. [f] Quartet. [g] Triplet. [h] Sextet. [i] Octet. [j] Singlet. [k] Complex.

The fluorosulphonate and trifluoromethanesulphonate salts (24)—(28) fragment in the mass spectrometer to give usually the base peak at *m/e* 171, corresponding to the original *N*-phenyl betaine (2), and a fragment ion corresponding to the respective dipolarophile obtained from the retro-1,3-dipolar cycloaddition. Thus initial dealkylation must occur (one of the three major fragmentation modes [19] for quaternary ammonium salts).

Stereochemistry of Quaternisation.—Evidence for the stereochemistry shown in structures (10)—(14) derives from nuclear Overhauser effect experiments [20] in which enhancement of the methyl signal was observed on saturation of the H-6-*exo* signal. This indicates the proximity of these protons and excludes structures of type (29).



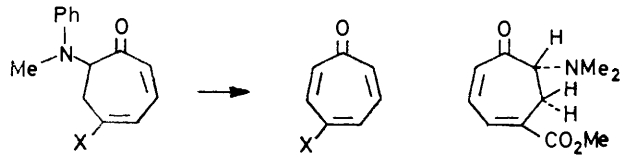
(29) (30) (31)

Fodor *et al.*[21] for tropanes and Supple and Eklum [22] for tropidines (30) demonstrated that the preferred steric course for quaternisation is equatorial approach of the entering group [*cf.* (30) ⟶ (31)]. Our results indicate that the *N*-phenyl cycloadducts (10)—(14) behave similarly to the tropidine (30), and that quaternisation of the nitrogen by methyl fluorosulphonate or trifluoromethanesulphonate takes place preferentially at the equatorial position to give the salts (24)—(28).

Attack of Base on the Quaternary Salts.—Hofmann degradation of the cations (24)—(27) could occur with attack of base at H-6 or -7. If H-6 is activated by a strongly electron-withdrawing group, ring-opening should proceed solely *via* cleavage of the C(5)–N bond to give the substituted cycloheptadienones of type (32), with possible further deamination to (33). Treatment of the quaternary salts (24) and (27)—(29) with sodium hydrogen carbonate, silver oxide, triethylamine, pyridine, sodium hydroxide, potassium t-butoxide, collidine, or lutidine, always gave either the unchanged salt or the original demethylated cycloadduct. This demethylation to the stable cycloadduct rather than Hofmann degradation is ascribed to the weak acidity of H-6-*exo*;

[16] R. W. Alder, *Chem. and Ind.*, 1973, 983.
[17] J. Burdon and V. C. R. McLoughlin, *Tetrahedron*, 1965, **21**, 1.
[18] G. Fraenkel and J. P. Kim, *J. Amer. Chem. Soc.*, 1966, **88**, 4203.
[19] H. Budzikiewicz, C. Djerassi, and D. H. Williams, 'Mass Spectrometry of Organic Compounds,' Holden–Day, San Francisco, 1967, p. 330.
[20] H. Booth and R. U. Lemieux, *Canad. J. Chem.*, 1971, **49**, 777.
[21] G. Fodor, R. V. Chastain, jun., D. Frehel, M. J. Cooper, N. Mandava, and E. L. Gooden, *J. Amer. Chem. Soc.*, 1971, **93**, 403.
[22] J. H. Supple and E. Eklum, *J. Amer. Chem. Soc.*, 1971, **93**, 6684.

similar demethylation on treatment with base has been observed [23] for other quaternised systems.

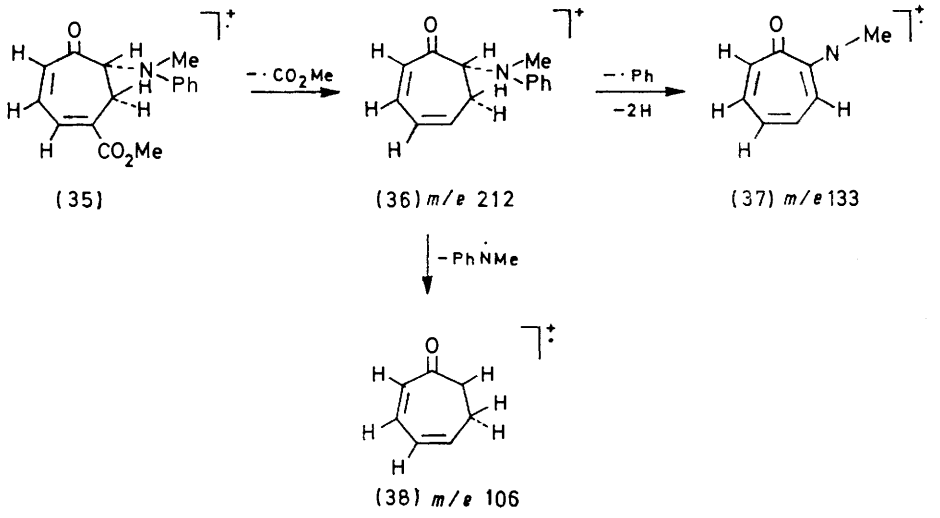


(32) (33) (34)

In the methoxycarbonyl quaternary salt (25) the acidity of H-6-*exo* is increased. Here sodium hydrogen carbonate causes Hofmann degradation to the deep-red cycloheptadienone (32; X = CO_2Me), which is stable to light and air, unlike (34), which was not isolated owing to further dehydrogenation.[2] Assignment of structure (32; X = CO_2Me) is based on spectral and analytical evidence. The i.r. spectrum showed ester (1 700 cm^{-1}) and ketone (1 660 cm^{-1}) ν(C=O). The low frequency of the former is due to extended conjugation, and the latter absorption is characteristic of a conjugated dienone system [24] such as eucarvone.[25] The u.v. spectrum (see Experimental section) also supports a highly conjugated structure.[24,26]

The n.m.r. spectrum exhibits the expected signals for the phenyl, vinyl, methylene, methine, and methyl protons: the H-2 signal occurs as a double doublet ($J_{2.3}$ 12.0, $J_{2.4}$ 0.5 Hz); that of H-3 is a quartet ($J_{3.4}$ 7.0 Hz); and H-4 gives a double doublet (coupled to both H-3 and H-2). The signals due to the saturated part of the ring approximate to an ABX pattern; the H-7-*ax* resonance occurs as a double doublet ($J_{6\text{-}eq,\ 7\text{-}ax}$ 1.5, $J_{6\text{-}ax,\ 7\text{-}ax}$ 12.0 Hz); and H-6-*eq* and H-6-*ax* give a double doublet and a complex multiplet respectively ($J_{6\text{-}eq,\ 6\text{-}ax}$ 14.0 Hz). Irradiation at the frequency of H-6-*ax* collapsed the double doublet of H-7-*ax* to a fine doublet; irradiation of the multiplet containing the H-3 and H-4 signals caused collapse of the double doublet of H-2 to a singlet. The coupling constants and chemical shifts agree with reported values for eucarvone [27] and other cycloheptadienones.[24,28]

Further confirmation of structure (32; X = CO_2Me) is provided by the low resolution mass spectrum. The base peak at *m/e* 107 corresponds to $PhNHMe^+$. Initial loss of carbon monoxide, typical of most aminotropones,[29] does not occur for (32; X = CO_2Me); instead the substituents dominate the initial cleavage. The molecular ion (35) loses a methoxycarbonyl radical to give (36) (*m/e* 212), and then a phenyl radical and molecular hydrogen to give (37) (*m/e* 133), which loses a hydrogen atom (*m/e* 132). Alternatively, an *N*-methylanilino-radical is lost from (36) to give (38) (*m/e* 106), which can lose a hydrogen atom (*m/e* 105) and then carbon monoxide (*m/e* 77) (Scheme 2). The last cleavage is typical of tropones.[29] Other tropones and tropolones fragment with initial cleavage of substituents before the loss of carbon monoxide [30] (Scheme 2).



(35) (36) *m/e* 212 (37) *m/e* 133

(38) *m/e* 106

SCHEME 2

Steric interactions between the *N*-methylanilino- and carbonyl groups probably contribute to the stability of (32; X = CO_2Me). Oxidation of compound (32; X = CO_2Me) with silver oxide,[2] which can also be used as a strong base in Hofmann degradations, gave 4-methoxycarbonyltropolone [2] (39). The i.r. spectrum showed ester ν(C=O) (1 725 cm^{-1}) and tropone ν(C=O) (1 620 cm^{-1}).[31,32] The u.v. spectrum also supported the

[23] K. T. Potts, S. K. Roy, and D. P. Jones, *J. Heterocyclic Chem.*, 1965, **2**, 105.
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[27] A. A. Bothner-By and E. Moser, *J. Amer. Chem. Soc.*, 1968, **90**, 2347.
[28] D. J. Bertelli, T. G. Andrews, jun., and P. O. Crews, *J. Amer. Chem. Soc.*, 1969, **91**, 5286.
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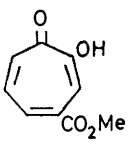
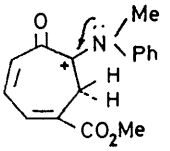
[30] P. L. Pauson, P. B. Kelly, and R. J. Porter, *J. Chem. Soc.* (*C*), 1970, 1323.
[31] Y. Ikegami, *Bull. Chem. Soc. Japan*, 1962, **35**, 972.
[32] S. Gronowitz, B. Yom-Tov, and U. Michael, *Acta Chem. Scand.*, 1973, **27**, 2257.

tropolone structure [33] (39) (see Experimental section). The n.m.r. spectrum confirmed structure (39) (absence of the anilino and aliphatic protons and the presence of aromatic proton signals).


(39)


(40)

The mass spectrum was also characteristic of structure (39), with a base peak at *m/e* 121 due to the loss of a methoxycarbonyl radical and subsequent losses of two molecules of carbon monoxide to give *m/e* 93 and *m/e* 65; a final loss of a hydrogen forms *m/e* 64. This is a typical [29] tropolone fragmentation; a more intense molecular ion peak is found for tropolones than tropones. This oxidation to give (39) probably involves hydride ion loss to the silver oxide with (40) as intermediate.

EXPERIMENTAL

M.p.s were determined with Reichert and Mitamura apparatus. Spectra were recorded with a Perkin-Elmer 257 i.r. grating spectrophotometer, a Jasco DS-4039 i.r. spectrophotometer, a Hitachi–Perkin-Elmer RMU-6E mass spectrometer, a Hitachi RMU-60 mass spectrometer, a Unicam SP 800A u.v. spectrophotometer, a JEOL JMH-100 n.m.r. spectrometer, and a Varian HA-100 n.m.r. spectrometer. Compounds were purified until they were observed as single spots on t.l.c. (Kieselgel PF 254).

Reactions of 3-*Hydroxy*-1-*phenylpyridinium Chloride* (1). —(i) *With phenylacetylene.* 3-Hydroxy-1-phenylpyridinium chloride (1) (5 g, 0.024 mol) and phenylacetylene (5.0 g, 0.05 mol) in dry MeCN (20 ml) were heated under reflux (82 °C). Et_3N (5 ml) was added dropwise to the refluxing solution during 0.5 h, and the refluxing continued for a further 12 h. The cooled mixture was then extracted with chloroform (3 × 50 ml) and the extract evaporated *in vacuo*. The solid product was purified by thick-layer chromatography [Kieselgel PF 254; light petroleum (b.p. 60—80 °C)–ethyl acetate (80 : 20)], to give 6,8-*diphenyl*-8-*azabicyclo*[3.2.1]*octa*-3,6-*dien*-2-*one* (3) (3.0 g, 46%) as yellow hexagonal plates, m.p. 182—183 °C (from EtOH) (Found: C, 83.2; H, 5.5; N, 5.0. $C_{19}H_{15}NO$ requires C, 83.5; H, 5.5; N, 5.1%); $\nu_{max.}$ ($CHBr_3$) 1 680 (αβ-unsat. C=O), 1 640 (C=C), 1 600, and 1 500 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 208 (ε 2.65 × 10^4) and 246 nm (2.70 × 10^4); *m/e* 273.

(ii) *With styrene.* The salt (1) (5 g, 0.024 mol) and styrene (4. 8 g, 0.05 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. The solid residue was purified by thick-layer chromatography [Kieselgel PF 254; PhMe–EtOAc (50 : 50)] to give 6-endo-8-*diphenyl*-8-*azabicyclo*-[3.2.1]*oct*-3-*en*-2-*one* (10) (3.33 g, 50%) as yellow hexagonal prisms, m.p. 105—106 °C (from EtOH) (Found: C, 82.7; H, 6.2; N, 5.2. $C_{19}H_{17}NO$ requires C, 82.8; H, 6.2; N, 5.1%); $\nu_{max.}$ ($CHBr_3$) 1 680 (αβ-unsat. C=O), 1 600, and 1 502 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 209 (ε 2.21 × 10^4) and 238 nm (1.88 × 10^4); *m/e* 275.

(iii) *With* p-*bromostyrene.* The salt (1) (4 g, 0.024 mol) and *p*-bromostyrene (9.1 g, 0.05 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. The solid residue was purified by thick-layer chromatography [Kieselgel PF 254; PhMe–EtOAc (50 : 50)] to give 6-endo-(4-*bromophenyl*)-8-*phenyl*-8-*azabicyclo*[3.2.1]*oct*-3-*en*-2-*one* (11) (5.0 g, 60%) as yellow hexagonal prisms, m.p. 180—181 °C (from EtOH) (Found: C, 64.1; H, 4.7; N, 4.0. $C_{19}H_{16}BrNO$ requires C, 64.4; H, 4.6; N, 4.0%); $\nu_{max.}$ ($CHBr_3$) 1 680 (αβ-unsat. C=O), 1 600, and 1 502 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 209 (ε 2.50 × 10^4) and 232 nm (3.04 × 10^4); *m/e* 353.

(iv) *With* 4-*vinylpyridine.* The salt (1) (5 g, 0.024 mol) and 4-vinylpyridine (5.25 g, 0.05 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. The solid residue was purified by thick-layer chromatography [Kieselgel PF 254; PhMe–EtOAc (60 : 40)] to give 8-*phenyl*-6-endo-(4-*pyridyl*)-8-*azabicyclo*[3.2.1]*oct*-3-*en*-2-*one* (13) (3.7 g, 55%) as yellow hexagonal prisms, m.p. 165—166 °C (from EtOH) (Found: C, 78.0; H, 5.9; N, 10.0. $C_{18}H_{16}N_2O$ requires C, 78.2; H, 5.8; N, 10.1%); $\nu_{max.}$ ($CHBr_3$) 1 680 (αβ-unsat. C=O), 1 600, and 1 500 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 208.5 (ε 1.34 × 10^4) and 237 nm (1.41 × 10^4); *m/e* 276.

(v) *With* p-*chlorostyrene.* The salt (1) (5.0 g, 0.024 mol) and *p*-chlorostyrene (7.0 g, 0.05 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. The solid residue was purified by thick-layer chromatography [Kieselgel PF 254; PhMe–EtOAc (60 : 40)] to give 6-endo-(4-*chlorophenyl*)-8-*phenyl*-8-*azabicyclo*[3.2.1]*oct*-3-*en*-2-*one* (12) (4.8 g, 63%) as yellow hexagonal prisms, m.p. 171—172° (from EtOH) (Found: C, 73.6; H, 5.3; N, 4.5. $C_{19}H_{16}ClNO$ requires C, 73.7; H, 5.2; N, 4.5%); $\nu_{max.}$ ($CHBr_3$) 1 680 (αβ-unsat. C=O), 1 600, and 1 502 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 209 (ε 2.10 × 10^4) and 236 nm (1.82 × 10^4); *m/e* 309.

(vi) *With methyl acrylate.* The salt (1) (5 g, 0.024 mol) and methyl acrylate (10.5 g, 0.120 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. The resultant yellow oil on fractional recrystallisation gave yellow prisms of methyl 2-oxo-8-phenyl-8-azabicyclo[3.2.1] oct-3-ene-6-*endo*-carboxylate (14) (2.5 g, 41%), m.p. 96—98 °C (lit.,[3] 97—98 °C) and -6-*exo*-carboxylate (1.5 g, 24%), m.p. 89—90 °C (lit.,[3] 89—90 °C) (from MeOH).

(vii) *With acrylonitrile.* The salt (1) (5 g, 0.024 mol) and acrylonitrile (6.4 g, 0.120 mol) in dry MeCN (20 ml) were treated with Et_3N (5 ml) as above. On purification of the two stereoisomers by thick-layer chromatography [Kieselgel PF 254; PhMe–EtOAc (60 : 40)] 2-oxo-8-phenyl-8-azabicyclo[3.2.1]oct-3-ene-6-*exo*-carbonitrile (2.0 g, 31%), m.p. 122—124 °C (lit., 123—124 °C) was eluted first and then the 6-*endo*-carbonitrile (15) (2.5 g, 39%), m.p. 170—171 °C (lit ,[3] 170—171 °C)

(viii) (a) *With diethyl maleate.* Et_3N (10 ml, 0.1 mol) was added slowly with stirring to 3-hydroxy-1-phenylpyridinium chloride (1) (2 g, 0.01 mol) and diethyl maleate (10 ml, 0.06 mol) in MeCN (50 ml). The mixture was heated under reflux for 6 h. Occasionally samples were analysed by g.l.c. After 6 h, *ca.* 10% of diethyl maleate was isomerised to diethyl fumarate. The mixture was cooled to room temperature, Et_3N hydrochloride was filtered off, and the filtrate was evaporated to dryness. The residue was

[33] E. R. Krajniak, E. Ritchie, and W. C. Taylor, *Austral. J. Chem.*, 1973, **26**, 1337.

chromatographed on silica gel (benzene) to give first yellow crystals of a mixture of diethyl 2-oxo-8-phenyl-8-azabicyclo-[3.2.1]oct-3-ene-6-*endo*,7-*exo*- (16) and -6-*exo*,7-*endo*- (17) -dicarboxylates (1.31 g) and, second, a mixture of diethyl 2-oxo-8-phenyl-8-azabicyclo[3.2.1]oct-3-ene-6-*exo*,7-*exo*- (18) and -6-*endo*,7-*endo*- (19) -dicarboxylates (0.064 g).

The mixture of (16) and (17) was repeatedly recrystallised from MeOH to afford yellow *plates* of (16) (0.71 g, 20%) as the less soluble component, m.p. 105—106 °C (Found: C, 66.5; H, 6.4; N, 3.8. $C_{19}H_{21}NO_5$ requires C, 66.5; H, 6.2; N, 4.1%); $\nu_{max.}$ (KBr) 1 730 (ester C=O), 1 675 (αβ-unsat. C=O), 1 600, and 1 500 cm^{-1}; *m/e* 343. The concentrated filtrate was set aside overnight to afford two kinds of crystals. Faintly yellow *plates* of (17) (0.603 g, 17%), m.p. 79.5—80.5 °C (from n-hexane) were collected manually (Found: C, 66.4; H, 6.0; N, 4.2%); $\nu_{max.}$ (KBr) 1 730 (ester C=O), 1 685 (αβ -unsat. C=O), 1 592, and 1 495 cm^{-1}; *m/e* 343.

The mixture of (18) and (19) was chromatographed on silica gel [Et_2O–n-hexane (1 : 1)] to give first faintly yellow *needles* of (18) [(0.050 g, 1.4%), m.p. 120—121 °C (from n-hexane) (Found: C, 66.5; H, 5.9; N, 4.1%); $\nu_{max.}$ (KBr) 1 729 (ester C=O), 1 690 (αβ-unsat. C=O), 1 598, and 1 490 cm^{-1}; *m/e* 343] and, second, yellow *plates* of (19) [(0.014 g, 0.4%), m.p. 69—71 °C (n-hexane + a trace of benzene) (Found: C, 66.5; H, 6.2; N, 4.1%); $\nu_{max.}$ (KBr) 1 745 (ester C=O), 1 680 (αβ-unsat. C=O), 1 599, and 1 505 cm^{-1}; *m/e* 343].

(b) *With diethyl maleate.* Et_3N (1 g, 0.01 mol) was added to 3-hydroxy-1-phenylpyridinium chloride (2 g, 0.01 mol) in MeCN (30 ml). Solid was filtered off and the filtrate concentrated *in vacuo*. The residue, diethyl maleate (10 ml, 0.062 mol), and benzene (50 ml) were heated under reflux for 6 h and the product was worked up as above. The solid residue was chromatographed on silica gel (benzene) to give cycloadducts (16) (0.006 g, 1.8%), (17) (0.007 g, 2.0%), (18) (0.34 g, 9.6%), and (19) (0.27 g, 7.7%).

(ix) (a) *With diethyl fumarate.* 3-Hydroxy-1-phenylpyridinium chloride (1) (3.5 g, 0.0175 mol), diethyl fumarate (15 ml, 0.093 mol), and Et_3N (10 ml) in MeCN (75 ml) were heated under reflux for 10 h and then treated as above to give cycloadducts (16) (1.92 g, 31%), (17) (1.18 g, 19%), and (18) (0.074 g, 0.6%).

(b) *With diethyl fumarate.* 3-Oxido-1-phenylpyridinium (1.7 g, 0.01 mol) and diethyl fumarate (10 ml, 0.062 mol) in benzene (50 ml) were heated under reflux for 6 h, and then treated as above to give cycloadducts (16) (0.603 g, 17%) and (17) (0.957 g, 27%).

Quaternisation of Cycloadducts with Methyl Fluorosulphonate.—(*a*) The 6-*endo*-phenyl cycloadduct (10) (1.0 g, 0.004 mol) and methyl fluorosulphonate (4.48 g, 0.04 mol) were stirred vigorously in dry CH_2Cl_2 (20 ml) at 20 °C for 12 h. Filtration then gave 8-*methyl*-6-endo,8-*diphenyl*-8-*azoniabicyclo*[3.2.1]*oct*-3-*en*-2-*one fluorosulphonate* (24) (1.2 g, 80%) as hexagonal plates, m.p. 189—191 °C (from water) (Found: C, 61.4; H, 5.4; N, 3.6. $C_{20}H_{20}FNO_4S$ requires C, 61.7; H, 5.2; N, 3.6%); $\nu_{max.}$ ($CHBr_3$) 1 700 (αβ-unsat. C=O), 1 595, and 1 500 cm^{-1} (aromatic); *m/e* 275 ($M^+ - CH_3SO_3F$). Treatment of the salt (24) (0.5 g, 0.001 3 mol) with $NaHCO_3$ (aqueous) yielded the cycloadduct (10) (0.30 g), m.p. 105—106°.

(*b*) The 6-*endo*-(4-chlorophenyl) cycloadduct (12) (1.0 g, 0.003 mol) and methyl trifluoromethanesulphonate (3.2 g, 0.03 mol) in dry CH_2Cl_2 (20 ml) at 20 °C were treated as above to give 6-endo-(4-*chlorophenyl*)-8-*methyl*-8-*phenyl*-8-*azoniabicyclo*[3.2.1]*oct*-3-*en*-2-*one trifluoromethanesulphonate* (27) (1.0 g, 77%) as hexagonal plates, m.p. 234—235 °C (from 25% aqueous EtOH) (Found: C, 53.0; H, 4.2; N, 2.8. $C_{21}H_{19}ClF_3NO_4S$ requires C, 53.2; H, 4.0; N, 3.0%); $\nu_{max.}$ ($CHBr_3$) 1 700 (αβ-unsat. C=O), 1 595, and 1 502 cm^{-1} (aromatic); *m/e* 309 ($M^+ - CH_3SO_3CF_3$).

(*c*) The 6-*endo*-(*p*-bromophenyl) cycloadduct (11) (1.0 g, 0.003 mol) and methyl trifluoromethanesulphonate (3.2 g, 0.03 mol) in dry CH_2Cl_2 (20 ml) were treated as above to give 6-endo-(4-*bromophenyl*)-8-*methyl*-8-*phenyl*-8-*azoniabicyclo*-[3.2.1]*oct*-3-*en*-2-*one trifluoromethanesulphonate* (26) (1.0 g, 79%) as hexagonal prisms, m.p. 209—210 °C (from 95% EtOH) (Found: C, 48.7; H, 3.8; N, 2.7. $C_{21}H_{19}BrF_3NO_4S$ requires C, 48.7; H, 3.7; N, 2.7%); $\nu_{max.}$ ($CHBr_3$) 1 700 (αβ-unsat. C=O), 1 595 and 1 500 cm^{-1} (aromatic); *m/e* 353 ($M^+ - CH_3SO_3CF_3$). Treatment of the salt (26) (0.5 g, 0.001 1 mol) with $NaHCO_3$ (aqueous) yielded the cycloadduct (11) (0.32 g), m.p. 180—181°.

(*d*) The 6-*endo*-(4-pyridyl) cycloadduct (13) (1.0 g, 0.004 mol) and methyl trifluoromethanesulphonate (4.0 g, 0.04 mol) in dry dichloroethane (20 ml) were treated as above to give the *bistrifluoromethanesulphonate salt* (28) as hexagonal plates (1.0 g, 73%), m.p. 191—192° (from 95% EtOH) (Found: C, 43.5; H, 3.8; N, 4.6. $C_{22}H_{22}F_6N_2O_7S_2$ requires C, 43.7; H, 3.7; N, 4.6%); $\nu_{max.}$ ($CHBr_3$) 1 700 (αβ-unsat. C=O), 1 600, and 1 502 cm^{-1} (aromatic); *m/e* 276 ($M^+ - 2CH_3SO_3CF_3$).

(*e*) The methyl 6-*exo*-carboxylate cycloadduct (14) (1.0 g, 0.004 mol) and methyl fluorosulphonate (4.0 g, 0.04 mol) in dry CH_2Cl_2 (20 ml) were treated as above to give *methyl* 8-*methyl*-2-*oxo*-8-*phenyl*-8-*azoniabicyclo*[3.2.1]*oct*-3-*ene*-6-endo-*carboxylate fluorosulphonate* (25) (1.0 g, 75%) as white hexagonal plates, m.p. 191—193 °C (from water) (Found: C, 51.8; H, 5.0; N, 3.8. $C_{16}H_{18}FNO_6S$ requires C, 51.7; H, 4.9; N, 3.8%); $\nu_{max.}$ ($CHBr_3$) 1 720 (ester C=O), 1 700 (αβ-unsat. C=O), 1 595, and 1 500 cm^{-1} (aromatic); *m/e* 257 ($M^+ - CH_3SO_3F$).

Treatment of Methyl 8-*Methyl*-2-*oxo*-8-*phenyl*-8-*azoniabicyclo*[3.2.1]*oct*-3-*ene*-6-endo-*carboxylate Fluorosulphonate* (25) *with Sodium Hydrogen Carbonate Solution.*—The salt (25) (0.96 g, 0.002 6 mol) and $NaHCO_3$ (2.0 g) in water (100 ml) were stirred at 20 °C for 24 h. The reaction was monitored by t.l.c. and, after 3 h, the mixture was extracted with ether (3 × 30 ml). The combined extracts on evaporation *in vacuo* yielded 2,3-*dihydro*-4-*methoxycarbonyl*-2-(N-*methylanilino*)*tropone* (32) (0.35 g, 50%) as deep red, hexagonal prisms, m.p. 86—88 °C (from EtOH) (Found: C, 70.3; H, 6.3; N, 5.1. $C_{16}H_{17}NO_3$ requires C, 70.8; H, 6.3; N, 5.2%); $\nu_{max.}$ ($CHBr_3$) 1 700 (ester C=O), 1 660 (αβ-unsat. C=O), 1 630 (C=C), and 1 600 cm^{-1} (aromatic); $\lambda_{max.}$ (EtOH) 208.5 (ε 2.08 × 10^4), 251 (1.50 × 10^4), and 292.5 nm (1.04 × 10^4); *m/e* 271; δ ($CDCl_3$) 6.65 (q, H-3, $J_{2,3}$ 12.0, $J_{3,4}$ 7.0 Hz), 6.62 (dd, H-4, $J_{2,4}$ 0.5 Hz), 6.61 (dd, H-2), 4.36 (dd, H-7-*ax*, $J_{6\text{-}eq,7\text{-}ax}$ 1.5, $J_{6\text{-}ax,7\text{-}ax}$ 12.0 Hz), 3.72 (s, CO_2Me), 3.24 (dd, H-6-*eq* $J_{6\text{-}eq,6\text{-}ax}$ 14.0 Hz), 2.84 (s, NMe), and 2.88 (H-6-*ax*, complex).

Conversion of 2,3-*Dihydro*-4-*methoxycarbonyl*-2-(N-*methylanilino*)*tropone* (32) *into the Tropolone* (39).—The dihydrotropone (32) (0.30 g, 0.001 1 mol) and silver oxide (0.5 g) were stirred at 20 °C for 3 h in distilled water (10 ml). The remaining solid was filtered off and the filtrate was extracted with ether (3 × 50 ml). Evaporation of the dried extracts (Na_2SO_4) *in vacuo* gave a dark red oil, which showed i.r. bands [3 320 (NH) and 1 610 cm^{-1} (C=C)] corresponding to *N*-methylaniline. The aqueous layer was

acidified with 2N-HCl and extracted with ether (3 × 50 ml); evaporation of this extract gave pale yellow needles of 4-methoxycarbonyltropolone (39) (0.60 g, 30%), m.p. 116—117 °C (lit.,[2] 116—118 °C) (Found: C, 59.7; H, 4.6. Calc. for $C_9H_8O_4$: C, 60.0; H, 4.5%); $\nu_{max.}$ ($CHBr_3$) 1 725 (ester C=O), 1 620 (tropolone C=O), and 1 600 cm^{-1} (C=C); $\lambda_{max.}$ (EtOH) 248 (ε 2.82 × 10^4) and 327 nm (4.80 × 10^3); *m/e* 180.

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