

## Bridged Ring Systems. Part XVII.<sup>1</sup> The Mechanism of a Transannular Acylation

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Earlier reports that diethyl 5-methylcyclo-oct-4-ene-1,1-dicarboxylate was transformed into 5-methyl-9-oxobicyclo[3.3.1]non-3-ene-1-carboxylic acid by aqueous alkali and into 1-hydroxymethyl-5-methylbicyclo[3.3.1]non-3-en-9-ol by reduction with lithium aluminium hydride are shown to be erroneous. These products arise from a bicyclic impurity formed by an acid-catalysed process.

In an earlier publication<sup>2</sup> one of us reported that alkaline hydrolysis of the diesters (I) and (II) afforded, in addition to the expected carboxylic acids, the keto-acids (III) and (IV), and, more surprisingly, that reduction of the diester (I) by lithium aluminium hydride yielded *only* the diol (V). These events were rationalised in terms of a base-catalysed transannular cyclisation which seemed sufficiently unusual to warrant a full investig-

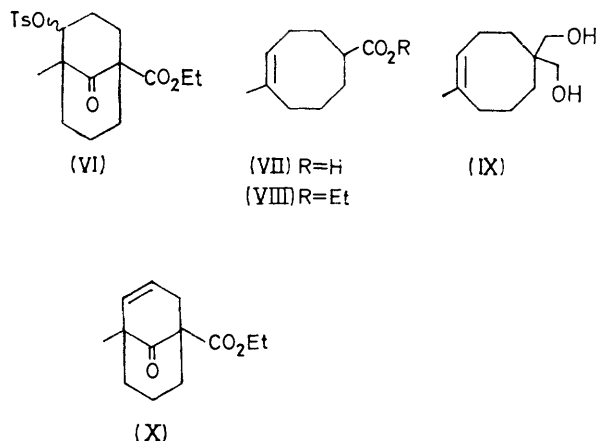
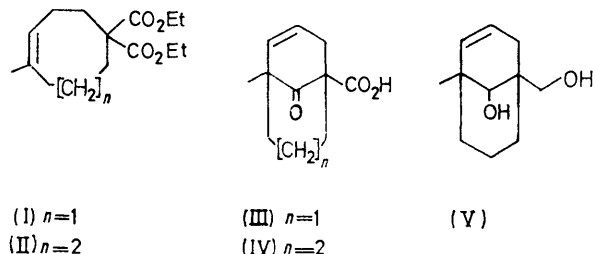
ation. We now report that such a re-examination has shown that the cyclisation is acid-catalysed.

The *gem*-diester (I), prepared as described<sup>2</sup> by treating the tosylate mixture (VI) with sodium ethoxide, was purified by preparative t.l.c. and subjected to the alkaline hydrolysis conditions previously described. The cyclo-octenecarboxylic acid (VII) was the only product isolated; no trace of the bicyclic keto-acid was

<sup>1</sup> Part XVI, E. W. Colvin, J. Martin, W. Parker, R. A. Raphael, B. Shroot, and M. Doyle, *J.C.S. Perkin I*, 1972, 860.

<sup>2</sup> G. L. Buchanan, A. McKillop, and R. A. Raphael, *J. Chem. Soc.*, 1965, 833.

detected. Reduction by means of lithium aluminium hydride transformed the diester (I) into the diol (IX) and a search (g.l.c.) revealed no trace of the diol (V). Thus there was no justification for postulating a base-catalysed cyclisation. The ester was also unchanged when heated at 150° for several hours so there is no justification for postulating a purely thermal mechanism. On the other hand, when it was heated briefly at 150° with a crystal of toluene-*p*-sulphonic acid, the diester (I) rapidly cyclised to the bicyclononene (X).



Re-examination of the published preparation revealed that the diester (I), prepared from (VI), was purified by distillation. In the course of this, the axial tosylate (which is unaffected by mild base<sup>3</sup>) would probably break down thermally to the olefin (X) and toluene-*p*-sulphonic acid—which, in turn, could promote the cyclisation (I) → (X). Indeed, when the *gem*-diester (prepared as before) was isolated by distillation, the crude product was found to contain both compounds (I) and (X). Later fractions were particularly rich in the latter and so reduction with lithium aluminium hydride might well yield only (V), as was claimed.

#### EXPERIMENTAL

The micro-analysis was performed by Mr. J. M. L. Cameron. Mass spectra were recorded by Mr. A. Ritchie on an A.E.I. MS12 instrument, and n.m.r. spectra by Mr. A. Haetzman on a Varian T60.

*Ethyl 5-Methyl-4-p-tolylsulphonyloxy-9-oxobicyclo[3,3,1]-*

<sup>3</sup> G. L. Buchanan, *Topics Carbocyclic Chem.*, 1969, **1**, 199; J. Martin, W. Parker, and R. A. Raphael, *J. Chem. Soc.*, 1964, **289**; C. S. Dean, J. R. Dixon, J. H. Graham, and D. O. Lewis, *J. Chem. Soc. (C)*, 1968, 1491.

*nonan-1-carboxylate* (VI).—The parent alcohol, prepared by the published method,<sup>2</sup> was tosylated in the normal manner. N.m.r. integration of the HC·OTs proton signal from the epimeric mixture of tosylates indicated an equatorial-axial ratio of 3 : 2.

*Diethyl 5-Methylcyclo-oct-4-ene-1,1-dicarboxylate* (I).—Repetition of the literature method,<sup>2</sup> but avoiding distillation, afforded a crude product, which was separated by preparative t.l.c. (20% ethyl acetate-petroleum) into the monoester (VIII) (9%),  $\tau$  (CCl<sub>4</sub>) 4.6 (1H, m), 5.9 (2H, q), and 7.6–9.0 (17H, m), and the *gem*-diester (I) (42%),  $\nu_{\max}$  (film) 1725, 1260, and 830 cm<sup>-1</sup>, g.l.c.  $t_R$  10.5 min (one symmetrical peak; on 5% QF1 at 150°). The identity of the latter was confirmed by co-injection with an authentic sample.<sup>2</sup>

*5-Methylcyclo-oct-4-enecarboxylic Acid* (VII).—Hydrolysis of the diester (I) as before gave the known acid (VII) as an oil, which resisted all attempts at crystallisation,  $\tau$  (CCl<sub>4</sub>) –0.1 (1H), 4.6 (1H, m), and 7.4–8.9 (14H, m). There was no evidence to suggest that any bicyclic material (III) had been produced.

*5-Methylcyclo-oct-4-ene-1,1-dimethanol* (IX).—A solution of the diester (I) (120 mg) in anhydrous ether (5 ml) was added dropwise to a stirred slurry of lithium aluminium hydride (40 mg) in ether (20 ml). Stirring was continued under gentle reflux for 24 h; excess of hydride was then decomposed by ethyl acetate. The organic layer was washed with dilute hydrochloric acid and brine, dried, and concentrated to give the monocyclic diol (62 mg, 79%), m.p. 70–71° (benzene-petroleum),  $\tau$  (CDCl<sub>3</sub>) 4.6 (1H, t, *J* 5 Hz), 6.2 (2H, s), 7.6–8 (4H, m), 6.5 (4H, s), 8.3 (3H, s), and 8.3–8.8 (6H, m) (Found: C, 71.65; H, 10.95. C<sub>11</sub>H<sub>20</sub>O<sub>2</sub> requires C, 71.7; H, 10.95%), *m/e* 184 (*M*<sup>+</sup>), 166, 148, 135, 125, and 93. G.l.c. analysis of the product showed only one symmetrical peak,  $t_R$  15 min (on 1% QV1 at 140°; flow rate 45 ml min<sup>-1</sup>). Under the same conditions the bicyclic diol (V) had  $t_R$  8 min.

*Effects of Heat and Acid on the Diester (I).*—The diester (I) (38 mg) was heated at 150° and the course of any reaction monitored by g.l.c. on 5% QF1 at 150°. After 5 h the diester was unchanged. A small crystal of toluene-*p*-sulphonic acid was added; the mixture immediately turned dark brown. G.l.c. analysis 1 h later indicated a 1 : 3 mixture respectively of the bicyclic monoester (X) ( $t_R$  8 min) and the monocyclic *gem*-diester (I),  $t_R$  10.5 min, with a number of unidentified products of longer retention time.

*Isolation of the Mixture of Compounds (I) and (X) by Distillation.*—The epimeric mixture of tosylates (VI) (7.4 g), was added to a solution of sodium ethoxide [from sodium (240 mg) in absolute ethanol (50 ml)] and the solution was refluxed for 2 h. After cooling, the mixture (containing precipitated sodium tosylate) was poured onto ice (70 g) and 6*N*-hydrochloric acid (10 ml), then extracted with ether. The extract was washed, dried, and concentrated to give a viscous oil which was distilled under vacuum. Three fractions were obtained, and these were examined by g.l.c. (5% QF1 at 150°) (see Table).

B.p. (°C) at 0.3 mmHg	Weight (g)	% (VIII)	% (X)	% (I)
102–106	0.525	16	8	76
106–112	1.089	1	7	92
112–118	0.900	1	59	40

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