Thermal Rearrangement of *trans*-2,3-Epoxy-1,3-diphenylbutan-1-one. A Concerted 1,2-Carbonyl Migration

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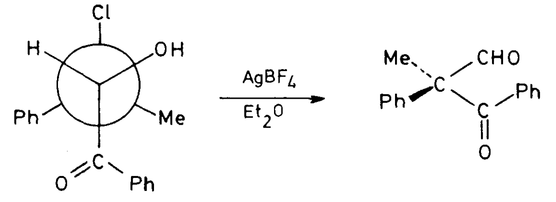
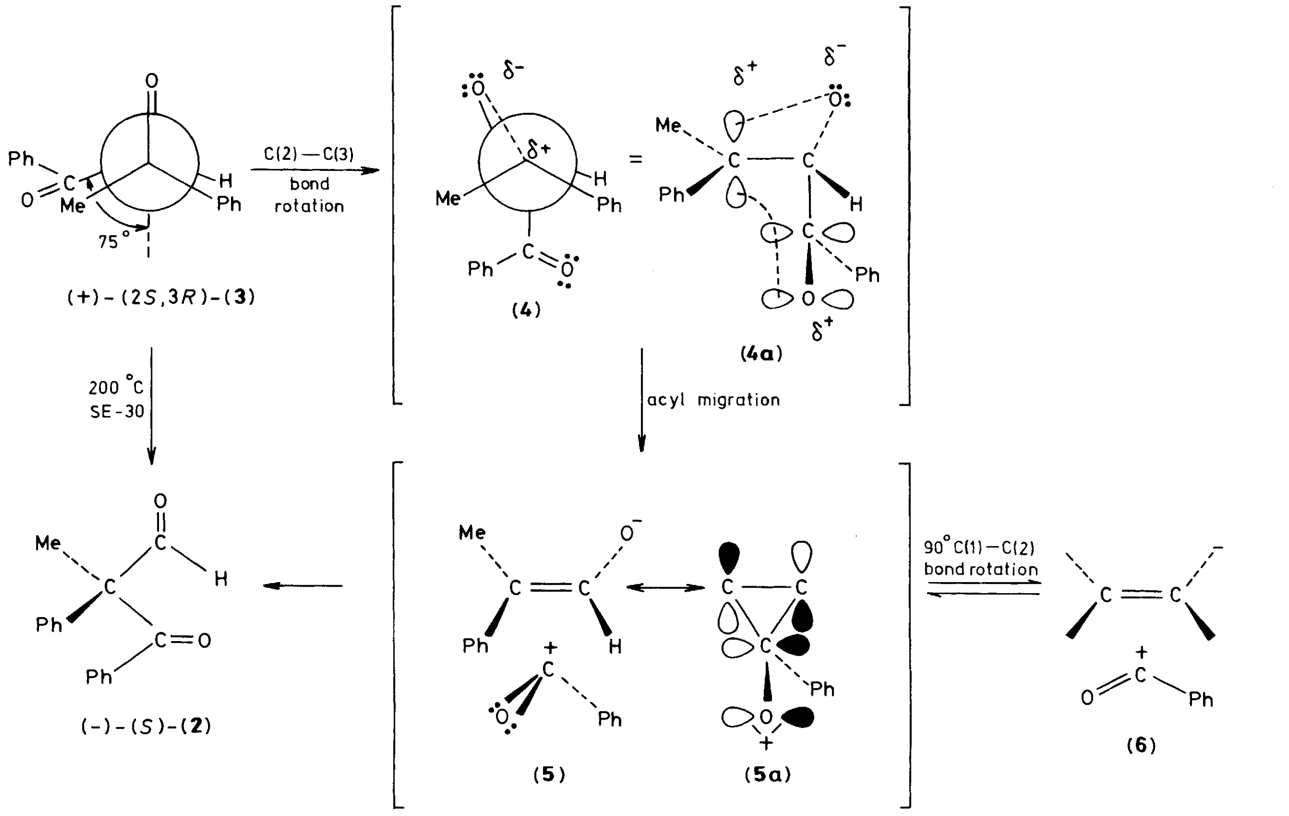
The thermal rearrangement of a chiral α,β-epoxyketone is a concerted process that proceeds without loss of optical activity and with inversion of configuration at the migration terminus.

The migration of a carbonyl moiety to an adjacent developing positive centre in an α,β-epoxy ketone is an intramolecular process[1] that occurs with inversion of configuration at the migration terminus.[2a] Concerted benzoyl migration, with neighbouring group participation at carbonyl carbon, in the chlorohydrin (**1**) also occurred with inversion even though the ground-state structure necessary for simultaneous C–Cl bond rupture and acyl migration must be the least stable of three possible conformers [equation (1)].[2b]



(−)-(2*R*,3*R*)-(**1**) (−)-(*S*)-(**2**) (1)



Scheme 1

Despite our increased understanding of the mechanism of Lewis acid-catalysed carbonyl migration in α,β-epoxy ketones, we can never unambiguously exclude the intervention of an undetectable halohydrin intermediate followed by its rapid rearrangement in a second kinetically distinguishable step. This is a particularly nagging concern since $BF_3\cdot Et_2O$ is the catalyst most commonly employed in 1,2-acyl migrations and fluorohydrins are readily formed.[3] We now provide an example of concerted benzoyl migration that unequivocally excludes an intermediate that precedes the migration of the carbonyl functionality.

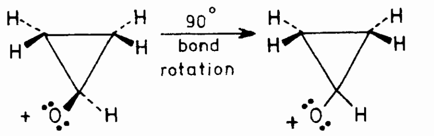
In order to demonstrate the intrinsic migratory aptitude of the benzoyl moiety, we excluded the influence of both the solvent and the $BF_3\cdot Et_2O$ by carrying out the rearrangement on a gas chromatography column (20% SE-30 on Chromosorb P). We again chose compound (**3**) as a substrate because of the accepted inherent stability of any putative α-methylbenzyl carbenium ions that may potentially intervene. The absolute configuration and optical purity of compounds (**2**) and (**3**) have been established.[4] Three separate injections (13.3 mg each) of optically pure,[4a] neat (+)-(**3**), $[\alpha]_D$ 147.2° (*c* 1.3, $CHCl_3$), on the g.l.c. column (200 °C) afforded optically pure (within experimental error) (*S*)-(−)-1,2-diphenyl-2-methylpropane-1,3-dione (**2**), $[\alpha]_D^{25}$ −416.8° (*c* 0.83, $CHCl_3$) after isolation and further purification by repassing the material through the g.l.c. column. Several experiments at various temperatures are given below. In a similar fashion, racemic (**3**) could be rearranged in 91% isolated yield. The rearrangement was accompanied by 9% hydrogen migration affording 1,3-diphenylbutane-1,2-dione.[5] These data establish that acyl migration takes place in a concerted fashion, displaying no tendency for racemization, under the extreme reaction conditions employed. The rearrangement need not necessarily be a purely thermal process since it may occur on the surface of the liquid column support or be catalysed by acidic sites on the solid support. However, we have rigorously excluded the necessity for a halohydrin intermediate and have provided stereochemical evidence for a completely concerted acyl migration that proceeds without the intervention of solvent or added catalyst.

Table 1. Rearrangement of optically pure (+)-(2*S*, 3*R*)-(**3**).

T/°C[a]	Liquid phase[b]	$[\alpha]_D{}^{25}$ of (**2**)	Optical purity of (**2**), %
185	20% SE-30	−411.2°	98
200	20% SE-30	−416.8°	100
200	10% SE-30	−409.3°	98
215	20% SE-30	−417.7°	100

[a] Column and injection port. [b] On Chromosorb P.

A mechanism consistent with a concerted acyl migration with inversion at the migration terminus[2] is given in Scheme 1. A C(2)–C(3) bond rotation of ~75° is required in order to get the carbon–carbon σ bond (C–C=O) parallel to the developing vacant p orbital at C(3) as shown in (**4**). Although the carbon–oxygen bond is essentially broken, the developing positive centre may be stabilized from both faces by the departing oxygen and the carbonyl carbon. A second geometric requirement[3] for neighbouring group participation is that the atomic p orbital of the migrating carbonyl π bond must become (nearly) parallel to the C(2)–C(3) bond axis in order for the developing Walsh orbitals to stabilize the transition state as migration occurs. *Ab initio* calculations on a model system[6] indicate that although C(1)–C(2) bond elongation in



(2)

(**5**) is extensive, the molecular orbitals of the transition state are best described by structure (**5a**) rather than an acylium ion complexed to a double bond as in (**5**). If (**5**) were an important resonance structure, then one would expect that the barrier to a 90° C(1)–C(2) bond rotation in the cyclopropyloxenium ion (**5**) to afford the planar structure (**6**) would be very low. In contrast, the rotational barrier in the parent cyclopropyloxenium ion $(C_3H_5O^+)$[6a] was calculated (STO-3G)[6b] to be 35.6 kcal/mol [equation (2)] (1 cal = 4.184 J). These arguments tend to exclude the involvement of an acylium ion π complex such as (**6**) and suggest that a concerted carbonyl migration cannot simply involve the 1,2-shift of a C–C=O σ bond.

We therefore attribute the unusual facility with which an acyl group can undergo 1,2-rearrangement to stabilization of the transition state by reverse polarization of the carbonyl π bond. We suggest that the cyclopropyloxenium ion (**5a**) lies on the reaction surface, at or near the transition state, and that the developing positive charge may be effectively dispersed by a Walsh orbital in a manner analogous to that of a cyclopropyl methyl cation.

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References

1 H. O. House and G. D. Ryerson, *J. Am. Chem. Soc.*, 1961, **83**, 979.

2 J. M. Domagala and R. D. Bach, *J. Am. Chem. Soc.*, (a) 1978, **100**, 1605; (b) 1979, **101**, 3118.

3 For example, the $BF_3 \cdot Et_2O$-catalysed rearrangement of pulegone oxide in CH_2Cl_2 at 25 °C affords 2,2,5-trimethylcycloheptane-1,3-dione (99%) in 1 min. However, oxirane cleavage to form a fluorohydrin intermediate precedes carbonyl migration (R. D. Bach and R. C. Klix, *Tetrahedron Lett.*, submitted for publication).

4 J. M. Domagala and R. D. Bach, *J. Org. Chem.*, (a) 1979, **44**, 3168; (b) 1979, **44**, 2429.

5 Deuterium labelling experiments have established that hydrogen migration in solution is intramolecular (unpublished results).

6 (a) R. D. Bach and J. M. Domagala, *Tetrahedron Lett.*, 1976, **45**, 4205; (b) J. M. Domagala, Ph.D. Thesis, Wayne State University, 1977.