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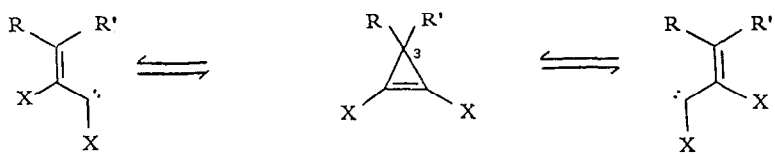
THE STEREOSELECTIVITY OF RING-OPENING OF 3-SUBSTITUTED CYCLOPROPENES AND INTERMOLECULAR TRAPPING OF DERIVED VINYLCARBENES

Juma'a Al-Dulayymi, Mark S.Baird*, and William Clegg
Department of Chemistry, University of Newcastle upon Tyne,
Newcastle upon Tyne, NE1 7RU.

Cyclopropene (4, X = Ph) reacts with 2,3-dimethylbut-2-ene or methyl methacrylate to produce predominantly the cyclopropanes (5k) and (5m) with an E-stereochemistry at the alkene and, in the latter case, cis-stereochemistry of the alkene and ester about the cyclopropane; dichloro-cyclopropenes (4, X = Cl, OMe) react with electron rich and electron poor alkenes at ambient temperature to give the cyclopropanes (5, X = Cl, OMe) with even higher stereoselectivity.

The ring-opening of a cyclopropene (1) to a vinylcarbene,[1] which is reported in several cases to be reversible, involves a formal monorotation at C_3 and could, provided (2) and (3) are reasonable representations of the product, lead to *E*- or *Z*-isomers about the alkene:

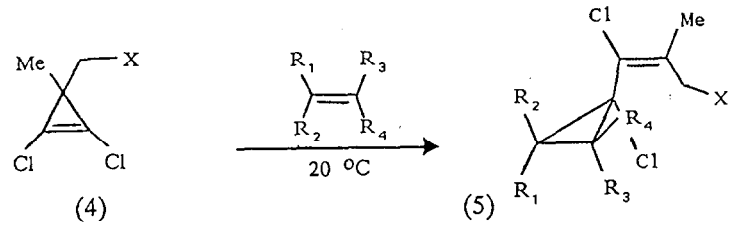


(2) (1) (3)

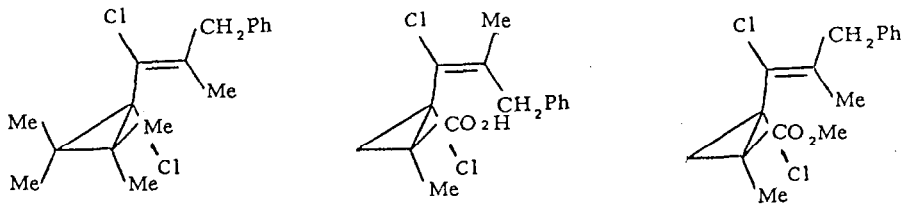
There are several examples of intramolecular trapping of the carbene centre by a 3-substituent which require these to be *Z*-related;[2] this may arise by stereocontrolled ring-opening but could be the result of a reversible process and selective trapping of one isomer.[3] Most reported intermolecular trappings of vinylcarbenes derived from cyclopropenes do not distinguish between the 3-substitutents of the latter, though thermolysis of 3-methyl-3-phenylcyclopropene at 180 °C does lead to selective trapping of the *E*-carbene (2, X = H, R = Ph, R' = Me) by alkenes, albeit in low yield.[4] Moreover, the metal induced ring-opening of (1, X = H, R = Ph, R' = Me) in the presence of alkenes leads to the trapping of both *E*- and *Z*- 'carbene' isomers.[5]

It is known that cyclopropenes (4, X = H) ring-open to vinylcarbenes at ambient temperature, and that these may be trapped by alkenes.[6] A solution of (4, X = Cl)[7] in ether or chloroform remained largely unchanged on being allowed to stand for 10 h at 20 °C. However, addition of 2,3-dimethylbut-2-ene led to complete reaction in ca. 2 h and the formation of one cyclopropane (5a)[8] (See Table), suggesting either that the alkene promotes the ring-opening of the cyclopropene, or that a reversible ring-opening to a carbene was occurring and this was only trapped rapidly in the presence of added alkene. In the same way (4, X = OMe) was converted to (5e). There was no evidence in either case for the presence of a second stereoisomer. The ^{1}H n.m.r. spectra of cyclopropanes (5a) and (5e) each showed four singlets for the ring methyl groups, in agreement with a preferred orientation of the vinyl group that was not perpendicular to the opposite cyclopropane bond,[9] and with rotation that was slow on the n.m.r. time scale. The

stereochemistry about the alkene was assigned as E- because an n.O.e. examination of (5e) showed an enhancement in the methylene rather than the olefinic methyl signal when a signal for a methyl group at δ 1.17 was irradiated.



(4) (5)



(6) (7) (8)

Treatment of (4, X = Cl, OMe) with other alkyl-substituted alkenes also led to cyclopropanes (See Table). Addition of (4, X = OMe) to E-but-2-ene gave a single product, but the ^{1}H n.m.r. at ambient temperature included a number of broad signals; on cooling to -40 °C the spectra of two rotamers of the adduct (5h) were observed. In the case of addition to Z-but-2-ene, n.m.r. and g.l.c. analyses revealed the presence of two adducts in ratio ca. 6:1; the major isomer showed only one doublet for the ring methyls and a multiplet for the ring hydrogens even at -40 °C, and was assigned as (5g). The signals for the minor isomer were not clearly resolved, but since the MeO-substituent appears only in the E-configuration in the above adducts (ie., 5a, 5e and 5h), it was characterised as (5g'). G.l.c. analysis showed that no (5h) was produced in this experiment; in the same way no (5g) was obtained from the reaction of (4, X = OMe) with E-but-2-ene.

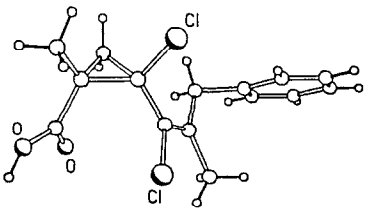
Table **Reactions of Cyclopropenes (4, X = Cl, OMe, Ph) with alkenes**

Alkene	Cyclopropane(5)												
	R_1	R_2	R_3	R_4	X	No	%*	X	No	%	X	No	%
$Me_2C=CMe_2$	Me	Me	Me	Me	Cl	5a	77	OMe	5e	69	Ph	5k#	84
Me_2C-CH_2	Me	Me	H	H	Cl	5b	70	OMe	5f	68			
Z-MeCH=CHMe	Me	H	Me	H				OMe	5g	56			
	H	Me	H	Me				OMe	5g'				
E-MeCH=CHMe	Me	H	H	Me				OMe	5h	54			
$CH_2=CH-CO_2Me$	H	H	H	CO_2Me	Cl	5c	75	OMe	5i	75	Ph	51#	68
$CH_2=CMe-CO_2Me$	H	H	Me	CO_2Me	Cl	5d	82	OMe	5j	84	Ph	5m#	80

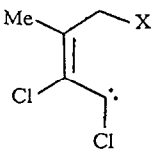
When the cyclopropene (4, X = Ph)[7] was allowed to stand in ether at 20 °C in the presence of 2,3-dimethylbut-2-ene, complete reaction occurred over a period of 2 h, to give a mixture of two isomeric cyclopropanes (5k) and (6) in ratio ca. 5:1. In the presence of methyl methacrylate, complete reaction of (4, X = Ph) occurred in *ca.* 2 h. to give an ester which was one spot by

t.l.c. (80 %). Hydrolysis with sodium hydroxide in aqueous methanol led after recrystallisation to an acid, the structure of which was established by X-ray crystallography as (7) (Fig.1).[10] Re-esterification by reaction with diazomethane gave the ester (5m).[11] Comparison of its ^1H n.m.r. at 240K with that of the crude reaction product from (4, X = Ph) showed that it was identical to the major component, but that the crude product also showed signals for two rotamers of a minor isomer (ca. 15%); by comparison with the reaction of (4, X = Ph) with 2,3-dimethylbut-2-ene, and because the activation energy for rapid interconversion of the two rotamers on the n.m.r. time scale was very similar to that for (5m), this is characterised as (8).

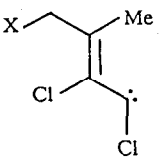
Molecular structure of compound (7) (Fig.1)



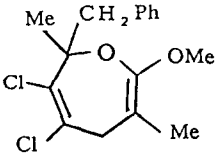
The additions thus gave predominantly the E-alkenes derived by trapping of carbenes (9), and only with (4, X = Ph) were minor products obtained by trapping of the alternative, but possibly less hindered, carbene (10). It is not clear why this species, if formed, should be trapped less efficiently by the added alkene. It would appear, therefore, either that the carbene (9) is formed selectively from (4), or that the representation of these species in two geometrical forms is not correct and that more subtle factors control the geometry of addition. Further experiments are under way to characterise the intermediate in more detail. The cyclopropane (5m) was formed with the ester and alkenyl-groups cis- to each other.[12] It may arise by stereocontrol in a concerted cyclopropanation or by dipolar attraction in an intermediate resembling a Michael-type addition; indeed formation of a fully cyclised ethoxydihydro-oxepine (11), followed by a Cope rearrangement would offer a possible explanation in the present case.



(9)



(10)



(11)

The cyclopropanes (5c,d) and (5i,j) were also formed when (4, X = Cl, OMe) was treated with methyl acrylate or methacrylate at 20 °C. The single diastereoisomers formed in each case showed temperature variable ^1H n.m.r. spectra. Thus the spectrum of (3d) was very broad at 303K but two sets of signals are observed at 230 K, corresponding to two rotamers in ratio 3:1; although there were some minor additional signals, these amounted to no more than ca. 5% of the product and could not be assigned to alternative stereoisomers. The rotation barriers for these esters are similar to those for (5m), suggesting that the ester group is again cis- to the alkene.

The cyclopropenes (4, X = Cl, OMe) therefore provide a convenient source of functionalised isoprenoid carbenes (9, X = Cl, OMe) which are trapped by both electron rich and electron poor alkenes. The derived cyclopropanes (4, X = Cl) also provide a potential source of a range of

other derivatives (5) through allylic substitution; eg., reaction of (5b) or (5d) with sodium methoxide in methanol leads to (5f) and (5j), identical to samples prepared directly from (4, **X** = OMe).

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2. See eg., A. Padwa and T.J. Blacklock, *J.Amer.Chem.Soc.*, 1984, **106**, 4446; J.A.Pincock and N.C. Mathur, *J.Org.Chem.*, 1982, **47**, 3699.
3. See eg., J.A. Pincock and A.A. Moutoskapis, *Can.J.Chem.*, 1977, **55**, 979.
4. I.N. Domnin and A. de Meijere, *Zh.Org.Khim.*, 1983, **19**, 1528.
5. P. Binger and B. Biedenbach, *Chem.Ber.*, 1987, **120**, 601.
6. M.S.Baird, S.R.Buxton and J.S.Whitley, *Tetrahedron Letters*, 1984, 1509.
7. J.AlDulayymi and M.S.Baird, preceding paper.
8. Compound (5a) showed δ_H 4.19 (1H, d, J 11.6 Hz), 4.1 (1H, d, J 11.6 Hz), 1.97 (3H, s), 1.28 (3H, s), 1.2 (3H, s), 1.17 (3H, s), 1.15 (3H, s).
9. See eg., A.deMeijere and W.Luttke, *Angew.Chem.Int.Edn.Engl.*, 1980, *19*, 138.
10. Compound (7) formed monoclinic crystals, a = 11.113(2), b = 12.969(3), c = 11.247(2) Å, β = 12.04(1) °, Z = 4, space group $P2_1/c$. The structure was solved from 2357 diffractometer reflections with $F > 4\sigma(F)$ and $2\theta < 130$ ° (CuKα radiation) and refined to R = 0.039 and R_W = 0.048.
11. The 300 MHz ^{1}H n.m.r. spectrum of (5m) at 240K showed signals for two rotamers in ratio 10:3. The major rotamer showed δ_H 7.2 - 7.4 (5H, complex), 3.98 (1H, d, J 15.6 Hz), 3.79 (3H, s), 3.64 (1H, d, J 15.6 Hz), 2.42 (1H, d, J 6.35 Hz), 1.73 (3H, s), 1.60 (3H, s), 1.56 (1H, d, J 6.35 Hz). The minor rotamer showed δ_H 7.2 - 7.4 (5H, complex), 3.93 (1H, d, J 15.9 Hz), 3.68 (3H, s), 2.94 (1H, d, J 15.9 Hz), 2.33 (1H, d, 6.75 Hz), 1.64 (6H, s), 1.39 (1H, d, J 6.75 Hz).
12. There are reports that (1, X = R = R' = Cl)[9] and (1, X = H, R = R' = OMe)[13] can add to electron poor alkenes to give cis-products, although in the latter case the reaction with methyl methacrylate leads to a 1:1 mixture of stereoisomers in low yield.
13. D.L. Boger and C.E. Brotherton, *Tetrahedron Letters*, 1984, 5611.

* The cyclopropenes are derived by 1,2-dehalogenation of the corresponding 1,1,2,2-tetrachloro-cyclopropane and, although they could be isolated, this was not generally necessary and yields are based on starting cyclopropane.[7]

\# A minor product (ca.15 -20 %) was also obtained, isomeric with (5) about the alkene.

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