Tetrahedron Letters Vol. 21, pp 4601 - 4604

0040-4039/80/1122-4601$02.00/0

DIELS-ALDER REACTION OF CYCLOPROPENYLKETONE[1)]

Yoshiro Kobayashi*, Tsutomu Yoshida, Yuji Hanzawa, and Itsumaro Kumadaki

Tokyo College of Pharmacy, Horinouchi, Hachioji, Tokyo 192-03, Japan

Abstract: The Diels-Alder reactions of tris(trifluoromethyl)trifluoroacetylcyclopropene with dienes gave syn-adducts mainly, due to the electronic effects of the fluorinated substituents.

Synthesis of 1,2,3-tris(trifluoromethyl)-3-trifluoroacetylcyclopropene (1) and its conversion to tetrakis(trifluoromethyl)furan were reported by Lemal et al. in 1978.[2)] Compound 1 has two reaction centers of interest for its conversion to many compounds; one is a strained double bond[3)] and the other is a carbonyl group,[4)] both of which seem to be activated by trifluoromethyl groups, but the latter was reported to be much less reactive than usual ketones.[2)]

Now we wish to report the Diels-Alder reaction of 1 with some dienes and the stereochemistry of the products.

Compound 1 reacted with 1,3-butadiene (2) in a stainless steel tube at 60° for 6 h to give two products (3) and (4)[5)] in the ratio of 1:6. The structures of 3 and 4 were estimated by the coupling patterns of the CF_3CO group in ^{19}F-NMR; the signal of CF_3CO group of 4 appears in quartet coupled only with a vicinal CF_3 group, while that of 3 in multiplet due to the through-space F-F coupling in syn configuration. These structure were confirmed by bromination of both compounds. Compound 3 gave dibromide (5) while 4 gave a cage compound (6),[6)] possibly through a path shown in chart.

Reaction of 1 with 2,3-dimethyl-1,3-butadiene (7) at 60° for 6 h (in a sealed Pyrex tube) gave two products in the ratio of 1:8. Minor one is anti adduct (8) and major is a cage compound (9),[7)] which was formed by ene-reaction of the syn adduct. Thus, the addition occurred mainly in syn-form, too.

It was surprising that the reaction of 1 with 7 needed as strong conditions as that with 2 since much higher reactivity of 7 in a usual Diels-Alder reaction than that of 2 was reported.[8)] We assumed that 1 and 7 took endo conformation in the transition state, and that the repulsion between the substituents on 3-position in 1 and methyl groups in 7 balanced out the higher reactivity of 7. To clarify this predominance of the endo transition state, we tried the reaction of 1 with cyclopentadiene (10).

Compound 1 reacted with 10 immediately at room temperature to give the adduct (11)[9] quantitatively. Based on the quartet of $COCF_3$ in ^{19}F-NMR, the same chemical shift of two methyne protons and the different chemical shift of two olefinic protons in ^1H-NMR, and the low frequency of $\nu_{C=O}$ the structure of (11) was assumed as endo-syn form. Formation of a cage compound (12)[10] on bromination supported this structure.

Compound 1 reacted with furan (13) immediately at room temperature to give the adduct (14).[11] ^{19}F-NMR shows that 14 is syn form. ^1H-NMR shows one peak due to two olefinic protons and two peaks due to two methyne protons, probably because the latter became non-equivalent due to hindered rotation of the trifluoroacetyl group. The reaction of 14 with bromine gave dibromide (15)[12] by addition to the double bond and not the cage compound. These results show that 14 has exo-syn form.

Compound 1 reacted with 2,5-dimethylfuran (16) or tetramethylfuran (17) immediately to give an exo-syn adduct (18) or (19).[13] Very small effect of methyl groups on 3- and 4-positions supports the exo-syn form.

The reaction of 1 with pyrrole (20) proceeded at room temperature to give a cage compound (21).[14] Its structure was determined from spectral data, especially from presence of ν_{O-H} and absence of $\nu_{C=O}$ in IR.

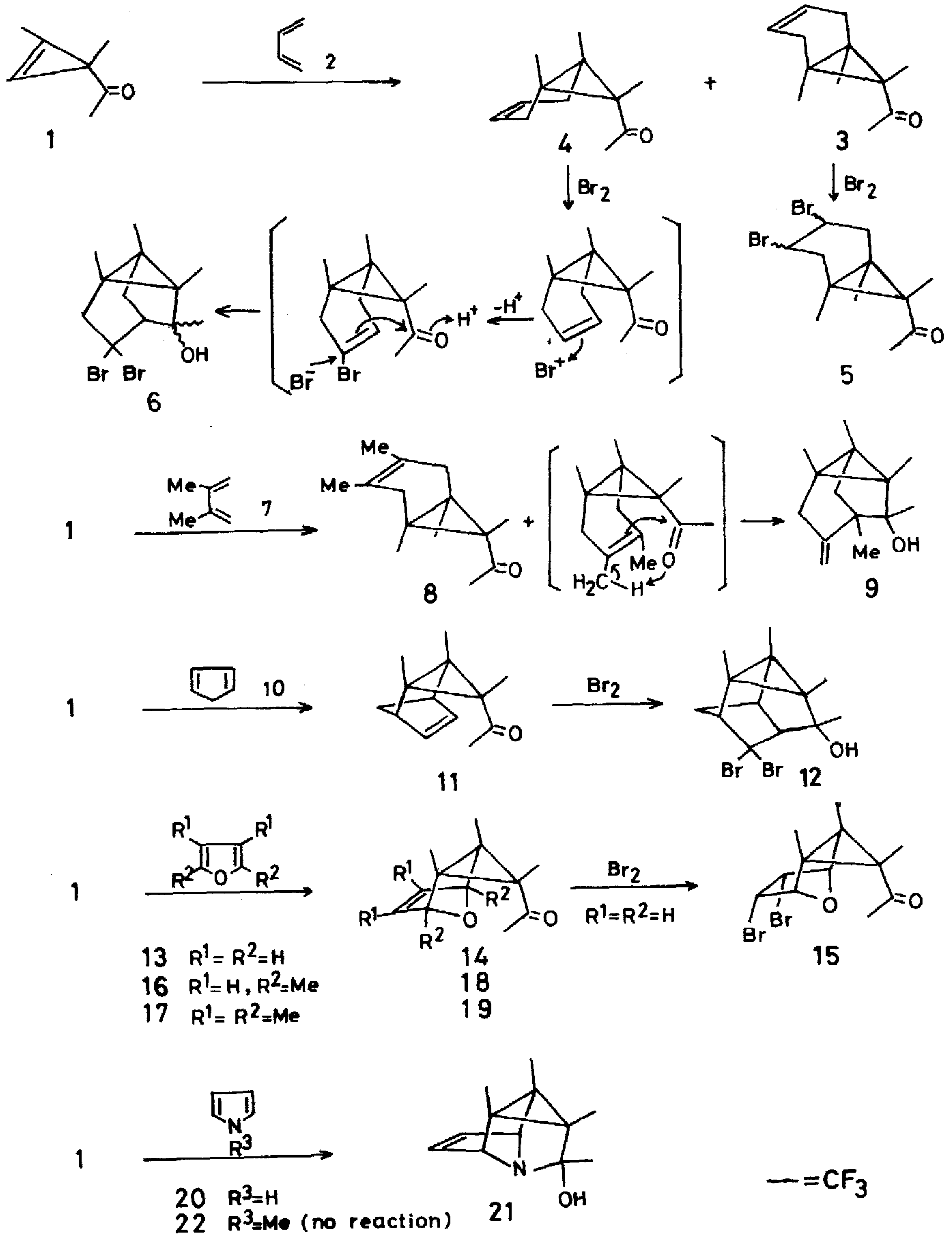
This shows that pyrrole reacted with 1 in the exo-syn form and the primary adduct afforded 21 by intramolecular nucleophilic addition of N-H to C=O.

N-Methylpyrrole (22) did not give any product and decomposition of 1 was observed in ^{19}F-NMR. This result shows that 1 would not be able to react with 22 in Diels-Alder manner because of steric influence of N-methyl group. All the results are shown in chart.

In conclusion, I reacts with reactive dienes, in syn form rather than anti form. The electron rich part, diene or hetero atom, takes endo position due to the electron attracting effect of the trifluoroacetyl group.

Monti and Bertrand reported that 3-methyl-3-acetylcyclopropene could not react with 10 at room temperature, but thermal 1,3-shift of acetyl group occurred at 140° followed by the Diels-Alder reaction affording endo-anti adduct.[15] Compared with the result, trifluoromethyl groups have great influence on the reaction of 1.

In our case electronic interaction between the electron rich part (diene, oxgen atom, or nitrogen atom) and the electron deficient part (carbonyl carbon) will govern the stereochemistry of the transition state.


1
2
4
+
3
Br2
Br2
Br
Br
5
6
OH
Br Br
H+
-H+
Br−
Br
Br+
1
Me
Me
7
Me
Me
8
+
Me O
H2C
H
9
Me OH
1
10
11
Br2
12
OH
Br Br
1
R1
R1
R2
O
R2
13 R1= R2=H
16 R1= H, R2=Me
17 R1= R2=Me
R1
R1
R2
R2
O
14
18
19
Br2
R1=R2=H
Br
Br
O
15
1
N
R3
20 R3=H
22 R3=Me (no reaction)
N
OH
21
— =CF3

References and Notes

1) Part of this work was presented at the 99th Annual Meeting of the Pharmaceutical Society of Japan, Sapporo, August, 1979.
2) C. J. Boriack, E. D. Laganes, and D. M. Lemal, Tetrahedron Lett., 1978, 1015.
3) Cyclopropenes are good dienophiles in the Diels-Alder reaction. Their reaction is reported to be a stereoselective endo-addition: the substituent on 3-position controls the reaction. K. B. Wiberg, and W. J. Bartley, J. Am. Chem. Soc., 82, 6375 (1960); G. L. Closs, L. E. Closs, and W. A. Böll, J. Am. Chem. Soc., 85, 3796 (1963).
4) T. Tsuchiya, H. Arai, and H. Igeta, Tetrahedron, 29, 2747 (1973).
5) Compound 3: bp 89-90°C/50 mmHg; $\nu_{C=O}$ 1770 cm^{-1}; ^{1}H-NMR δ 5.70 (bs), 2.82 (4H, bs); ^{19}F-NMR δ (up field to $C_6H_5CF_3$) -9.1 (3F, q, J=5.9 Hz) -1.9(6F, m), +10.3 (3F, m). Compound 4: mp 53-54°C; $\nu_{C=O}$ 1755 cm^{-1}; ^{1}H-NMR δ 5.52 (2H, bs), 2.84 (4H, bs); ^{19}F-NMR δ -12.7 (3F, m), -2.8 (6F, q, J=13.7 Hz), +7.8 (3F, q, J=5.4 Hz).
6) Compound 5; mp 65-67°C; $\nu_{C=O}$ 1770 cm^{-1}. Compound 6; bp 110-112°C/5 mmHg; ν_{OH} 3580 cm^{-1}.
7) Compound 8; bp 114°C/29 mmHg; $\nu_{C=O}$ 1780 cm^{-1}; ^{1}H-NMR δ 2.70(4H, b), 1.65(6H, s); ^{19}F-NMR δ -7.3(3F, q, J=7.7 Hz), -0.5(6F, m), +11.4(3F, m). Compound 9: bp 127°C/16 mmHg; ν_{OH}=3500 cm^{-1}; ^{1}H-NMR δ 5.05(2H, b), 3.26(1H, d, J=20.0 Hz), 2.72 (1H, b, OH), 2.59(1H, d, J=12.8 Hz), 2.08(1H, d, J=12.8 Hz), 1.29(3H, q, J_{HF}=3.1 Hz); ^{19}F-NMR δ -6.6(3F, m), -3.4(3F, m), -2.1(3F, m) +7.8(3F, q, J=15.4 Hz).
8) J. Sauer, Angew. Chem., Int. Ed., 5, 211 (1966).
9) Compound 11; mp 79-83°C; $\nu_{C=O}$ 1750 cm^{-1}, ^{1}H-NMR δ 6.30(1H, b), 6.05(1H, m), 3.65(2H, b), 2.27(1H, d, J=9.0 Hz), 1.94(1H, d, J=9.0 Hz).
10) Compound 12; mp 158°C; ν_{OH} 3460 cm^{-1}.
11) Compound 14; mp 62°C; $\nu_{C=O}$ 1760 cm^{-1}; ^{1}H-NMR δ 6.72(2H, bs), 5.35(1H, bs), 5.08(1H, bs); ^{19}F-NMR δ -6.3(3F, m), -5.8(6F, m), +11.6(3F, q, J=3.4 Hz).
12) Compound 15; mp 69°C; $\nu_{C=O}$ 1760 cm^{-1}.
13) Compound 18; mp 94-97°C; $\nu_{C=O}$ 1760 cm^{-1}; 6.42(2H, bs), 1.82(3H, s), 1.72(3H, s); ^{19}F-NMR δ -8.0--5.4(9F, m), +8.4(3F, q, J=6.0 Hz). Compound 19; mp 62-63°C; $\nu_{C=O}$ 1750 cm^{-1}; ^{1}H-NMR δ 1.75(9H,s), 1.64(3H, s); ^{19}F-NMR δ -8.2(3F, q, J=9.5 Hz), -7.1(3F, b), -6.2(3F, q, J=9.5 Hz), +7.6(3F, q, J=9.5 Hz).
14) Compound 21; mp 78-79°C; ν_{OH} 3200 cm^{-1}; ^{1}H-NMR δ 6.70(1H, bs), 6.50(bs), 3.76(1H, b, OH), 3.62(1H, bs), 3.17(1H, bs); ^{19}F-NMR δ -4.0(3F, m) -3.5(3F, m), -1.3(3F, m), +11.2(3F, q, J=13.1 Hz).
15) H. Monti, and M. Bertrand, Tetrahedron Lett., 1970, 2591.

(Received in Japan 1 August 1980)