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CYCLOADDITION REACTIONS OF 4,6-DIPHENYLTHIENO[3,4-c]-1,2,5-OXADIAZOLE AND -1,2,5-THIADIAZOLE WITH 6,6-DIPHENYLFULVENE AND TROPONE[1]

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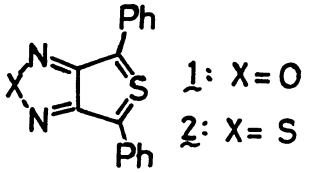
4,6-Diphenylthieno[3,4-c]-1,2,5-oxadiazole (1) reacts as a thiocarbonyl ylide with 6,6-diphenylfulvene to give the exo-[4 + 2] adduct via a stereoselective and regiospecific cycloaddition. The exo-adduct undergoes thermal cleavage of the oxadiazole ring to nitrile and nitrile oxide moieties which can be trapped as 1,3-cycloadducts to the fulvene and dimethyl acetylenedicarboxylate. The reaction of 4,6-diphenylthieno[3,4-c]-1,2,5-thiadiazole (2) with the fulvene affords a mixture of analogous exo- and endo-adducts which are subject to a retro-cycloaddition reaction. On the other hand, 1 reacts with tropone to give the corresponding [4 + 6] adduct which is susceptible to a retro-cycloaddition reaction. However, 2 did not react with tropone.

Recently, 10π-electron condensed thiophenes containing tetravalent sulfur have become considerable practical and theoretical interest.[2] Previously, we have reported that 4,6-diphenylthieno-[3,4-c]-1,2,5-oxadiazole (1)[3] containing tetravalent sulfur is a reactive substrate for cycloadditions, behaving as a thiocarbonyl ylide.[3,4] It has also been found that both the endo- and exo-adducts obtained from 1 and N-phenylmaleimide undergo thermal cleavage of the oxadiazole ring to nitrile and nitrile oxide moieties which can be captured as 1,3-cycloadducts by olefins and acetylenes,[5,6] whereas analogous cycloadducts formed from 4,6-diphenylthieno[3,4-c]-1,2,5-thiadiazole (2)[7] and the maleimide are subject to a retro-cycloaddition reaction.[5]



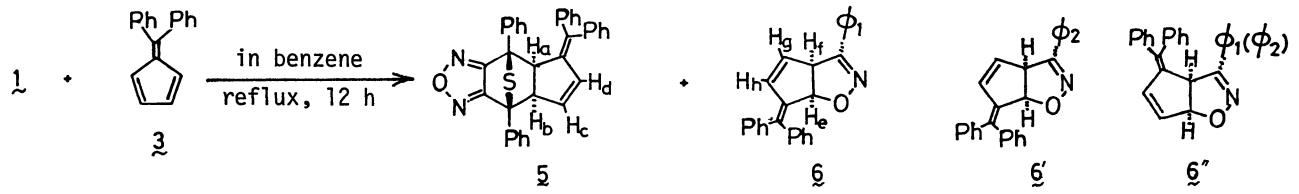
1: X = O
2: X = S

It has recently been recognized by several workers that the fulvene[8-10] and tropone systems[11-13] can function as either a 2π- or 6π-addend with several 1,3-dipoles. Thus, the fulvene and tropone systems seemed to be interesting substrates in the cycloadditions of 1 and 2 behaving as a thiocarbonyl ylide. In the present paper we wish to report the cycloaddition reactions of 1 and 2 with 6,6-diphenylfulvene (3) and tropone (4).[14]

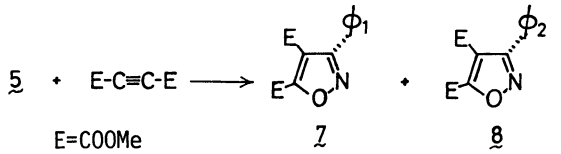
Reaction with Fulvene 3. When a solution of 1 and 3 in benzene was refluxed, under nitrogen, for 12 h, a 1:1 adduct 5 was obtained as the major product, accompanied by a 1:2 adduct 6. In the reaction employing excess of 1, 5 was obtained as the sole product (Scheme 1). The ^{1}H and ^{13}C NMR spectra of 5 exclude both the [4 + 2] adduct to the exocyclic C=C bond of 3 and [6 + 4] adduct from possible structures for 5, and are compatible with either exo- or endo-[4 + 2] adducts. On the basis of comparison of ^{1}H NMR spectral data with those of analogous cycloadducts of 2 to 3 described below, however, it was concluded that exo structure is more reasonable than endo structure.

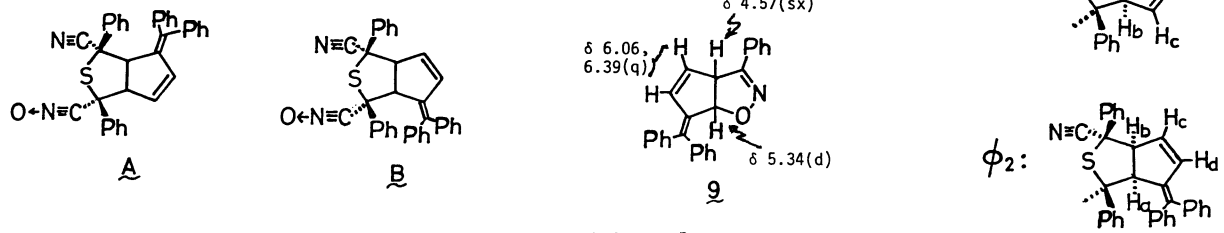
On the other hand, 1:2 adduct 6 was assigned as an isoxazoline derivative arising from a 1,3-cycloaddition of 3 to a nitrile oxide moiety generated from 5 on the basis of the following evidences. The reaction of 5 with 3 afforded a 23% yield of 6 as an isolable product.[15] In addition, 5 reacted with dimethyl acetylenedicarboxylate (DMAD) to give two 1:1 adducts 7 and 8 in 48 and 15% yields

respectively. The IR spectra of 6 as well as of 7 and 8 exhibited a weak band ascribable to $\nu_{C\equiv N}$ absorption as observed in the 1:2 adducts of 1 to acetylenes.[4] It is thus reasonable to conclude that 6 or 7 and 8 are cycloadducts of 3 or DMAD to a nitrile oxide moiety generated from 5, respectively.



1/3 mol/mol	Yield, % 5	6	Recovery, % 1	3
1/1	23	11	24	23
2/1	51	trace	40	—
3/1	52	—	54	—





Scheme 1

Now, the generation of two isomeric nitrile oxides, A and B, is possible from 5. On the basis of NMR spectral data, 7 and 8 were assigned as the isoxazole derivatives arising from A and B respectively. Differences in chemical shifts of H_a and H_b in 7 and 8 can be accounted for by considering the effects of isoxazole ring and phenyl group on the exo-methylene moiety. Based on the similarities of the ^{1}H NMR pattern with those of 7 (for H_a and H_b) and the reported adduct 9[9] (for H_e — H_h), the 1:2 adduct was assigned as 6 but not 6' nor 6". Stereochemistry of the isoxazoline moiety in 6 was based on the comparison of ^{1}H NMR spectral data of the isoxazoline derivatives obtained from the reaction of the exo-adduct of 1 to N-phenylmaleimide with olefins.[6]

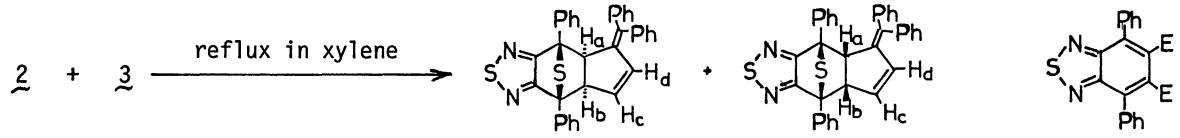
5: mp 191-194°C(dec); ^{1}H NMR($CDCl_3$) δ 4.04(1H, ddd, H_b, J=6, 2.5, 1.5 Hz), 4.54(1H, d, H_a, J=6 Hz), 5.56(1H, dd, H_c, J=6, 2.5 Hz), 6.75(1H, dd, H_d, J=6, 1.5 Hz), 6.3-6.5(2H, m), 6.8-7.7(18H, m); ^{13}C NMR ($CDCl_3$) δ 55.41, 63.79(tert. C), 66.61, 68.85(quat. C), 165.97, 166.32(C=N).

6: mp > 300°C; IR(KBr) 2220 cm^{-1}; ^{1}H NMR($CDCl_3$) δ 4.63(1H, dd, H_g, J=5.5, 2 Hz), 4.73(1H, ddd, H_f, J=7.5, 2, 2 Hz), 5.02(2H, broad s, H_a, H_b), 5.40(1H, d, H_d, J=6 Hz), 5.54(1H, d, H_e, J=7.5 Hz), 6.00 (1H, dd, H_h, J=5.5, 2 Hz), 6.33(1H, d, H_c, J=6 Hz), 6.9-7.6(30H, m); ^{13}C NMR($CDCl_3$) δ 57.38, 59.93, 64.26, 86.74(tert. C), 57.56, 67.25(quat. C), 121.58(C≡N), 160.99(C=N).

7: mp 135-137°C(dec); IR(KBr) 2220 cm^{-1}; ^{1}H NMR($CDCl_3$) δ 3.50, 3.94(each 3H, s), 5.00(1H, ddd, H_b, J=6, 2.5, 2 Hz), 5.12(1H, d, H_a, J=6 Hz), 5.35(1H, dd, H_d, J=6, 2 Hz), 6.35(1H, dd, H_c, J=6, 2.5 Hz), 6.6-7.5(20H, m).

8: mp 283-285°C(dec); IR(KBr) 2220 cm^{-1}; ^{1}H NMR($CDCl_3$) δ 3.38, 3.91(each 3H, s), 4.33(1H, ddd, H_b, J=6, 2.5, 2 Hz), 5.33(1H, dd, H_d, J=6, 2 Hz), 6.20(1H, d, H_a, J=6 Hz), 6.26(1H, dd, H_c, J=6, 2.5 Hz), 6.45-7.8(20H, m).

Next, our attention was directed toward the reaction of 2 with 3. When a solution of 2 and 3 in xylene was refluxed under nitrogen, two isomeric [4 + 2] adducts 10 and 11 like 5 were obtained. On the basis of ^{1}H NMR spectral data, 10 and 11 were assigned as the exo- and endo-adducts respectively. Thus, the protons H_a and H_b in 11 appear at low field than those in 10, because of the deshielding effect of the sulfur bridge. Analogous effects have been noted for other related exo-endo adducts pairs containing a sulfur bridge.[3, 16] As mentioned above, the protons H_a and H_b in 5 appear at δ 4.54 and 4.04 respectively, positions very close to those in exo-adduct 10.



10 11 12

Reaction conditions		Yield, %		Recovery, %	
2/3(mol/mol)	time, h	10	11	2	3
1/1	6	16	7	56	52
1/1	18	13	21	40	42
1/4	18	26	59	—	42

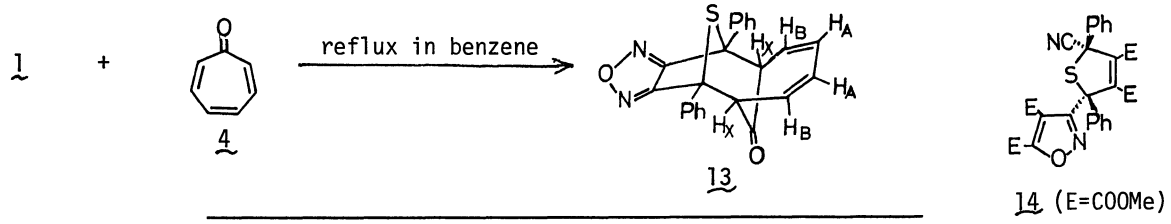
Scheme 2

10: mp 204-205°C(dec); ^{1}H NMR($CDCl_3$) δ 4.08(1H, ddd, H_b, J=5.5, 2.5, 1.5 Hz), 4.52(1H, d, H_a, J=5.5 Hz), 5.51(1H, dd, H_c, J=6, 2.5 Hz), 6.69(1H, dd, J=6, 1.5 Hz), 6.3-6.5(2H, m), 6.75-7.65(18H, m).

11: mp 194-195°C(dec); ^{1}H NMR($CDCl_3$) δ 4.86(1H, dd, H_b, J=7.5, 2.5, 1.5 Hz), 5.47(1H, d, H_a, J=7.5 Hz), 5.66(1H, dd, H_c, J=6, 2.5 Hz), 5.89(1H, dd, H_d, J=6, 1.5 Hz), 6.65-8.0(20H, m).

As shown in Scheme 2, the 10/11 ratio depended on reaction time, indicating that both the adducts 10 and 11 are subject to a retro-cycloaddition reaction to yield 2 and 3, which undergo re-cyclo-addition. In fact, when a solution of endo-adduct 11 in xylene was refluxed with DMAD, under nitrogen, for 18 h, benzothiadiazole derivative 12[4], which was formed from the reaction of 2 with DMAD, was obtained in 48% yield.

Reaction with Tropone 4. When a solution of 1 and 4 in benzene was refluxed under nitrogen, a 1:1 adduct 13, mp 138-140°C (dec), was obtained together with recovery of starting materials (Scheme 3). The structure of 13 was deduced to be the [4 + 6] adduct on the basis of spectral data. The IR spectrum of 13 showed the bridging carbonyl absorption at 1730 cm^{-1}, while the ^{1}H NMR spectrum ($CDCl_3$)



4 13 14 (E=COOMe)

Reaction conditions		Yield, %	Recovery, %	
1/4(mol/mol)	time, h	13	1	4
1/1	16	2	78	98
1/1	48	15	68	73
1/3	48	30	44	85

Scheme 3

indicating $A_2B_2X_2$ spin system at δ 3.93 (2H, d, J=6.5 Hz), 5.38 (2H, H_B), and 6.24 (2H, H_A) demonstrated the symmetrical nature of the adduct, and corresponded closely to the NMR spectra of the [6 + 6] photodimer of 4[17] and [6 + 4] adduct of 4 to a cyclopentadienone.[18]

It has also been found that 13 undergoes a retro-cycloaddition reaction. Upon heating 13 in refluxing benzene for 48 h, 1 and 4 were formed in 48 and 44% yields respectively, besides recovery of 13 (48%). Furthermore, when a solution of 13 in benzene was refluxed with an excess of DMAD for 24 h, isoxazole derivative 14[6] corresponded to a 1:2 adduct of 1 to DMAD was formed in 34% yield.

References and Notes

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14. All new compounds in this paper gave satisfactory elemental analyses.
15. In the reaction of 1 with an equimolar amount of 3 as well as in this case, a mixture of 1:2 adducts ($\nu_{C\equiv N}$ 2220 cm^{-1}, ^1H NMR ($CDCl_3$) complex signals at δ about 3.8 and 4.5-6.5) other than 6 was obtained. However, attempts to isolate pure adduct(s) were unsuccessful.
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