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Photoreaction of 1,6-Disubstituted-1,3,5-hexatriynes with 2,3-Dimethyl-2-butene

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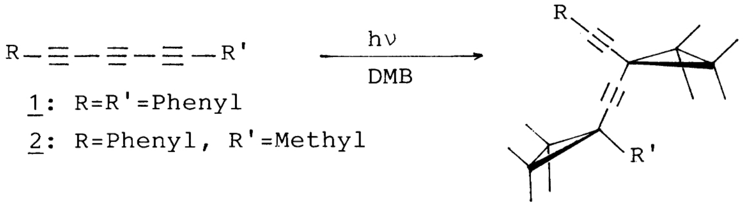
Irradiation of 1-phenyl-6-methyl- and 1,6-diphenyl-1,3,5-hexatriynes with N_2 purged 2,3-dimethyl-2-butene yields 1:2 photoadducts, 1-(1'-phenylethynyl-2',2'3',3'-tetramethylcyclopropyl)-2-(1",2",2",3",3"-pentamethylcyclopropyl)acetylene and 1-(1'-phenylethynyl-2',2',3',3'-tetramethylcyclopropyl)-2-(1"-phenyl-2",2",3",3"-tetramethylcyclopropyl)acetylene, respectively. The photoaddition reactions seem to proceed from the triplet excited states.

Certain naturally occurring conjugated polyacetylenes have been reported to be phototoxic to a variety of microorganisms, human skin fibroblasts, mosquito larvae and Paramecium.[1-5] In particular, 1-phenyl-1,3,5-heptatriyne (PHT) is phototoxic to many organisms containing membranes, including eukaryotic cells, fungi, bacteria, and viruses in the presence of UVA(300-400 nm UV light).[6] However it was reported that the phototoxicity of PHT is different from the 8-methoxypsolaren phototoxicity which involves cross-link in DNA.[1,6,7] No cross-link in calf thymus DNA was formed on irradiation with UVA. Oxygen effect studies for the PHT phototoxicity have suggested competing type II photooxidation and the nonoxidative process not involving oxygen (possibly a radical mechanism) which is clearly favored for aliphatic acetylenes.[8] But no information is available for phototoxic sites and photoadducts of PHT with substrates. To elucidate these problems, 1-phenyl-1,3,5-heptatriyne and 1,6-diphenyl-1,3,5-heptatriyne in nitrogen gas purged 2,3-dimethyl-2-butene (DMB) solution were photolyzed as a model reaction for the PHT phototoxicity.



1: R=R'=Phenyl
2: R=Phenyl, R'=Methyl

When deaerated DMB solution of DPH is irradiated with 350 nm UV light 1-(1'-phenylethynyl-2',2',3',3'-tetramethylcyclopropyl)-2-(1"-phenyl-2",2",3",3"-tetramethylcyclopropyl)acetylene is obtained predominantly while 1-(1'-phenyl-2',2',3',3'-tetramethylcyclopropyl)-2-(1",2",2",3".3"-pentamethylcyclopropyl)-acetylene is obtained as a major product from 2. In the latter case, some photoproducts are detected on the TLC but not isolated because they exist in very minor quantities. When aerated DMB solutions of 1 and 2 were irradiated with 350 nm UV light, no photoproducts was observed.

The structures of the photoproducts were identified by the various spectral data. In particular, ^{13}C NMR (Fig. 1) and mass spectra gave good informations for their structure. Figure 1(a) shows four sp hybridized carbons and two kinds of substituted phenyl ring carbons. The peaks at 140.22 and 124.22 ppm reveal that the substituents are cyclopropyl and ethynyl group, respectively, by the additivity rule of ^{13}C chemical shift. The remaining eight ring carbons of two phenyl groups appear as six peaks and eight alkyl carbons of 14 carbon alkyl chain are shown in the region of 18-32 ppm because of their symmetry. In Fig. 1(b), four sp hybridized carbon peaks and four phenyl carbon peaks are shown and nine alkyl carbon peaks are observed in the region of 16-33 ppm. In particular, the carbon peak at 124.26 ppm and disappearance of the carbon peak at 4.8 ppm which is shown in PHT support the structure of 4.

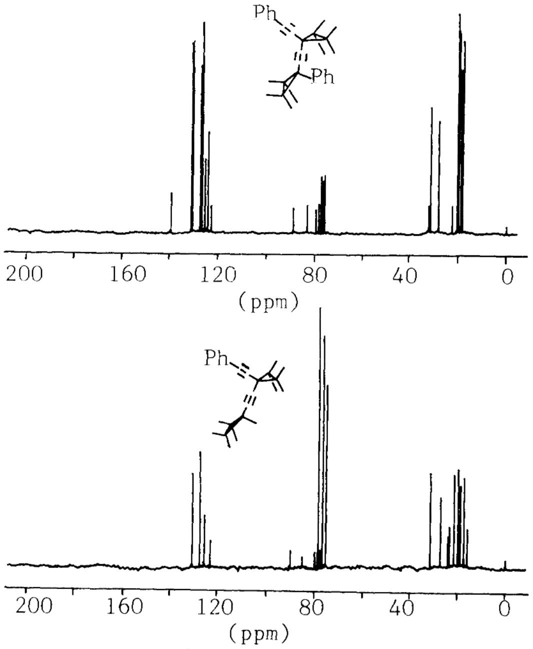
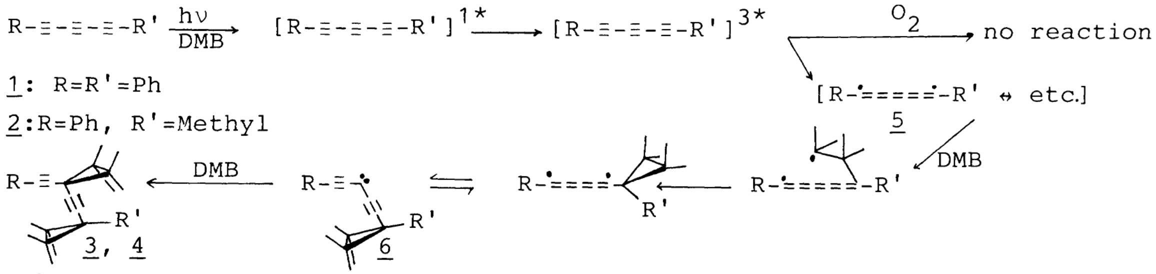


Fig.1. (a) ^{13}C NMR spectrum of 3 in $CDCl_3$.
(b) ^{13}C NMR spectrum of 4 in $CDCl_3$.

A plausible reaction mechanism on the photoaddition reaction of 1 and 2 with DMB is shown in Scheme 1.



Scheme 1. A Plausible reaction mechanism for 1 and 2-DMB photoaddition reaction.

The triplet state of PHT was efficiently quenched by oxygen or by a good electron acceptor with almost diffusion controlled rates.$^{9)}$ The photoadduct formation in deaerated but not in aerated DMB solution indicates that the photoaddition reactions proceed from the triplet state rather than the singlet state. Two reactive sites at 3 and 6-positions in 2 can be justified by the resonance structure of cummulene type diradical species, 5, which supports the triplet mechanism because the triplet diradicaloids favor the geometry in which the free(radical) valences are as far apart as possible.^{10} DMB reacts first at 6-position because the radical formed at 1-position is better stabilized by phenyl group compared to radical formed at 6-position. The first addition of DMB molecule to 5 at 6-position probably generates carbene at 3-position which attacks the second DMB molecule.

The photoreaction of 1 and 2 with DMB is the first photochemical model reaction to reveal the photochemical reactivity of PHT with substrates in vivo or vitro, and the results show the possibility of cross-adducts formation between PHT and C=C double bonds in the biomolecules on irradiation with UVA.

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11) Preparative photolysis of 1 and 2; Deaerated 4 mM DMB solutions of 1 and 2 were irradiated with 350 nm UV light in a Rayonet Photochemical Reactor Model RPR-208 equipped with RUL-3500 A$^{\circ}$ lamps. After the irradiation for 48

h , the resulting photoreaction mixture was concentrated in vacuo. The photoproducts, 3 and 4, were isolated by column chromatography using n-pentane as an eluent in 33% and 11% yields, respectively.

12) 1: ^{1}H NMR ($CDCl_3$) δ 7.4(m,10H); ^{13}C NMR ($CDCl_3$) δ 134.0, 131.0, 129.9, 122.2, 80.0, 75.9, 68.0; IR (NaCl) 3080, 2260, 2200, 1600, 1585, 1505, 1450, 910, 755, and 687 cm^{-1}; UV (methanol) λmax(logε) 358(4.47), 332(4.64), 311 (4.53), 283(4.86), 267(4.93), and 254(4.98) nm; MS, m/e 226 ($M^{+\cdot}$,100).

13) 2: ^{1}H NMR ($CDCl_3$) δ 7.3(m,5H), 2(s,3H); ^{13}C NMR ($CDCl_3$) δ 133.1, 130.0, 129.0, 120.4, 79.0, 75.7, 75.0, 68.0, 65.4, 59.5, 4.8; IR (NaCl) 3080, 2940, 2240, 1600, 1500, 1450, 1380, 760, and 690 cm^{-1}; UV (methanol) λmax(logε) 330(4.41), 309(4.54), 289(4.44), 273(4.16), 249(5.11), and 237(4.88) nm; MS, m/e 164 ($M^{+\cdot}$,100), 153 ($M^{+\cdot}$-H,51).

14) 3: ^{1}H NMR ($CDCl_3$) δ 7.2(m,10H), 1.3(s,6H), 1.1(s,6H), 1.0(s,6H), 0.9(s,6H); ^{13}C NMR ($CDCl_3$) δ 140.22, 131.55, 131.07, 128.04, 127.93, 127.25, 125.99, 124.22, 89.65, 84.00, 80.15, 78.65, 32.96, 32.52, 30.69, 28.69, 23.22, 20.63, 20.55, 19.28, 19.17; IR (NaCl) 3020, 2940, 2240, 1630, 1500, 1460, 1390, 760, 710, and 695 cm^{-1}; UV (methanol) λmax(logε) 253(4.21), 242(4.20) nm; MS, m/e 394 ($M^{+\cdot}$,8.6), 379 ($M^{+\cdot}$-CH_3,7.1), 310 ($M^{+\cdot}$-DMB,100), 226 ($M^{+\cdot}$-2DMB, 41.4).

15) 4: ^{1}H NMR ($CDCl_3$) δ 7.3(m,5H), [1.32(s), 1.3(s), 1.23(s), 1.07(s), 27H]; ^{13}C NMR ($CDCl_3$) δ 131.26, 128.05, 127.28, 124.26, 89.86, 85.31, 80.16, 76.75, 32.23, 26.02, 23.80, 22.80, 20.51, 19.40, 19.33, 17.49, 16.10; IR (NaCl) 3080, 3020, 2940, 2240, 1610, 1500, 1450, 1390, 1100, 760, and 690 cm^{-1}; UV (methanol) λmax(logε) 252(4.24), 240(4.25) nm; MS, m/e 332 ($M^{+\cdot}$,36.5), 317 ($M^{+\cdot}$-CH_3,76), 248 ($M^{+\cdot}$-DMB,8.3), 164 ($M^{+\cdot}$-2DMB,90.1)

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