



A novel intramolecular arene–alkene photocycloaddition in 2-alkenyl naphtha-4-chromanones—a short route to functionalised multicyclic systems

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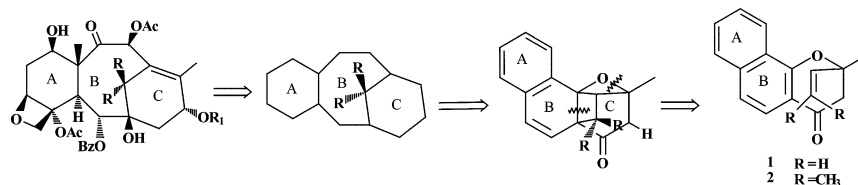
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Abstract—On irradiation, 2-methyl-2-ethenyl naphtha-4-chromanone **1** undergoes an unusual intramolecular arene–alkene photocyclisation, followed by rearrangements to give a [5.3.1.0^{6,1}]benzotricycloundecene, **5**. © 2003 Elsevier Science Ltd. All rights reserved.

Recently, we have described an efficient 1,2-arene–alkene photocycloaddition in 2-alkenyl-4-chromanones resulting in the formation of oxatetracyclotetradecanediones, which on further rearrangements gave functionalised multicyclic systems.¹ Construction of a tricyclopentadecane core with 6+8+6 carbon framework is one of the most challenging problem in the synthesis of taxoids.² Retro-synthetically, the 1,2-arene–alkene photocycloaddition³ of the 2-alkenyl-4-naphthachromanones, such as 2-methyl-2-ethenyl-2,3-dihydro-4*H*-naphtho[1,2-*b*]pyran-4-one **1** and 2-methyl-2-(2,2-dimethylethenyl)-2,3-dihydro-4*H*-naphtho[1,2-*b*]pyran-4-one **2** presented a possibility for a simple and short route to tricyclo[9.3.1.0^{3,8}]pentadecane, the carbon framework of the taxanes (Scheme 1). The photo transformations of the model substrate **1** was chosen for our initial studies. Contrary to our expectation, **1** gave an unusual but interesting intramolecular arene–alkene photocycloadduct **5**. Our results are described in the present communication.

The synthesis of **1** was carried out by the kinetically controlled aldol condensation⁴ of methyl vinyl ketone and 2-acetyl-1-naphthol **3** using LDA at -78°C (yield 80%), followed by cyclodehydration with HMPT or methanolic HCl (10%) (yield 60%). The product **1** was characterised by spectral analysis. (UV λ : 254, 260, 361 nm.; MS: M^{+} , 240; ^1H NMR δ : 5.15 and 5.3 (2H, dd, $J=11$ and 17 Hz), 5.96 (1H, dd $J=11$ and 17 Hz), 7.37 (2H, d, $J=8.6$) and 8.37 (2H, d, $J=8.6$ Hz).

Irradiation of **1** was carried out in 5% aqueous methanol using UV irradiation (above 330 nm) in an Hanovia immersion well. A highly crystalline photo-product **5** (mp 175°C) was isolated from the complex reaction mixture by prep. TLC in 20% yield. The structure of **5** (analysed for $\text{C}_{17}\text{H}_{18}\text{O}_3$) was established using the following evidence: (i) The IR (1635 cm^{-1}) and UV (265 nm) absorptions indicated the presence of an enone system. This was further confirmed by the olefinic carbon signals at δ_c 121.4 and 165.8 in ^{13}C



Scheme 1.

Keywords: arene–alkene photocycloaddition; 2-alkenyl naphtha-4-chromanones; benzotricycloundecene; taxol.

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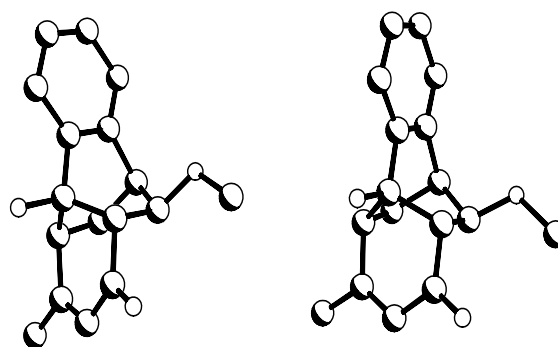
Table 1. NMR data of **5**

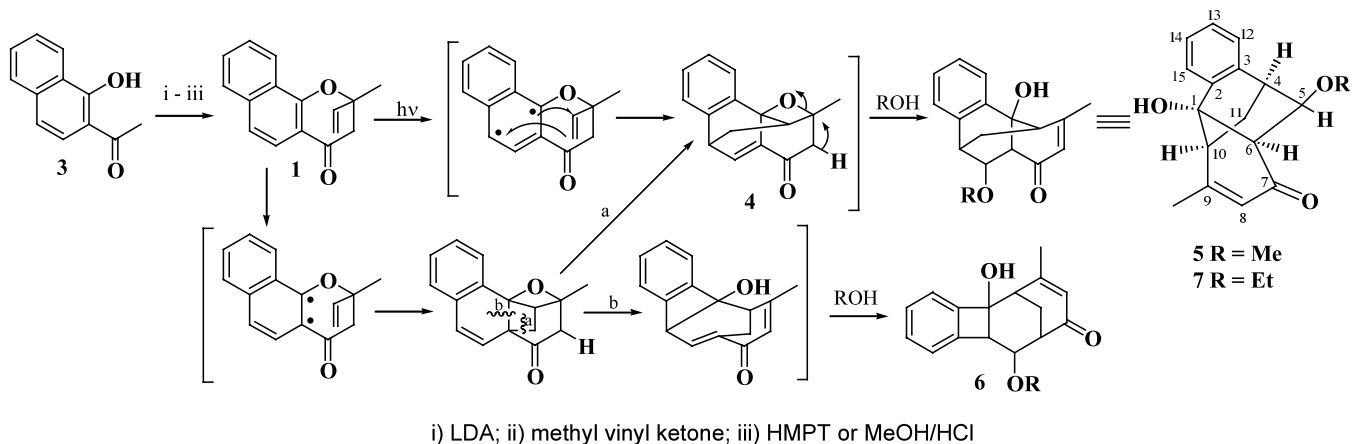
Carbon no.	δ (^{13}C) in ppm	Carbon multiplicity DEPT	δ (^1H) based on HETCOR (ppm)	δ (^1H) in ppm		
				COSY	NOESY	COLOC
C1	75.9	>C<	—			2.28, 2.18
Ar-C2	140.8	>C<	—			3.35, 1.94, 2.28
Ar-C3	139.0	>C<	—			1.71, 1.94, 3.63
C4	42.4	CH	3.35	3.63, 1.71, 1.94	1.71, 1.94, 3.63	
C5	81.4	CH	3.63	3.35, 2.28	2.28, 3.35	3.35, 2.28
C6	59.0	CH	2.28	3.63, 2.18	3.63, 2.18	2.18
C7	200.2	>C<	—			2.28, 3.63
C8	121.4	CH	5.86	2.04	2.04, 2.67	2.28, 2.04
C9	165.8	>C<	—			2.04
C10	41.7	CH	2.18	2.28, 1.71, 1.94	1.71, 1.94, 2.28	2.28, 5.86
C11	32.8	CH ₂	1.71, 1.94	2.18, 3.35	2.28, 3.35	
Ar-C12	124.9	CH	7.24	7.34		
Ar-C13	126.9	CH	7.34	7.24, 7.36		
Ar-C14	127.4	CH	7.36	7.56, 7.34		
Ar-C15	120.3	CH	7.56	7.36		
9-Methyl	23.9	CH ₃	2.04	5.86	5.86	
5-OMe	56.0	CH ₃	3.26			
1-OH	—		2.67		5.86	

NMR spectra along with a ^1H NMR singlet at δ_{H} 5.86; (ii) The molecular ion peak (M^+) at 270 (30 amu higher than that of **1**, mass spectral fragment at $\text{M}^+ - \text{OMe}$, and a signal for OMe at δ_{H} 3.26 in ^1H NMR spectrum, indicated an addition of CH_3OH during the photoreaction; (iii) The absence of vinylic protons, the appearance of several upfield signals in ^1H NMR and the disappearance of four aromatic signals in the ^{13}C NMR spectrum (Table 1) suggested the possible arene–alkene cycloaddition; (iv) A deuterium exchangeable ($\text{CD}_3\text{ONa}/\text{CD}_3\text{OD}$, ^1H NMR) singlet for a methyl group at δ 2.04 could be assigned the position 9 (α - to trisubstituted double bond of enone); (v) In contrast to **1**, signals for several saturated aliphatic carbons were observed in the ^{13}C NMR spectrum. These changes are suggestive of deep-seated rearrangements and the addition of a methanol molecule.

These observations were further supported by 2D NMR spectroscopic studies. The allylic nature of the methyl at position 9 was confirmed by the COSY interactions with olefinic proton (8-H). On the basis of the COSY, HETCOR and NOESY (see Table 1) two structures, **5** and **6** could be proposed. These could arise by an intramolecular 1,4- or 1,2-arene–alkene photocycloaddition respectively. The final structure could be arrived at by $^{13}\text{C}-^1\text{H}$ shift correlations via long range coupling in 2D COLOC experiments. The benzotricyclic fusion with $-\text{CH}_2-$ bridging was confirmed by the following COLOC experiments: (i) C-2 (aromatic) with H-6, 11-H $_{\beta}$ and H-10 (only possible in structure **5**), (ii) C-3 (aromatic) with 11-H $_{\alpha}$, 11-H $_{\beta}$ and H-5, (iii) C-1 with H-6 and H-10. In addition, the COLOC interactions at C-10 with H-8 and H-6; C-7 with H-6 and H-5 and C-8 with allylic methyl (C-9) protons (δ_{H} 2.04) unequivocally proved the structure of the photoproduct as **5**.⁵ The structure **5** was further supported by X-ray crystallography (Fig. 1).⁶

The formation of **5** can be visualised through intramolecular 1,2- or 1,4-arene–alkene photocycloaddition.⁷ 1,4 Cycloadditions are comparatively rare, possibly due to less favourable orbital overlap between the two participating components. However naphthalene is known to act as a 4π unit in 4+2 photoadditions with alkenes.^{7c} 1,2-Addition would result in the formation of a cyclobutane intermediate which on subsequent cleavage by pathway ‘a’, Michael addition of CH_3OH at the bridged head double bond⁸ of **4**, and deprotonation at the position α to carbonyl or vice versa (Scheme 2) would give **5**. This postulate was tested by carrying out the photoreaction in ethanol as solvent wherein the ethanol adduct (**7**, mp 184–85°C; M^+ , 284) was obtained in 20% yield. Though, **7** was obtained as a single compound (GLC, TLC and GC–MS), two quartets at δ_{H} 3.4 and 3.55 for the OCH_2 of ethoxy group at C-5 were observed indicating that addition of EtOH was non-stereospecific. Irradiation of the triplet at δ_{H} 1.04 for the CH_3 of the ethoxy group at C-5 resulted in

**Figure 1.** X-Ray Structure of **5** (PLUTO diagram).



Scheme 2.

the collapse of the quartets at δ 3.40 and 3.55 into singlets. The remainder of the ^1H NMR spectrum of **7** was almost identical with that of **5**.

In summary, a rare intramolecular arene–alkene photocycloaddition has been observed during irradiation of **1**. The stereocontrolled photochemical intramolecular reorganizations of the easily accessible 2-alkenyl-4-chromanones to derivatives of benzotricyclo[5.3.1.0^{6,1}]undecenes could provide a short and atom efficient route to complex polycyclic compounds.

Acknowledgements

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References

- Kalena, G. P.; Pradhan, P.; Banerji, A. *Tetrahedron* **1999**, *55*, 3209–3218.
- Nicolaou, K. C.; Dai, W.; Guy, R. K. *Angew. Chem., Int. Ed. Engl.* **1994**, *33*, 15–44.
- Wender, P. A.; Siegel, L.; Nuss, J. M. In *Organic Photochemistry*; Padwa, A., Ed.; 1989; Vol. 10, pp. 357–473.
- Banerji, A.; Goomer, N. C. *Tetrahedron Lett.* **1979**, *20*, 3685–3686.
- IUPAC nomenclature: 4a,9,10,10a-tetrahydro-4a-hydroxy-10-methoxy-3-methyl-4,9-methano phenanthrene-1(4H)-one. Thanks to Chemical Nomenclature Advisory Service, LGC, UK for providing the IUPAC nomenclature.
- Crystal system*: triclinic; space group: $P\bar{1}$; cell parameters: $a=8.120(2)$, $b=12.302(3)$, $c=14.175$ Å; $\alpha=74.18(2)$, $\beta=85.51(2)^\circ$, $\gamma=77.72(2)^\circ$; $v=1330.9$ Å³. This is a PLUTO diagram with two molecules in the asymmetric unit. Details will be published elsewhere.
- (a) Wender, P. A.; von Gelderin, T. W. In *Photochemistry in Organic Synthesis*; Coyle, J. D., Ed.; Royal Society of Chemistry: London, 1986; pp. 226–255; (b) Wagner, P. J.; Sakamoto, M. *J. Am. Chem. Soc.* **1989**, *111*, 9254–9255; (c) Kohmoto, S.; Miyaji, Y.; Tsuruoka, M.; Kishikawa, K.; Yamamoto, M.; Yamada, K. *J. Chem. Soc., Perkin Trans. 1* **2001**, 2082–2088.
- Hart, H.; Chen, B.; Jeffares, M. *J. Org. Chem.* **1979**, *44*, 2722–2726.