Photochemical Synthesis of Bicyclo[4.1.0]hept-2-enes

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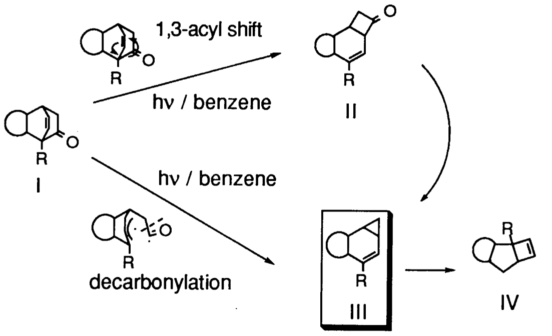
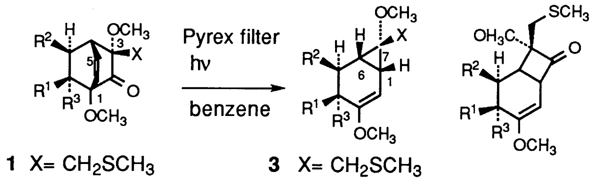
Bicyclo[4.1.0]hept-2-enes (norcarenes) were obtained in good yield by photolysis of 3-methylthiomethyl or 3-(2-ethoxycarbonyl)vinylbicyclo[2.2.2]oct-5-en-2-ones in benzene upon high pressure Hg lamp irradiation.

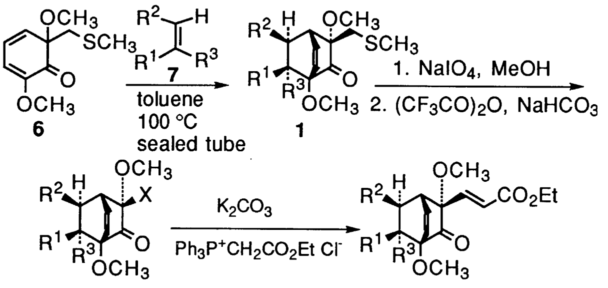
The photochemistry of the bicyclo[2.2.2]oct-5-en-2-ones (I) has been investigated widely. Although it is well-known that the bicyclo[4.2.0]octenones (II) are obtained via the 1,3-acyl shift,[1] the formation of the decarbonylation products, III were scarcely obserbed owing to their successive rapid photoisomerization,[2] except for a few cases.[3] We found that irradiation of the bicyclo[2.2.2]octenones (**1** or **2**) introduced an appropriate group such as methylthiomethyl or (2-ethoxycarbonyl)vinyl group at C_3 position, gave the corresponding norcarenes, bicyclo[4.1.0]hept-2-enes (**3** and **4**).





1 X= CH_2SCH_3 **3** X= CH_2SCH_3 **5**

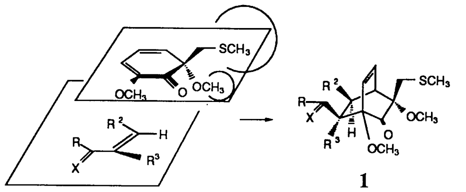
2 X= $CH=CHCO_2Et$ **4** X= $CH=CHCO_2Et$



8 X= CHO **2**

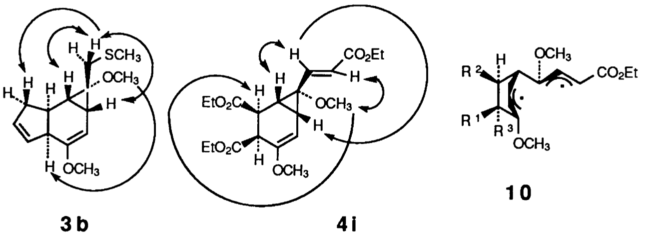
9 X= $CH(SCH_3)_2$

The bicyclo[2.2.2]oct-5-en-2-ones (**1a-j**) were obtained by cycloaddition of cyclohexadiene (**6**)[4] with a variety of dienophiles (**7a-j**), in toluene in a sealed tube at 100 °C.[5] The stereochemistry of the compounds was confirmed (to be the endo adducts) by ^{1}H-^{1}H coupling constants or nuclear Overhauser effect (nOe). This is explained by the endo attack of the dienophiles from the less hindered face (Scheme 1). 3-(2-Ethoxycarbonyl)vinylbicyclo[2.2.2]oct-5-en-2-ones (**2**) was prepared by Wittig reaction[6] of aldehyde (**8**) which was obtained via oxidation with sodium metaperiodate followed by Pummerer reaction with trifluoracetic anhydride[7] in 38-77% total yield from **1**.[8]



Scheme 1.

A solution of **1** in benzene (1.4 x 10^{-2} M) was irradiated with a 400-W high pressure Hg lamp for an appropriate time in a Pyrex immersion well at 0 °C. The solvent was evaporated , and the resiedue was purified by column chromatography on silica gel (100-200 mesh, Micro Bead 4B, Fuji Davison Chemical Ltd., eluent; 10% ethyl acetate in hexane) afforded the desired norcarenes (**3**) in moderate yields (Table 1). A short irradiation gave mainly the 1,3-acyl shift products (**5**) (entry 7), which was converted to the decarbonylation products (**3**) after longer reaction time (entry 8). Although in the photolysis of the compounds having acyl or formyl group, rearrangement of acyl group or deformylation occurred (entry 9-11), the desired norcarenes (**3k-m**) were obtained by protection of these acyl or formyl group as an acetal (entry 12-14). The structure of these norcarenes (**3a-p**) was confirmed by the nOe difference spectra and the other spectra. For example, the nOe experiment of **3b** showed the cis arrangement of 1-H, 6-H, and methylthiomethyl group at C-7 (Scheme 2). This suggested that the decarbonylation-recyclization sequence proceeded retaining the stereochemistry at the quarternary carbon (C-7 of **3**). The ^{1}H NMR spectra displayed resonance at δ 1.0-1.4 ($J_{1,6}$ 9.2-9.6 Hz) for two characteristic protons (nOe) of cyclopropane ring junction[9] and at δ 4.7-4.9 as doublet for a olefinic proton of the



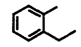
Scheme 2. NOes obserbed in **3 b** and **4 s**.

cyclohexene ring.

In direct irradiation of **2** in benzene upon Pyrex immersion well, the desired norcarenes (**4**) were obtained in much better yields than **3** (Table 2). This was due to the stability of the biradical intermediate (**10**) in the photolysis. In order to complete the reaction, **2a-f** required only 2-5 h, but **2g-i** needed some-what long irradiation time (10-12 h). The structure of **4** was confirmed in a similar manner as **3** (nOe of **4i** was shown in Scheme 2).

Further exploitation of this transformation as a versatile approach to sesquiterpenes such as sesquicarene and sirenin is under study.

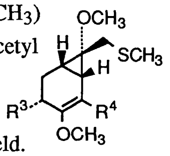
Table 1. Synthesis of **3** by photolysis of **1**

Entry		**1**			Irradiation	Yield / %	
		R^1	R^2	R^3	time / h	**3**	**5**
1	**a**			H	8	46	-
2	**b**	$-CH=CH-CH_2-$		H	8	59	-
3	**c**	$C(CH_3)=CH_2$	H	H	8	59	-
4	**d**	CO_2Et	H	H	10	71	-
5	**e**	$CO_2{}^tBu$	H	H	4	69	8
6	**f**	CO_2Me	H	Me	4	58	14
7	**g**	COEt	H	H	2	9	66
8	**g**	COEt	H	H	10	48	-
9	**h**	COMe	H	Me	5	26[a]	-
10	**i**	CHO	H	H	5	0[b]	-
11	**j**	CHO	H	Me	5	0[c]	-
12	**k**	$C(OCH_2)_2Me$	H	H	5	56	-
13	**l**	$CH(OCH_2)_2$	H	H	5	52	-
14	**m**	$CH(OCH_2)_2$	H	Me	5	54	-

a The norcarene (**3n**; R^3= CH_3, R^4= $COCH_3$) was also formed by rearrangement of acetyl group in 35% yield.

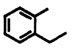
b The norcarene (**3o**; R^3, R^4= H) was formed afetr deformylation in 22% yield.

c The norcarene (**3p**; R^3= CH_3, R^4= H) was formed after deformylation in 42% yield.



3n-p

Table 2. Synthesis of **4** by photolysis of **2**

Entry		**2**			Irradiation	Yield / %	
		R^1	R^2	R^3	time / h	**4**	**2**
1	**a**			H	5	62	-
2	**b**	$-CH=CH-CH_2-$		H	5	65	-
3	**c**	$C(CH_3)=CH_2$	H	H	5	60	-
4	**d**	CO_2Et	H	H	5	92	-
5	**e**	$CO_2{}^tBu$	H	H	5	72	-
6	**f**	CO_2Me	H	Me	2	77	-
7	**g**	CN	H	H	10	56	14
8	**h**	H	CO_2Et	CO_2Et	12	75	-
9	**i**	CO_2Et	CO_2Et	H	12	72	-
10	**j**	$CH(OCH_2)_2$	H	Me	5	64	-
11	**k**	$CH=CHCO_2Et$	H	Me	8	55	33

References and Notes

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5 **1k** was obtained by cycloaddition of **6** with **7k** (R^1= $COCH_3$, R^2= R^3= H), followed by refluxing with ethylene glycol and *p*-TsOH; **1l-m** was derived from **1i-j**, repectively, by treatment ethylene glycol and *p*-TsOH.

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8 In these Pummerer reaction process, 3-bis(methylthio)-methyl derivative (**9**) generated as a byproduct together with **8**. These structures were confirmed by several spectral data such as ^1H NMR and conversion into **8** by treatment with $AgClO_4$; T. Mukaiyama, S. Kobayashi, K. Kamio, and H. Takei, *Chem. Lett.*, **1972**, 237.

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