Photochemical Transformation of γ,δ-Unsaturated Ketone *O*-(*p*-Cyanophenyl)oximes to 3,4-Dihydro-2*H*-pyrrole Derivatives

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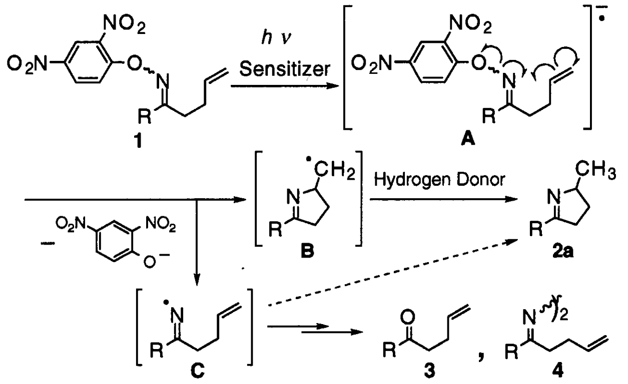
γ,δ-Unsaturated ketone *O*-(*p*-cyanophenyl)oximes are transformed to 3,4-dihydro-2*H*-pyrroles by the photosensitized electron transfer process.

Alkylideneaminyl radicals, conventionally called iminyl radicals, are attractive intermediates for the construction of nitrogen-containing heterocycles.[1] As a leading group in this area, Zard and co-workers have presented various systems for the generation of alkylideneaminyl radicals.[2] Their latest report described a new system for generating these species using nickel powder and acetic acid in 2-propanol.[2f] Weinreb and colleagues also developed the generation of alkylideneaminyl radicals from *O*-(2,6-dimethylbenzenesulfinyl)oximes via the modified Hudson reaction.[3]

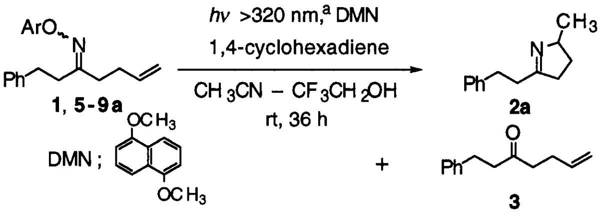
Recently, we have reported that the cyclization of *γ,δ*-unsaturated ketone *O*-(2,4-dinitrophenyl)oximes proceeds on the oxime nitrogen atom by treatment with sodium hydride and 3,4-methylenedioxyphenol, giving 3,4-dihydro-2*H*-pyrroles.[4] Because this cyclization is considered to proceed via one-electron transfer from the sodium phenolate to the dinitrophenyloxime, it was expected that similar electron transfer would occur between a sensitizer and electron deficient *O*-aryloximes by photoirradiation (Scheme 1).

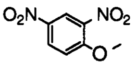
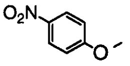
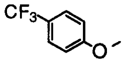
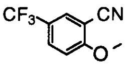
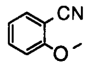
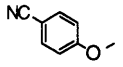


Scheme 1. Photochemical cyclization of *O*-dinitrophenyloxime **1**.

In our first experiment (Table 1, Entry 1), UV irradiation of 1-phenylhept-6-en-3-one *O*-(2,4-dinitrophenyl)oxime (**1**) was performed in the presence of 1,5-dimethoxynaphthalene (DMN, a 0.5 molar amount) as a sensitizer for the electron-transfer[5] and 1,4-cyclohexadiene (7.6 molar amounts) as a hydrogen source in acetonitrile–2,2,2-trifluoroethanol (1 : 1)[6] by 250 W mercury–xenon lamp through a UV cut filter (>320 nm). The desired cyclization product, 2-methyl-5-(1-phenylethyl)-3,4-dihydro-2*H*-pyrrole (**2a**), was obtained in 69% conversion yield, while side products, 1-phenylhept-6-en-3-one (**3**) and 1-phenylhept-6-en-3-one azine (**4**), were generated in 9% conversion yield and in a trace amount, respectively.

Table 1. Reaction of 1-phenylhept-6-en-3-one *O*-aryloximes



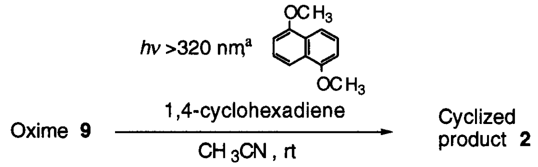
Entry	ArO–		Conversion Yield / %		Conversion of 1, 5-9a/%
			2a	3	
1		**1**	69	9	51
2			40	10	57[b]
3			64	12	25[c]
4		**5**	65	7	44
5		**6**	40	40	8
6		**7**	53	22	98
7		**8**	66	23	79
8		**9a**	70	9	86
9			77	7	96[d]
10			70	9	98[e]
11			47	7	85[f]

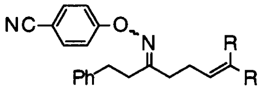
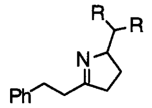
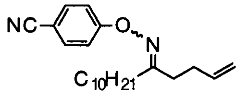
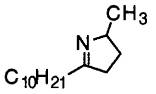
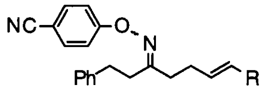
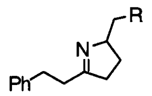
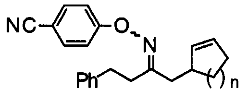
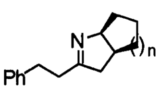
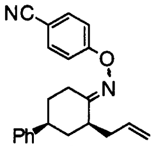
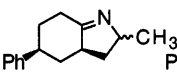
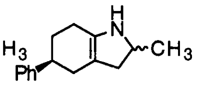
[a] Hamamatsu Photonics Co. 250 W high pressure mercury–xenon lamp and Kenko UV-32 filter. [b] Kenko UV-30 filter (>300 nm). [c] Kenko UV-34 filter (>340 nm). [d] For 24 h in acetonitrile. [e] For 24 h in acetonitrile with 3.5 molar amounts of 1,4-cyclohexadiene. [f] For 24 h in acetonitrile without 1,4-cyclohexadiene.

Concerning the influence of wavelength, the irradiation of the dinitro derivative **1** with shorter wavelength >300 nm of UV increased the yield of the ketone **3** and the azine **4** (Entry 2), and that with longer wavelength (>340 nm) proceeded more slowly than that with >320 nm (Entry 3).

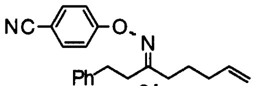
Since a fluorescence quenching of excited DMN by an adding of the oxime **1** was observed, the electron transfer presumably proceeds in an excited singlet state, giving an anion radical **A**. The anion radical **A** would cyclize to generate alkyl radical intermediate **B**, which is trapped with 1,4-cyclohexadiene to yield the cyclic imine **2a**. The ketone **3** might be produced by hydrogen abstraction of the alkylideneaminyl radical

Table 2. Cyclization of several *O*-(*p*-cyanophenyl)oximes



Oxime **9**	Cyclized product **2**
 **9a**(R = H) **9b**(R = CH_3)	 **2a** 75% **2b** 78%
 **9c**	 **2c** 75%
 **9d**(R = $COOCH_2CH_3$) **9e**(R = OCH_3) **9f** (R = Ph)	 **2d** 64% **2e** 53% **2f** 13%
 **9g**(n = 1) **9h**(n = 2)	 **2g** 78% **2h** 69%
 **9i**	 **2i** 60%  **10** 15%

[a] Ushio Inc. 500 W Deep UV lamp (mercury–xenon; UXM-501MD) and Kenko UV-32 filter.
Molar ratio; Oxime / 1,5-dimethoxynaphthalene / 1,4-cyclohexadiene = 1 / 0.15 / 760.



9j

C, which is generated by O–N bond cleavage of the anion radical **A**, followed by hydrolysis of the resulting imine.[7] The formation of the azine **4** was thought to be formed by the dimerization of the aminyl radical **C**.

In order to screen the substituent effect of *O*-phenyl group, various oximes having electron-deficient *O*-aryl groups were prepared. The reaction of a mononitro derivative, *O*-(*p*-nitrophenyl)oximes **5**, proceeded slowly as compared with the dinitro derivative **1** (Entry 4), and *O*-(*p*-trifluoromethyl)phenyl derivative **6** cyclized scarcely (Entry 5). Though the reaction of *o*-cyanophenyl derivatives **7** and **8** gave good conversion of the starting material, a considerable amount of the side product, the ketone **3**, was increased (Entries 6 and 7). Photoreaction of *O*-(*p*-cyanophenyl)oxime **9a** proceeded most efficiently and afforded the cyclized product **2a** in 70% conversion yield (Entry 8).

While the complete conversion of **9a** was hardly attained in a mixture of acetonitrile and 2,2,2-trifluoroethanol even after 36 h irradiation (Table 1), the reaction was highly improved to consume the oxime **9a** after 24 h irradiation in acetonitrile, giving the cyclized product **2a** in 77% yield (Entry 9). Under lower concentration of 1,4-cyclohexadiene, the yield of **2a** slightly decreased (Entry 10), and, even without 1,4-cyclohexadiene, the cyclization proceeded to afford the cyclic imine **2a** in 47% yield (Entry 11). The reaction in acetonitrile-d_3 afforded the corresponding 2-monodeuterized methyl product **2a**, which indicated the hydrogen donor to be acetonitrile.

As summarized in Table 2, the photochemical reaction of various γ,δ-unsaturated ketone *O*-(*p*-cyanophenyl)oximes was examined in acetonitrile with DMN as a sensitizer and 1,4-cyclohexadiene as a hydrogen source by 500 W mercury–xenon lamp through the UV cut filter (>320 nm). Mono cyclic imines **2a-e** were obtained selectively by 5-*exo* cyclization of γ,δ-unsaturated ketone oximes **9a-e** in 53-78% yield. Only in the case of oxime **9f** having a styrene moiety, the desired product **2f** was obtained in only 13% yield along with many side products.

Bicyclic products, hexahydroazapentalene **2g** and hexahydroindole **2h** were also prepared by the present photochemical cyclization in 78% and 69% yield, respectively. In addition, the cyclization of oxime **9i** gave bicyclic imine **2i** and enamine **10** in 60% and 15% yield, respectively.

Thus, 5-*exo* cyclization proceeds successfully, while the trial of 6-*exo* cyclization of δ,ε-unsaturated ketone oxime **9j** gave a complex mixture, which contained the corresponding ketone and azine as major products.

In conclusion, γ,δ-unsaturated ketone *O*-(*p*-cyanophenyl)-oximes are converted into dihydropyrrole derivatives by using photosensitized electron transfer process.

References and Notes

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