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A New Photochemical Synthesis of Dihydropyrazoles. Novel Mode of Photocyclization of Some 1-Iminobut-3-enes Derivatives

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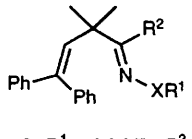
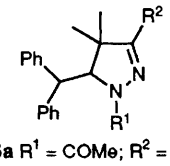
While some hydrazine derivatives **3** of 2,2-dimethyl-4,4-diphenylbut-3-enal undergo both the aza-di-π-methane (ADPM) rearrangement and a novel cyclization to afford dihydropyrazole derivatives **5** in varying yields, the tosylhydrazone derivative of 3,3-dimethyl-5,5-diphenylpent-4-en-2-one **7** gives exclusively an excellent yield of the corresponding dihydropyrazole **8**, in a reaction that is proposed to involve an electron transfer process.

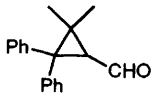
In general we have observed that the efficiency of the aza-di-π-methane photocyclization of 1-iminobut-3-enes can be controlled by the type of substituent attached to the nitrogen.[1] In one case, however, an alternative reaction mode was observed for the derivative **1**.[2] This unusual and unexpected reaction, which is not observed for the derivative **2**, is induced by electron transfer from the 1,1-diphenylalkenyl moiety to the trifluoroacetyl group (a group that has been recognized as a good single electron oxidizer[3]) followed by hydrogen abstraction from the proximate methyl group and fragmentation to yield 1,1-diphenyl-3-methylbut-1-ene. As a consequence of the foregoing we have carried out a study of the changes in reactivity that can be effected by a variety of electron-accepting groups on such systems and herein we report our findings.



1 X = O; R^1 = $COCF_3$; R^2 = Me
2 X = O; R^1 = $COCF_3$; R^2 = H
3a X = NH; R^1 = COMe; R^2 = H
3b X = NH; R^1 = COPh; R^2 = H
3c X = NH; R^1 = Tosyl; R^2 = H
7 X = NH; R^1 = Tosyl; R^2 = Me



5a R^1 = COMe; R^2 = H
5b R^1 = COPh; R^2 = H
5c R^1 = Tosyl; R^2 = H
8 R^1 = Tosyl; R^2 = Me



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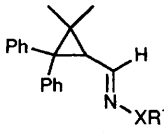
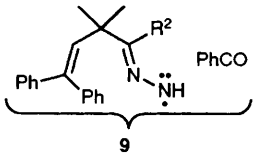


6a X = NH; R^1 = COPh
6b X = NH; R^1 = Tosyl



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On acetophenone-sensitized irradiation† the acetylhydrazone derivative **3a** undergoes the aza-di-π-methane (ADPM) rearrangement yielding the cyclopropylaldehyde **4** in 71% yield after hydrolysis of the photolysate. Careful chromatography of the photolysate gave a low yield (1%) of a new compound.‡ The ^{1}H NMR spectrum of this product suggested that it was a novel dihydropyrazole tentatively assigned as structure **5a**.§ Previously we had reported that the derivative **3b** also undergoes the ADPM rearrangement yielding the product **6a**.[4] This was confirmed in this study although the product **6a** was obtained in higher yield (62%). A careful examination of the photolysate permitted the isolation of a new compound in 22% yield identified by the usual spectroscopic techniques¶ as dihydropyrazole **5b**. The assignment of the structure of this product relies on specific resonances in the NMR spectra. Thus the ^{1}H NMR spectrum exhibits a double doublet at δ 4.2 and 5.4. This feature is not present in the

† The photolyses were carried out in an immersion well apparatus with a Pyrex filter and a 400 W medium pressure Hg arc lamp. Solutions of the compounds (0.8 mmol) and acetophenone as sensitizer in anhydrous benzene (450 ml) were purged with argon for 1 h and irradiated under a positive pressure of argon. After completion of the irradiation the solvent was removed under reduced pressure and the products were separated by column chromatography.

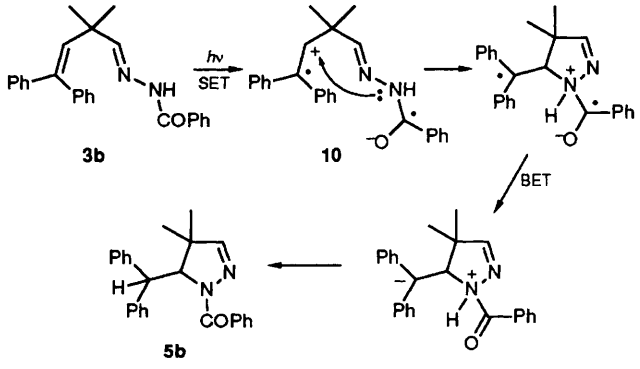
‡ Satisfactory microanalytical data were obtained for all new compounds.

§ The ^{1}H NMR spectrum obtained for this compound had resonances which were similar to those reported by us for a related compound, a dihydroisoxazole (see ref. 6).

¶ The following selected data were recorded for the dihydropyrazoles **5b** and **8**. Compounds **5a** and **5c** show similar spectral data.

5b, m.p. 193–194 °C; ν_{max}(KBr)/cm^{-1} 1655 (C=O) and 1640 (C=N); δ_H($CDCl_3$) 1.0 (3H, s, Me), 1.2 (3H, s, Me), 4.2 (1H, d, *J* 10 Hz, C*H*Ph_2), 5.4 (1H, d, *J* 10 Hz, CH–N), 6.7 (1H, s, CH=N) and 7.5–7.0 (5H, m, ArH); δ_C($CDCl_3$) 167.6 (CH=N), 158.1 (C=O) and 65.7 (C–N).

8, m.p. 122–123 °C; ν_{max}(KBr)/cm^{-1} 1620 (C=N); δ_H($CDCl_3$) 0.8 (3H, s, Me), 1.1 (3H, s, Me), 1.9 (3H, s, Me), 2.3 (3H, s, Me), 3.9 (1H, d, *J* 10 Hz, C*H*Ph_2), 5.0 (1H, d, *J* 10 Hz CH–N) and 7.1–7.4 (14H, m, ArH); δ_C($CDCl_3$) 170.0 (C=N) and 68.5 (C–N).



Scheme 1

spectra of the starting material or the cyclopropane **6a**. Furthermore the ^{13}C NMR spectrum of **5b** shows a resonance at δ 167.6 for C=N whereas the resonance for this occurs at δ 156.3 for the starting material and at δ 152.1 for the cyclopropane **6a**. In addition the product **5b** has a resonance at δ 65.7 for a C–N which is not present in **3b** or **6a**. The resonance position for the C=O group appears at δ 158.1 comparable to the chemical shift for this group in both **3b** and **6a**. The reactivity of **3c** was also investigated and yielded the cyclopropane **6b** in 9% yield and the corresponding dihydropyrazole **5c** in 18% yield. This novel formation of a heterocyclic compound can also be applied to keto derivatives such as **7**. In this case the acetophenone-sensitized irradiation is more efficient and yields the dihydropyrazole **8** in 75% yield, after 1 h irradiation. The efficiency of the hydropyrazole formation with **7** is to be contrasted with the poor efficiency with which such derivatives undergo the ADPM process.[5] It is worthy of note that no ADPM product was observed from the reaction of **7**.

The formation of the dihydropyrazoles **5** and **8** was a surprising and novel outcome for the acetophenone-sensitized irradiation of the derivatives **3** and **7**. In particular cyclization with retention of the acetyl, benzoyl or *p*-tolylsulfonyl group attached to the original nitrogen was unexpected. The failure of the reaction on direct irradiation suggested that the reaction did not merely involve *N*-substituent bond rupture to yield a radical pair **9** which could subsequently yield the heterocyclic compound. An alternative mechanism involving single electron transfer (SET) is suggested following our previous success in this area.[2,6] Thus acetophenone-sensitized irradiation affords an excited state which undergoes SET. This yields the zwitterionic biradical **10**. This transforms into the dihydropyrazole skeleton by a path involving cyclization, back electron transfer (BET) and a 1,3-prototropic shift (Scheme 1).

The new reaction described by us has considerable synthetic potential as a route to heterocyclic compounds. In particular the tosylhydrazone derivative of 3,3-dimethyl-5,5-diphenylpent-4-en-2-one reacts efficiently and currently a study is in hand to establish the versatility of the process.

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