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# The Cycloaddition of *N,N*-Diethyl-1,3-butadienylamine with Some Diarylnitrilimines

Tatsuo Oida,* Shigeo Tanimoto,* Hideyuki Ikehira, and Masaya Okano
*Institute for Chemical Research, Kyoto University, Uji, Kyoto 611*
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The cycloaddition of *N,N*-diethyl-1,3-butadienylamine with some diarylnitrilimines was investigated. 1,3-diaryl-4-vinylpyrazoles, (1,3-diaryl-2-pyrazolin-5-yl)acetaldehydes, 1,3-diaryl-4-(1,3-diaryl-2-pyrazolin-5-yl)-pyrazoles, and 1,3-diarylpyrazoles were obtained.

The presence of conjugated double bonds in conjunction with a amino group makes 1,3-butadienylamines potentially useful intermediates for organic synthesis. For example, recent publications from our laboratory have described the Diels-Alder reactions[1,2] of *N,N*-diethyl-1,3-butadienylamine (**3**) with *trans*-diaroylethylenes and with acetylenecarboxylic acid esters and have illustrated the utility of this diene for the synthesis of 1,3-diarylisobenzofurans and aromatic carboxylic acid esters. In addition to these publications, many reports on the reaction of **3** with various dienophilic reagents such as fulvenes,[3] benzofurazan oxide,[4] and triafulvene,[5] as well as alkyl esters of atropic acid[6] have appeared. Similar experiments using benzonitrile oxide as an enophile were performed in 1970 by Caramella and Bianchessi,[7] who demonstrated that the reaction is applicable to the preparation of 4,5′-diisoxazole ring system. As nitrilimines bear a structural resemblance to nitrile oxides, it would be interesting to utilize the nitrilimines in the cycloaddition with **3**. To our knowledge, there has not been any information published concerning the cycloaddition of **3** with nitrilimines, although the corresponding reaction of 1,3-butadiene (with *C,N*-diphenylnitrilimine) to afford 1,3-diphenyl-5-vinyl-2-pyrazoline has already been elucidated by Huisgen and his co-workers.[8] In this paper we wish to report that the cycloaddition of **3** with several diarylnitrilimines (**2**) proceeds smoothly in benzene to afford the following four kinds of compounds or at least the latter two of them; 1,3-diaryl-4-vinylpyrazoles (**6**), (1,3-diaryl-2-pyrazolin-5-yl)acetaldehydes (**8**), 1,3-diaryl-4-(1,3-diaryl-2-pyrazolin-5-yl)pyrazoles (**9**), and 1,3-diarylpyrazoles (**10**). Among these compounds, only **10** was an unexpected product. In order to explain the formation of **10**, we anticipated that intermediate *trans*-1,3-diaryl-4-(1,3-diaryl-2-pyrazolin-5-yl)-5-diethylamino-2-pyrazolines (**7**) were initially formed; these underwent a deprotonation at the 4′-position (see formula **7**) and the simultaneous bond fission between 4-C and 5′-C, accompanied by a release of the diethylamino group at the 5-position.

## Results and Discussion

First, the cycloaddition between **3** and *N*-(*p*-nitrophenyl)-*C*-phenylnitrilimine (**2a**) prepared *in situ* by the dehydrochlorination of *N*-(*p*-nitrophenyl)benzohydrazonoyl chloride (**1a**) was carried out in benzene at room temperature. The products isolated from the reaction mixture were shown to be 1-(*p*-nitrophenyl)-3-phenyl-4-vinylpyrazole (**6a**), [1-(*p*-nitrophenyl)-3-phenyl-2-pyrazolin-5-yl]acetaldehyde (**8a**), 1-(*p*-nitrophenyl)-4-[1-(*p*-nitrophenyl)-3-phenyl-2-pyrazolin-5-yl]-3-phenylpyrazole (**9a**), and 1-(*p*-nitrophenyl)-3-phenylpyrazole (**10a**). When the reaction was conducted at 80 °C, the products isolated from the reaction mixture were the latter two and neither of the former two was found. Similarly, the cycloaddition of **3** with *C,N*-diphenylnitrilimine (**2b**) in benzene at either room temperature or 80 °C gave two products; 1,3-diphenyl-4-(1,3-diphenyl-2-pyrazolin-5-yl)pyrazole (**9b**) and 1,3-diphenylpyrazole (**10b**). In the same manner, the cycloaddition reactions have also been achieved employing diarylnitrilimines derived from *N*-(*p*-chlorophenyl)benzohydrazonoyl chloride (**1c**) and *N*-phenyl-*p*-nitrobenzohydrazonoyl chloride (**1d**).

It is easy to understand the mechanism concerning the formations of **6a** and **8a**. The former should be

Table 1. Reaction of some nitrilimines (**2**) with *N,N*-diethyl-1,3-butadienylamine (**3**)

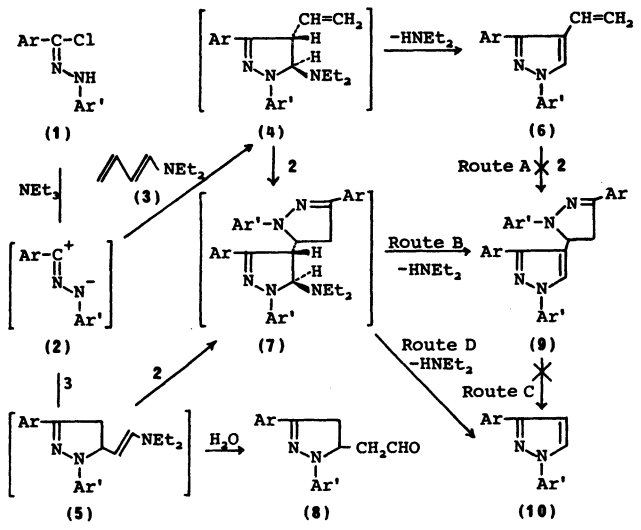
| Run | Hydrazonoyl chloride (**1**) used | | Mole ratio **1/3** | Reaction conditions[a] | | Yield/%[b] of | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ar | Ar′ | | Temp/°C | Time/h | **6** | **8** | **9** | **10** |
| 1 | $C_6H_5$ | *p*-$NO_2C_6H_4$ | 1.5 | rt, | 20 | 31 | 36 | 12 | 17 |
| 2 | $C_6H_5$ | *p*-$NO_2C_6H_4$ | 2.3 | rt, | 20 | 21 | 48 | 14 | 10 |
| 3 | $C_6H_5$ | *p*-$NO_2C_6H_4$ | 2.3 | −10[c] | 6 | 0 | 0 | 4 | 7 |
| 4 | $C_6H_5$ | *p*-$NO_2C_6H_4$ | 2.9 | 80 | 8 | 0 | 0 | 40 | 42 |
| 5 | $C_6H_5$ | $C_6H_5$ | 1.0 | rt, | 20 | 0 | 0 | 17 | 15 |
| 6 | $C_6H_5$ | $C_6H_5$ | 2.1 | rt, | 20 | 0 | 0 | 42 | 23 |
| 7 | $C_6H_5$ | $C_6H_5$ | 2.6 | 80 | 8 | 0 | 0 | 51 | 39 |
| 8 | $C_6H_5$ | *p*-$ClC_6H_4$ | 2.8 | 80 | 8 | 0 | 0 | 53 | 24 |
| 9 | *p*-$NO_2C_6H_4$ | $C_6H_5$ | 2.5 | 80 | 8 | 0 | 0 | 20 | 18 |

a) Benzene was used as the solvent unless otherwise noted. b) Yield was based upon **3**, and was of the isolated product. c) The solvent here is 50 ml of toluene.

TABLE 2. PHYSICAL PROPERTIES AND ANALYTICAL DATA OF THE PRODUCTS

| Product | Mp $\theta_m$/°C | $^1$H-NMR spectra[a] ($\delta$, in DMSO-$d_6$ or $CDCl_3$) | MS (70 eV) $m/e$ ($M^+$) | Found (Calcd) (%) C | H | N |
|---|---|---|---|---|---|---|
| **6a** | 163—165 (EtOH) | 5.23 (dd, 1H), 5.55 (dd, 1H), 6.55 (dd, 1H), 8.07 (s, 1H), 7.1—8.4 (m, 9H) | 291 | 70.07 (70.09) | 4.42 (4.50) | 14.65 (14.43) |
| **8a** | 185—186 (EtOH) | 2.8—3.3 (m, 2H), 3.53 (d, 2H), 4.7—5.3 (m, 1H), 7.0—8.4 (m, 9H), 9.9—10.0(broad s, 1H) | 309 | 65.78 (66.01) | 4.62 (4.89) | 13.80 (13.59) |
| **9a** | >300 (DMF) | 3.4—4.4 (m, 2H), 5.6—6.0 (m, 1H), 6.9—8.7 (m, 19H) | 530 | 67.78 (67.91) | 4.18 (4.18) | 15.80 (15.84) |
| **10a** | 170—171 (EtOH) (lit,[9] 169—169.5) | 6.78 (d, 1H), 7.1—8.4 (m, 9H), 7.82 (d, 1H) | 265 | 67.79 (67.91) | 4.20 (4.18) | 15.81 (15.84) |
| **9b** | 208 (EtOH) | 3.21 (dd, 1H), 3.85 (dd, 1H), 5.55 (dd, 1H), 6.7—8.1 (m, 21H) | 440 | 81.73 (81.79) | 5.49 (5.49) | 12.68 (12.71) |
| **10b** | 85—86 (EtOH) (lit,[10] 84—85) | 6.77 (d, 1H), 7.1—8.2 (m, 11H) | 220 | 82.06 (81.79) | 5.37 (5.49) | 13.00 (12.71) |
| **9c** | 282—286 (EtOH) | 3.2—4.0 (m, 2H), 5.61 (dd, 1H), 6.9—8.3 (m, 19H) | 508 | 70.62 (70.73) | 4.53 (4.35) | 10.89 (11.00) |
| **10c** | 132—133 (EtOH) | 6.66 (d, 1H), 7.2—8.0 (m, 10H) | 254 | 70.98 (70.73) | 4.52 (4.35) | 10.82 (11.00) |
| **9d** | 274—278 (DMF) | 3.3—4.2 (m, 2H), 5.6—5.8 (m, 1H), 6.8—8.8 (m, 19H) | 530 | 68.25 (67.91) | 4.24 (4.18) | 15.59 (15.84) |
| **10d** | 135—137 (EtOH) (lit,[11] 136) | 6.74 (d, 1H), 7.1—7.9 (m, 5H), 7.90 (d,1H), 7.9—8.3 (m, 4H) | 265 | 68.19 (67.91) | 4.41 (4.18) | 15.52 (15.84) |

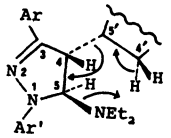
a) The $^1$H-NMR spectra of **9a**, **9c**, and **9d** were measured in DMSO-$d_6$ and the other products in $CDCl_3$.




Scheme 1.

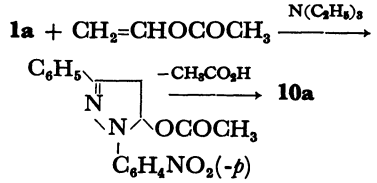
produced *via* a process which involves a regioselective addition of **2a** to the amino-substituted double bond of **3** and a subsequent releasing of the amino group from the intermediate *trans*-5-diethylamino-1-(*p*-nitrophenyl)-3-phenyl-4-vinyl-2-pyrazoline (**4a**). On the other hand, the formation of the latter is believed to be the result of a regioselective addition of **2a** to the terminal double bond of **3** to afford 5-(2-diethylaminovinyl)-1-(*p*-nitrophenyl)-3-phenyl-2-pyrazoline (**5a**), which is further converted to **8a** by hydrolysis. Regarding the formation of **9**, two routes are conceivable; these are represented as routes A and B in Scheme 1. If we assume that route A is operative for the formation of **9**, we are unable to find any substantial explanation of the fact that the cycloaddition of **3** with **2a** in toluene at −10 °C (Run 3 in Table 1) gave only **9a** and **10a**, and no **6a** wa detected. Presumably, **9** were produced by the deamination of the intermediate **7**.

All attempts to decompose **9** to **10** failed. For example, heating of **9** with triethylamine in benzene resulted in the recovery of the starting material together with a small amount of tarry matter, indicating that route C should be ruled out. Thus, we offer a feasible pathway (route D) as mentioned previously in this report. The



presumption that routes B and D are operative as mentioned above is in accord with the observation that the **9a** : **10a** mole ratio in the reaction products of **2a** with **3** was constant under the given reaction conditions and independent of the reaction time (see Experimental).

Because **10a** was an unexpected compound, we synthesized it by the reaction of **1a** with vinyl acetate in the presence of triethylamine, and confirmed that it is identical to that obtained by the cycloaddition of **2a** with **3** (see Experimental).




## Experimental

The $^1$H-NMR and mass spectra were recorded on Varian

EM-360 and JEOL-01SG spectrometers, respectively. The hydrazonoyl chlorides were prepared by the method of Huisgen and his co-workers.[1] Commercial organic materials were used and after distillation or recrystallization. Commercial inorganic materials were used without further purification.

*Reaction of a Hydrazonoyl Chloride (**1**) with* N,N-*Diethyl-1,3-butadienylamine (**3**) in the Presence of Triethylamine. General Procedure*: To a suspension of 0.30 g (2.4 mmol) of **3** and a hydrazonoyl chloride (the mole ratio of the hydrazonoyl chloride to **3** in each run is listed in Table 1) in 50 ml of benzene was added an excess of triethylamine. Exactly twice as much triethylamine as the hydrazonoyl chloride by molar quantity was used. The mixture was stirred under a nitrogen atmosphere in the manner described in Table 1, and poured into 50 ml of aqueous $NH_4Cl$. After the mixture was stirred thoroughly, the aqueous layer separated. The organic layer was dried ($MgSO_4$), and the volatile solvent was removed under reduced pressure leaving a residue, which was chromatographed ($SiO_2$, 20% chloroform–benzene).

*Determination of 1-(*p-*Nitrophenyl)-4-[1-(*p-*nitrophenyl)-3-phenyl-2-pyrazolin-5-yl]-3-phenylpyrazole (**9a**) : 1-(*p-*Nitrophenyl)-3-phenylpyrazole (**10a**) Mole Ratio in the Reaction Products of* N-*(p-Nitrophenyl)-*C-*phenylnitrilimine (**2a**) with* N,N-*Diethyl-1,3-butadienylamine (**3**)*. To a suspension of 0.26 g (2.1 mmol) of **3** and 1.5 g (5.4 mmol) of **1a** in 100 ml of benzene was added 1.0 g (10 mmol) of triethylamine. The mixture was heated at reflux temperature under a nitrogen atmosphere. After 2 h, an aliquot was taken of the homogeneous reaction mixture (0.25 ml). Similar aliquots were taken at 4, 8, and 20 h. From each of these aliquots, a mixture of **1a**, **9a**, and **10a** was isolated by preparative TLC ($SiO_2$, 40% chloroform-benzene as eluent) and **9a** : **10a** mole ratio was determined using a Waters Associates HPLC. The results are summarized in the following table:

| Reaction time/h | Mole ratio(**9a**/**10a**) |
|---|---|
| 2 | 0.33 |
| 4 | 0.34 |
| 8 | 0.33 |
| 20 | 0.35 |

*Synthesis of 1-(*p-*Nitrophenyl)-3-phenylpyrazole (**10a**) by the Reaction of* N-*(*p-*Nitrophenyl)benzohydrazonoyl Chloride (**1a**) with Vinyl Acetate in the Presence of Triethylamine.* To a mixture of 0.50 g (1.8 mmol) of **1a** and 4.7 g (55 mmol) of vinyl acetate was added 0.54 g (5.3 mmol) of triethylamine. The mixture was heated at reflux temperature for 8 h under a nitrogen atmosphere, after which the mixture was cooled and diluted with *ca.* 20 ml of benzene. The benzene solution was washed repeatedly with aqueous $NH_4Cl$, dried ($MgSO_4$), and the volatile solvent was removed under reduced pressure leaving a residue, which was slowly filtered through a $SiO_2$ column. The elution was carried out with 90% benzene–ether. The collected effluent was dried ($MgSO_4$) and evaporated, The resulting precipitate was collected and recrystallized from ethanol to afford 0.23 g of **10a**; mp 169—170 °C (yield, 48% based on **1a**).

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