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Synthesis of Phenethylamine Moiety by Photoamination of Styrene Derivatives with Ammonia

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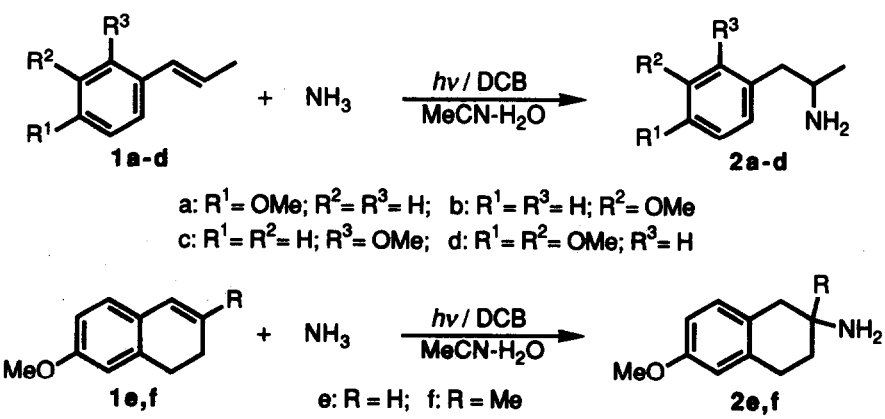
Abstract: *The photoaminations of trans-1-arylpropenes and 7-methoxy-1,2-dihydronaphthalenes with ammonia in the presence of dicyanobenzene gave 1-aryl-2-propylamines and 2-amino-6-methoxy-1,2,3,4-tetrahydronaphthalenes, respectively. The yields of the aminated compounds were improved by the addition of 1,3,5-triphenylbenzene or m-terphenyl.*

Photoinduced nucleophilic additions have provided a useful synthetic tool to introduce a certain functional group to various electron-rich substrates.[1] We have been interested in the preparation of various aminated compounds by the photoamination of electron rich substrates.[2-4] Construction of phenethylamine moiety has been extensively studied owing to their biological activity.[5] The photoamination of styrene derivatives may provide a useful synthetic tool for the preparation of phenethylamine derivatives. However, the nucleophilic addition of styrene derivatives by a photochemical electron transfer, in general, proceeds in poor yields.[6] We wish to report here the effective method for photoamination of styrene derivatives (1) with ammonia by a photochemical electron transfer.



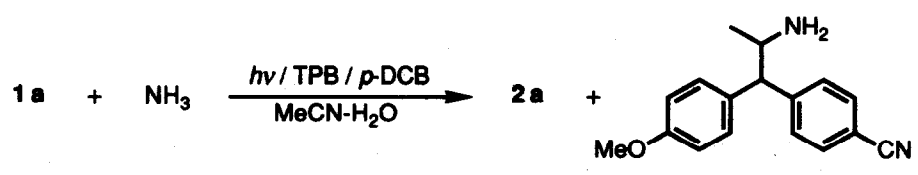
Scheme 1.

Table 1. Photoamination of Styrene Derivatives (**1a-f**)[a]

Substrate	($E_{1/2}^{ox}$)[b]	Additive[c]	A[d]	Product	Yield / %[e]	Conv. of **1** / %
1a	(0.93)	TPB	*m*-DCB	**2a**	91 (52)	98
1a		*m*-TP	*m*-DCB	**2a**	85	98
1a		1,2,4-TPB	*m*-DCB	**2a**	67	87
1a		*p*-TP	*m*-DCB	**2a**	66	97
1a		BP	*m*-DCB	**2a**	58	100
1b	(1.18)	TPB	*p*-DCB	**2b**	46 (28)	93
1c	(0.86)	TPB	*p*-DCB	**2c**	75 (68)	92
1d	(0.82)	TPB	*m*-DCB	**2d**	65 (26)	100
1e	(0.81)	TPB	*m*-DCB	**2e**	29 (23)	100
1f	(0.69)	TPB	*m*-DCB	**2f**	48 (42)	89

[a] Irradiation of an ammonia-saturated acetonitrile-water (9:1; 75 ml) solution containing **1** (2 mmol), DCB (3.75 mmol), and additive (0.75 mmol) for 4-24h. The additive arenes and DCB were recovered in more than 60%. [b] The oxidation potentials vs $Ag/AgNO_3$ in acetonitrile. [c] Additive arenes. See text. [d] Electron acceptor. [e] Isolated yields based on consumed **1**. The values in parenthesis are the yields for the photoamination in the presence of DCB without TPB.

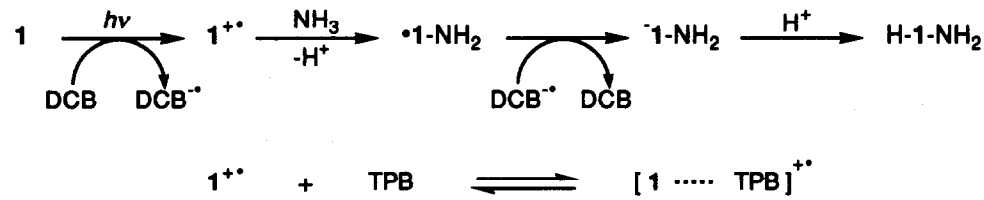
The photoaminations of **1** were performed by irradiating an ammonia-saturated acetonitrile-water solution containing **1** and dicyanobenzene (DCB) by a high-pressure mercury lamp through a Pyrex filter under cooling with water. The results are summarized in Table 1.[7] The photoamination of *trans*-anethole (**1a**) with ammonia gave exclusively 1-(*p*-methoxyphenyl)-2-propylamine (**2a**) in 52% yield. Similarly the photoaminations of *trans*-1-arylpropenes (**1b-d**) and 7-methoxyl-1,2-dihydronaphthalenes (**1e, f**) gave selectively the corresponding 1-aryl-2-propylamines (**2b-d**) and 2-amino-6-methoxy-1,2,3,4-tetrahydronaphthalenes (**2e, f**), respectively (Scheme 1). The yields of **2** were improved by the addition of 1,3,5-triphenylbenzene (TPB; $E_{1/2}^{ox}$= 1.52V) or *m*-terphenyl (*m*-TP; $E_{1/2}^{ox}$= 1.52V), but other arenes such as 1,2,4-triphenylbenzene (1,2,4-TPB; $E_{1/2}^{ox}$= 1.54V), *p*-terphenyl (*p*-TP; $E_{1/2}^{ox}$= 1.51V) and biphenyl (BP; $E_{1/2}^{ox}$= 1.54V) were not as effective as TPB or *m*-TB, as shown in Table 1. The amination of TPB itself did not occur at all to recover most of TPB after the photoreaction. The photoreaction in the absence of DCB did not give **2** at all. Under these reaction conditions incident light was almost absorbed by **1** even in the presence of TPB or *m*-TP; while 1,2,4-TPB, *p*-TP or BP absorbed appreciably incident light. In the cases of **1a,d-f**, *m*-DCB was used as an electron acceptor, because the photoamination in the presence of *p*-DCB resulted in substantial consumption of *p*-DCB and the formation of *p*-cyanophenyl group-incorporated compound. The photoamination of **1a**, for example, gave 1-(*p*-methoxyphenyl)-1-(*p*-cyanophenyl)-2-propylamine (**3a**) in 29% yield along with the formation of **2a** (18%) (Scheme 2).



Scheme 2.

As has been reported for the photoamination of arenes,[2] 1,1-diphenylalkenes,[3] and stilbenes,[4] the photoaminations of **1** were initiated by a photochemical electron transfer from **1** to DCB to give a cation radical of **1** ($\mathbf{1}^{+\cdot}$) and an anion radical of DCB ($DCB^{-\cdot}$), because the oxidation potentials of **1** were relatively low and no photoamination occurred in the absence of DCB. Thus the resulting $\mathbf{1}^{+\cdot}$ undergo the nucleophilic addition of ammonia to form the aminated cation radical ($\cdot\mathbf{1}\text{-}NH_2$) which is reduced by $DCB^{-\cdot}$ and followed by protonation to give **2** (Scheme 3). The incorporation of *p*-cyanophenyl group can be easily interpreted in terms of a radical coupling reaction between *p*-$DCB^{-\cdot}$ and $\cdot\mathbf{1}\text{-}NH_2$ to form **3a**, as reported for other photoinduced nucleophilic additions.[8]

In the presence of TPB or *m*-TP, the improvement of the yields was achieved by the stabilization of $\mathbf{1}^{+\cdot}$ due to π-complex formation with the arenes to suppress side reactions such as dimerization. Similar effect due to π-complex formation was observed in the photoamination of stilbenes in which the yields of the aminated products were improved by use of benzene as co-solvent.[4] BP has been used as a cosensitizer for 9,10-dicyanoanthracene (DCA)-photosensitized oxygenation: the cation radicals of BP ($BP^{+\cdot}$) generated by a photochemical electron transfer from BP to DCA produce efficiently the cation radicals of substrates by a hole transfer from $BP^{+\cdot}$ to substrates.[9] However, the present additive effect of TPB or *m*-TP is different from that of the cosensitizer, because the yields of the aminated products were not improved by the addition of BP, 1,2,4-TPB, or *p*-TP, though the cation radicals of these arenes may be formed by a photochemical electron transfer from these arenes to DCB. Probably a hole transfer from these cation radicals to **1** occurs inefficiently because of reduction of these cation radicals by ammonia.



Scheme 3.

The efficient photoinduced nucleophilic addition of styrene derivatives can be successfully achieved by the addition of arenes in some cases. Therefore, the present amination will be a useful tool for the preparation of phenethylamine and aminotetralin derivatives.[10]

REFERENCES AND NOTES

1. Mariano, P. S.; Stavinoha, J. L. *Synthetic Organic Photochemistry;* Plenum Press: New York. 1984; pp. 145-257.
2. Yasuda, M.; Yamashita, T.; Shima, K.; Pac, C. *J. Org. Chem.* **1987**, *52*, 753-759.
3. Yamashita, T.; Shiomori, K.; Yasuda, M.; Shima, K. *Bull. Chem. Soc. Jpn.* **1991**, *64*, 366-374.
4. Yasuda, M.; Isami, T.; Kubo, J.; Mizutani, M.; Yamashita, T.; Shima, K. *J. Org. Chem.* **1992**, *57*, 1351-1354.
5. Bick, I. R. C. *The Chemistry of Natural Products;* Blachie and Son Ltd: London. 1984; pp. 298-346.
6. Shigemitsu, Y.; Arnold, D. R. *J. Chem. Soc. Chem. Comm.* **1975**, 407-408. Maroulis, A. J.; Arnold, D. R. *J. Am. Chem. Soc.* **1978**, *100*, 535-541. Maroulis, A. J.; Arnold, D. R. *Synthesis.* **1979**, 819-820. Yasuda, M.; Pac, C.; Sakurai, H. *Bull. Chem. Soc. Jpn.* **1980**, *53*, 502-508.
7. A general procedure for isolation of **2** is as follows: After evaporation of acetonitrile, the residue was treated with acetic anhydride and pyridine to protect the amino group of **2**. The acetylated product, unreacted **1**, DCB, and additive arenes were isolated by chromatography on silica gel. The spectral data

of **2a-e** and **3a** are described as follows: **The acetamide of 2a**: ^{1}H NMR(250MHz, $CDCl_3$) δ 1.09 (d, *J*= 6.7 Hz, 3H), 1.93 (s, 3H), 2.63 (dd, *J*= 13.6, 7.2 Hz, 1H), 2.77 (dd, *J*= 13.6, 5.7 Hz, 1H), 3.78 (s, 3H), 4.20 (m, 1H), 5.74 (brd, *J*= 7.7 Hz, 1H), 6.83 (d, *J*= 8.5 Hz, 2H), and 7.08 (d, *J*= 8.5 Hz, 2H); ^{13}C NMR(250MHz, $CDCl_3$) δ 19.81, 23.29, 41.44, 46.40, 55.2, 113.85, 129.98, 130.38, 158.28, and 170.01; Found: *m/z* 207.1258. Calcd for $C_{12}H_{17}NO_2$: M, 207.1255. **The acetamide of 2b**: ^{1}H NMR(250MHz, $CDCl_3$) δ 1.07 (d, *J*= 6.7 Hz, 3H), 1.89 (s, 3H), 2.62 (dd, *J*= 13.4, 7.3 Hz, 1H), 2.98 (dd, *J*= 13.4, 7.6 Hz, 1H), 3.75 (s, 3H), 4.20 (m, 1H), 5.68 (brs, 1H), 6.71 (m, 3H), and 7.17 (m, 1H); ^{13}C NMR(250MHz, $CDCl_3$) δ 19.95, 23.42, 42.42, 46.11, 55.16, 111.77, 115.12, 121.82, 129.34, 139.59, 159.60, and 169.56; Found: *m/z* 207.1258. Calcd for $C_{12}H_{17}NO_2$: M, 207.1255. **The acetamide of 2c**: ^{1}H NMR(250MHz, $CDCl_3$) δ 1.15 (d, *J*= 6.6 Hz, 3H), 1.86 (s, 3H), 2.72 (dd, *J*= 13.5, 5.9 Hz, 1H), 2.81 (dd, *J*= 13.5, 7.6 Hz, 1H), 3.84 (s, 3H), 4.12-4.23 (m, 1H), 5.95 (brs, 1H), 6.85-6.98 (m, 2H), and 7.10-7.24 (m, 2H); ^{13}C NMR(250MHz, $CDCl_3$) δ 20.64, 23.47, 36.44, 46.62, 55.32, 110.45, 120.72, 126.76, 127.83, 131.18, 157.42, and 169.43; Found: *m/z* 207.1259. Calcd for $C_{12}H_{17}NO_2$: M, 207.1255. **The acetamide of 2d**: ^{1}H NMR(250MHz, $CDCl_3$) δ 1.11 (d, *J*= 6.6 Hz, 3H), 1.94 (s, 3H), 2.63 (dd, *J*= 13.6, 7.3 Hz, 1H), 2.80 (dd, *J*= 13.6, 5.6 Hz, 1H), 3.86 (s, 6H), 4.16-4.27 (m, 1H), 5.52 (brd, 1H), and 6.75 (m, 3H); ^{13}C NMR(250MHz, $CDCl_3$) δ 19.94, 23.48, 42.01, 46.21, 55.88, 111.14, 112.53, 121.42, 132.27, 147.65, 248.83, and 169.44; Found: *m/z* 237.1364. Calcd for $C_{13}H_{19}NO_3$: M, 237.1365. **2e**: A colorless oil; ^{1}H NMR(250MHz, $CDCl_3$) δ 1.25-1.89 (m, 3H), 2.45-2.46 (d, *J*= 2.5 Hz, 1H), 2.68-2.76 (m, 1H), 2.83-2.98 (m, 1H), 3.13-3.16 (d, *J*= 7.5 Hz, 1H), 3.76 (s, 3H), and 6.91-6.95 (d, *J*= 10.0 Hz, 1H); ^{13}C NMR(250MHz, $CDCl_3$) δ 26.8, 28.1, 35.3, 43.8, 55.2, 111.9, 113.8, 128.6, 132.9, 139.5, and 157.6; The acetamide: Found: *m/z* 219.1172. Calcd for $C_{13}H_{17}NO_2$: M, 219.1258; **The acetamide of 2f**: A colorless oil; ^{1}H NMR(250MHz, $CDCl_3$) δ 1.26 (s, 1H), 1.49 (s, 3H) 1.63-1.77 (m, 1H), 1.87 (s, 3H), 2.50-2.60 (m, 1H), 2.75 (d, *J*= 7.6 Hz, 1H), 2.81 (s, 2H), 3.77 (s, 3H), 5.35 (s, 1H), 6.65-6.72 (m, 2H), and 6.96 (d, *J*= 8.3 Hz, 1H); ^{13}C NMR(250MHz, $CDCl_3$) δ 24.36, 25.38, 26.35, 31.69, 41.82, 52.50, 55.21, 112.28, 113.33, 125.61, 130.43, 136.85, 157.93, and 170.18; Found: *m/z* 233.1413. Calcd for $C_{14}H_{19}NO_2$: M, 233.1414. **The diastereomeric mixture of the acetamide of 3a**: ^{13}C NMR(250MHz, $CDCl_3$) δ 20.09 and 20.44, 23.17 and 23.26, 47.12 and 47.43, 55.24, 57.08 and 57.60, 110.19 and 110.45, 114.24 and 114.39, 118.75 and 118.87, 128.78 and 128.92, 129.13 and 129.20, 132.27 and 132.39, 132.52 and 132.94, 148.16 and 148.33, 158.64 and 158.70, 169.83 and 169.94; Found: *m/z* 308.1524. Calcd for $C_{19}H_{20}N_2O$: M, 308.1520.

8. Mizuno, K.; Ogawa, J.; Otsuji, Y. *Chem. Lett.* **1981**, 741-744. Rao, V. R.; Hixson, S. S. *J. Am. Chem. Soc.* **1979**, *101*, 6458-6459. Yasuda, M.; Pac, C.; Sakurai, H. *J. Org. Chem.* **1981**, *46*, 788-792. Hixson, S. S.; Xing, Y. *Tetrahedron Lett.* **1991**, *32*, 173-174.
9. Schaap, A. P.; Siddiqui, S.; Prasad, G.; Palomino, E.; Lopez, L. *J. Photochem.* **1984**, *25*, 167-181. Davidson, R. S.; Goodwin, D.; Pratt, J. *J. Photochem.* **1985**, *30*, 167-171. Shim, S. C.; Song, J. S. *J. Org. Chem.* **1986**, *51*, 2817-2819. Xu, J.-H.; Song, Y.-L.; Shang, Y. *J. Chem. Soc., Chem. Commun.* **1991**, 1621-1662.
10. DeMarinis, D. M.; Shah, D. H.; Hall, R. F.; Hieble, J. P.; Pendleton, R. G. *J. Med. Chem.* **1982**, *25*, 136-141. Kanao, M.; Hashizume, T.; Ichikawa, Y.; Irie, K.; Isoda, S. *J. Med. Chem.* **1982**, *25*, 1358-1363.

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