Pergamon

Tetrahedron 55 (1999) 14079–14088

TETRAHEDRON

A Versatile Synthesis of Pyrrolo-, Furo- and Thienopyridines via Photocyclization of 3-Amino-2-alkene Imines in an Acid Medium

Pedro J. Campos,* Elena Añón, M. Carmen Malo and Miguel A. Rodríguez

Departamento de Química. Universidad de La Rioja. 26071-Logroño. Spain

Received 24 June 1999; revised 10 September 1999; accepted 30 September 1999

Abstract: We describe the synthesis of pyrrolo-, furo- and thieno[3,2-*b*]pyridines substituted by alkyl-, arylamino or NH_2 groups from irradiation of 2-pyrrolyl-, 2-furyl-, and 2-thienylalkene imines under mild reaction conditions. We also describe the irradiation of 3-pyrrolyl-, 3-furyl-, and 3-thienylalkene imines, which yields pyrrolo[3,2-*c*]pyridines in all cases. The mechanism for this procedure is proposed. The compounds obtained can potentially be used in medicinal chemistry.

Keywords: 'Imines', 'Pyrrolopyridines', 'Furopyridines', 'Thienopyridines'

INTRODUCTION

Pyrrolo-, furo- and thienopyridines are annelated aromatic heterocycles with a π-electron-rich ring and a π-electron-deficient pyridine ring, which are of general interest for the chemistry of heterocyclic compounds and theoretical organic chemistry. Moreover, some of them are required as starting materials for the synthesis of new drugs, because of their pharmacological activities.[1] For example, they were recently used as the antagonist of the human luteinizing hormone-releasing hormone (LHRH) receptor,[2] as a selective p38 kinase inhibitor,[3] and as an antagonist of melatonin sheep receptor.[4] The activity of these

0040-4020/99/$ - see front matter
PII: S0040-4020(99)00874-1

compounds can be modulated by the substituents and, thus, the presence of an electron-donor group at the 4-position of the fused pyridine resulted in a significant increase in potency.[3]

Due to the importance of this kind of compounds, the literature contains several procedures for the preparation of pyrrolopyridines,[5] and thienopyridines.[6] However, as far as we know, there is no general method to obtain all three pyrrolo-, furo- and thienopyridines. We have previously reported the synthesis of substituted quinolines by the irradiation of 3-amino-2-alkene imines.[7,8] Our methodology supposes the building of the pyridine ring on an aromatic ring through a photocyclization process. Furthermore, irradiation in the presence of tetrafluoroboric acid leads to the formation of quinolines bearing an amino group on the pyridine ring.[8] The growing relevance of the above mentioned annelated aromatic heterocycles prompted us to test the feasibility of our method in the preparation of such compounds. Herein, we wish to report our results in this field.

RESULTS AND DISCUSSION

First, we prepared the 3-(1-methylpyrrol-2-yl)-3-(phenylamino)-1-*p*-tolyl-2-alkene imine **1a**.[9] The absorption spectrum of **1a** in methanol showed bands at 206, 244, and 378 nm ($\varepsilon \approx$ 32900, 19000, and 21700 $M^{-1}cm^{-1}$, respectively) and, after protonation with tetrafluoroboric acid, a displacement of the bands at 244 and 378 nm to higher wavelengths was observed, together with an absorption decrease (264 nm, $\varepsilon \approx$ 16100 $M^{-1}cm^{-1}$, which indicated a $n \rightarrow \pi^*$ electronic transition) or increase (392 nm, $\varepsilon \approx$ 22500 $M^{-1}cm^{-1}$, which indicated a $\pi \rightarrow \pi^*$ electronic transition). These data are related to that previously described[7,8] and we therefore carried out the irradiation through quartz of a $2x10^{-2}$ M methanolic solution of this compound with a 125 W medium-pressure mercury lamp. The reaction was monitored by ^1H NMR spectroscopy. Complete consumption of the starting material occurred after 25 h. The resulting product was purified by column chromatography (silica gel, hexane/Et_2O, 1:2), recrystallized (hexane/Et_2O) and identified as 1-methyl-7-(phenylamino)-5-*p*-tolylpyrrolo[3,2-*b*]pyridine **2a** by its spectroscopic data (^1H and ^{13}C NMR) and mass spectrometry (Scheme 1). The formation of this compound could be explained with a mechanism involving a six-electron electrocyclic process.[8]

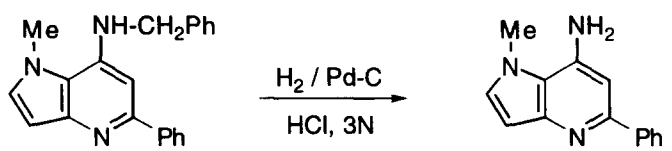
1 **2**

	X	R^1	R^2	R^3	t (h)	Yield (%)
a	N-Me	C_6H_5	H	*p*-MeC_6H_4	25	35
b	N-Me	C_6H_5-CH_2	H	C_6H_5	30	35
c	O	C_6H_5	H	C_6H_5	60	13
d	O	C_6H_5	H	*p*-MeC_6H_4	45	8
e	S	C_6H_5	H	*p*-MeC_6H_4	29	32
f	S	C_6H_5	Me	C_6H_5	24	24
g	S	*c*-C_6H_{11}	H	*p*-MeC_6H_4	20	22

Scheme 1

The previous approach was extended to the irradiation of alkene imines bearing different five-membered heterocyclic rings substituted at the 2-position: **1b** (X = N-Me),[9] **1c-d** (X = O),[9] and **1e-1g** (X = S).[9,10] Under these conditions, compounds **1b-g** led to the formation of pyrrolo-, furo- and thieno[3,2-*b*]pyridines **2b-g** (Scheme 1). Compounds **2** were obtained with a large amount of polymeric material and, therefore, the yields of isolated product (purified by column chromatography) were not high.

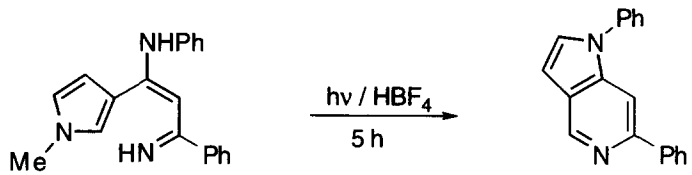
Furthermore, the benzyl group from alkene imine **2b** can be catalytically hydrogenated,[11] and this allowed us to carry out the preparation of pyrrolopyridine **3b** substituted by a NH_2 group (Scheme 2). This kind of compound has been recently used as an entry to Tröger's base analogs.[12]



2b **3b** (98%)

Scheme 2

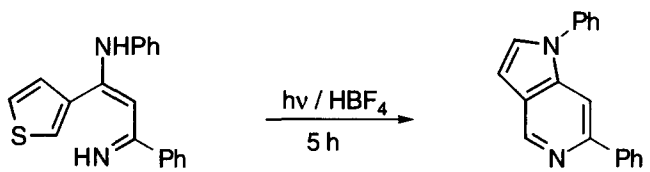
We were also interested in studying the photochemical behaviour of the analogue alkene imines bearing the 3-substituted five-membered heterocyclic ring. First, we selected the 3-(1-methylpyrrol-3-yl)-1-phenyl-3-(phenylamino)-2-alkene imine **4**.[9] However, the irradiation of **4** under the above described conditions did not give the expected product but instead the 1,6-diphenylpyrrolo[3,2-*c*]pyridine **5** (Scheme 3).



4 **5** (25%)

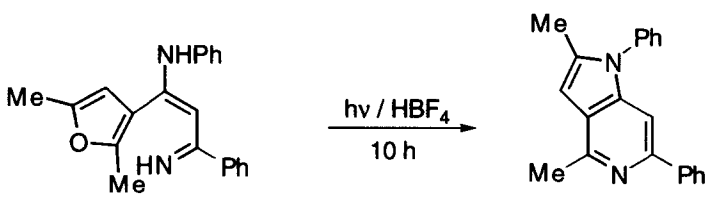
Scheme 3

Interestingly, the irradiation of 1-phenyl-3-(phenylamino)-3-(3-thienyl)-2-alkene imine **6**[9] also led to the formation of 1,6-diphenylpyrrolo[3,2-*c*]pyridine **5** (Scheme 4); the 3-furylalkene imine **7**[9] gave the pyrrolo[3,2-*c*]pyridine **8** (Scheme 5) after the usual work-up procedure.



6 **5** (44%)

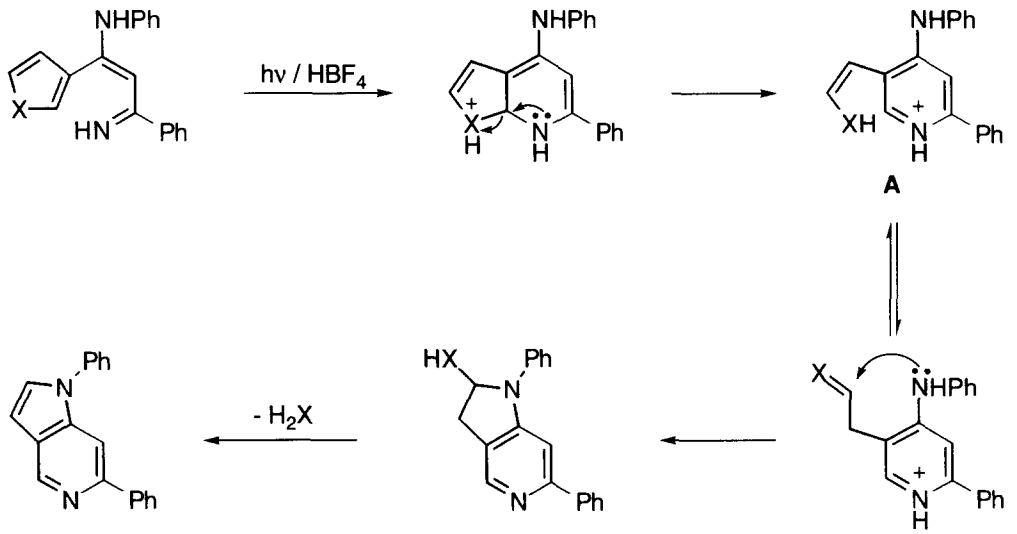
Scheme 4



7 **8** (15%)

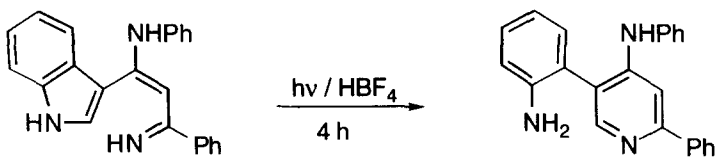
Scheme 5

These results prompted us to suggest the following mechanism for the formation of pyrrolo[3,2-*c*]pyridines **5** and **8** (Scheme 6). After initial six π-electron photocyclization,[8] ring opening occurs (assisted by the nitrogen lone pair and the presence of acid), to give an intermediate **A** that undergoes a tautomerism, followed by attack from the nitrogen of the amine group with final evolution to the corresponding pyrrolo[3,2-*c*]pyridine.



Scheme 6

In order to confirm the proposed mechanism, we designed a reaction where the intermediate **A** could not tautomerize. The irradiation of 3-(3-indolyl)-1-phenyl-3-(phenylamino)-2-alkene imine **9**[9] gave the pyridine derivative **10**, which is an analog of intermediate **A** but does not evolve due to the stability of the aniline ring (Scheme 7).



9 **10** (36%)

Scheme 7

CONCLUSIONS

The irradiation of 2-pyrrolyl-, 2-furyl-, and 2-thienylalkene imines allows the synthesis of pyrrolo-, furo- and thieno[3,2-*b*]pyridines substituted by alkyl-, arylamino or NH_2 groups under mild reaction conditions. The irradiation of 3-pyrrolyl-, 3-furyl-, and 3-thienylalkene imines yields pyrrolo[3,2-*c*]pyridines in all cases. The importance of pyrrolo-, furo- and thieno[3,2-*b*]pyridines and pyrrolo[3,2-*c*]pyridines in medicinal chemistry and their potential use as an entry to Tröger's base analogs enhances the significance of the compounds described herein.

EXPERIMENTAL

^1H and ^{13}C spectra were recorded on a Bruker ARX-300 spectrometer in $CDCl_3$ with TMS as internal standard. Electrospray mass spectra were obtained on an HP 5989 B apparatus with an HP 59987 A interface, in positive-ion mode with methanol-water-acetic acid (60:35:5) as the mobile phase. IR spectra were obtained on a Perkin Elmer 1000 spectrophotometer. Elemental analyses were made using a CE Instrument Model 1110. All solvents were purified by standard procedures and freshly distilled prior to use. Reagents were of commercial grades (Aldrich). 3-Amino-2-alkene imines were prepared in accordance with the method described in ref 9. Alkene imine **2f** was synthesized according to ref 9 and 10. **3b** was obtained by hydrogenation of **2b** according to ref 11 and was purified by recrystallized (hexane/$HCCl_3$).

Irradiation of 3-amino-2-alkene imines in acid medium; General procedure: A solution of the corresponding 3-amino-2-alkene imine (1 mmol) and HBF_4 (1 mmol, 0.14 mL of a 54% ethereal solution) in anhydrous MeOH (50 mL) was irradiated, at room temperature under an Ar atmosphere, using a medium-pressure mercury lamp (125 W) until the complete consumption of the starting material had occurred (monitored by ^1H NMR spectroscopy, see Schemes 1-5 and 7). The solvent was evaporated under reduced pressure and the residue was treated with $NaHCO_3$ (25 mL, 10% aq solution) and extracted with Et_2O (3 x 25 mL). The organic layer was dried (Na_2SO_4), filtered and the solvent removed under reduced pressure. The resulting products were separated and/or purified by column chromatography [silica gel, hexane/Et_2O, 1:2 (**2a**, **2b**, **2f**, **5** and **8**), hexane/Et_2O,

2:1 (**2c**, **2d** and **2g**), hexane/Et_2O, 1:1 (**2e** and **10**)] and recrystallized (hexane/Et_2O). The yields described refer to isolated products, relative to the starting alkene imine.

1-Methyl-7-(phenylamino)-5-*p*-tolylpyrrolo[3,2-*b*]pyridine 2a. Yield 109 mg (35%), white crystal, mp 146-148 °C; IR ($CHCl_3$): ν = 3399 (NH), 3030, 2923, 1599 and 1567 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 2.38 (s, 3H), 3.95 (s, 3H), 5.97 (s, 1H), 6.70 (d, J = 3 Hz, 1H), 7.03 (m, 3H), 7.13 (d, J = 3.3 Hz, 1H), 7.21-7.34 (m, 5H), 7.83 (d, J = 8.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 21.0, 36.2, 102.4, 105.3, 118.3, 121.7, 121.7, 126.7, 129.1, 129.4, 133.1, 136.7, 137.6, 137.7, 143.1, 148.8, 152.6; ESMS *m/z* 314 (MH^+). Anal. Calcd for $C_{21}H_{19}N_3$: C: 80.48, H: 6.11, N: 13.41. Found: C: 80.24, H: 6.08, N: 13.68.

7-Benzylamino-1-methyl-5-phenylpyrrolo[3,2-*b*]pyridine 2b. Yield 110 mg (35%), white crystal, mp 123-125 °C; IR ($CHCl_3$): ν = 3402 (NH), 2930, 1615 and 1567 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 4.08 (s, 3H), 4.53 (d, J = 5.1 Hz, 2H), 4.84 (m, 1H), 6.6.3 (d, J = 3.3 Hz, 1H), 6.77 (s, 1H), 7.02 (d, J = 3 Hz, 1H), 7.31-7.46 (m, 8H), 7.92 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 37.0, 47.7, 97.4, 102.5, 118.3, 127.2, 127.5, 127.7, 127.8, 128.4, 128.9, 132.0, 138.1, 141.3, 141.9, 147.5, 153.4.; ESMS *m/z* 314 (MH^+). Anal. Calcd for $C_{21}H_{19}N_3$: C: 80.48, H: 6.11, N: 13.41. Found: C: 80.42, H: 6.12, N: 13.46.

5-Phenyl-7-(phenylamino)furo[3,2-*b*]pyridine 2c. Yield 37 mg (13%), white crystal, mp 60-62 °C; IR ($CHCl_3$): ν = 3422 (NH), 2930, 1627 and 1579 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 6.53 (s, 1H), 7.02 (d, J = 2.4 Hz, 1H), 7.17 (t, J = 7.2 Hz, 1H), 7.30-7.45 (m, 8H), 7.77 (d, J = 2.1 Hz, 1H), 7.88 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 100.6, 109.0, 121.5, 124.2, 127.3, 128.3, 128.5, 129.6, 136.2, 136.9, 139.2, 140.6, 147.2, 147.5, 156.1; ESMS *m/z* 287 (MH^+). Anal. Calcd for $C_{19}H_{14}N_2O$: C: 79.70, H: 4.93, N: 9.78. Found: C: 79.67, H: 4.94, N: 9.82.

7-(Phenylamino)-5-*p*-tolylfuro[3,2-*b*]pyridine 2d. Yield 24 mg (8%), white crystal, mp 87-89 °C; IR ($CHCl_3$): ν = 3421 (NH), 2927, 1627 and 1577 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 2.39 (s, 3H), 6.48 (s, 1H), 7.02 (d, J = 2.1 Hz, 1H), 7.16-7.45, (m, 8H), 7.78 (m, 3H); ^{13}C NMR ($CDCl_3$) δ 21.2, 100.4, 109.0, 121.4, 124.2, 127.2, 128.9, 129.3, 129.6, 136.1, 136.7, 138.3, 139.3, 147.2, 147.4, 156.2; ESMS *m/z* 301 (MH^+). Anal. Calcd for $C_{20}H_{16}N_2O$: C: 79.98, H: 5.37, N: 9.33. Found: C: 79.99, H: 5.34, N: 9.40.

7-(Phenylamino)-5-*p*-tolylthieno[3,2-*b*]pyridine 2e. Yield 101 mg (32%), pale yellow crystal, mp 108-110 °C; IR ($CHCl_3$): ν = 3412 (NH), 3034, 2924, 1594 and 1498

cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 2.37 (s, 3H), 6.30 (s, 1H), 7.17-7.29 (m, 5H), 7.34 (s, 1H), 7.36-7.41 (m, 2H), 7.57 (d, J = 5.4 Hz, 1H), 7.60 (d, J = 5.4 Hz, 1H), 7.81 (d, J = 8.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 21.2, 99.9, 119.4, 122.2, 124.4, 126.4, 127.2, 128.2, 129.3, 129.5, 137.4, 138.5, 139.4, 146.4, 157.4, 157.7; ESMS *m/z* 317 (MH^+). Anal. Calcd for $C_{20}H_{16}N_2S$: C: 75.92, H: 5.10, N: 8.85, S: 10.13. Found: C: 75.88, H: 5.13, N: 8.81, S: 10.18.

6-Methyl-5-phenyl-7-(phenylamino)thieno[3,2-*b*]pyridine 2f. Yield 76 mg (24%), pale yellow crystal, mp 180-182 °C; IR ($CHCl_3$): ν = 3433 (NH), 3062, 1601 and 1535 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 2.29 (s, 3H), 6.11 (s, 1H), 7.05 (d, J = 7.5 Hz, 2H), 7.16 (t, J = 7.5 Hz, 1H), 7.31-7.56 (m, 9H); ^{13}C NMR ($CDCl_3$) δ 15.2, 114.6, 121.4, 122.2, 123.8, 125.3, 127.7, 128.2, 128.9, 129.1, 129.2, 140.2, 141.4, 144.2, 155.8, 158.7; ESMS *m/z* 317 (MH^+). Anal. Calcd for $C_{20}H_{16}N_2S$: C: 75.92, H: 5.10, N: 8.85, S: 10.13. Found: C: 75.80, H: 5.14, N: 8.88, S: 10.18.

7-(Cyclohexylamino)-5-*p*-tolylthieno[3,2-*b*]pyridine 2g. Yield 70 mg (22%), white crystal, mp 70-72 °C; IR ($CHCl_3$): ν = 3415 (NH), 2936 and 1565 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 1.26-1.87 (m, 8H), 2.17 (m, 2H), 2.42 (s, 3H), 3.63 (m, 1H), 4.10 (d, J = 9 Hz, 1H), 6.80 (s, 1H), 7.28 (d, J = 7.8 Hz, 2H),7.53 (d, J = 5.4 Hz, 1H), 7.57 (d, J = 5.4 Hz, 1H), 7.87 (d, J = 8.1 Hz, 2H); ^{13}C NMR ($CDCl_3$) δ 21.3, 24.8, 25.6, 33.2, 51.4, 97.3, 117.9, 126.7, 127.1, 127.3, 129.3, 138.2, 138.3, 148.1, 157.0, 157.7; ESMS *m/z* 321 (MH^+). Anal. Calcd for $C_{20}H_{22}N_2S$: C: 74.49, H: 6.88, N: 8.69, S: 9.94. Found: C: 74.36, H: 6.92, N: 8.74, S: 9.98.

7-Amino-1-methyl-5-phenylpyrrolo[3,2-*b*]pyridine 3b. Yield 109 mg (98%, obtained from 0.5 mmol of alkene imine **2b** according to ref 11), white crystal, mp 110-112 °C; IR ($CHCl_3$): ν = 3409 (NH_2), 2963, 1624 and 1570 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 4.07 (s, 3H), 4.27 (s, 2H), 6.61 (d, J = 3 Hz, 1H), 6.78 (s, 1H), 7.05 (d, J = 3.3 Hz, 1H), 7.36-7.46 (m, 3H), 7.94 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 36.6, 101.9, 102.4, 118.8, 127.1, 127.8, 128.5, 132.5, 140.0, 140.9, 148.4, 152.0; ESMS *m/z* 224 (MH^+). Anal. Calcd for $C_{14}H_{13}N_3$: C: 75.31, H: 5.87, N: 18.82. Found: C: 75.28, H: 5.85, N: 18.87.

1,6-Diphenylpyrrolo[3,2-*c*]pyridine 5. Yield 67 mg (25%) from **4** and 119 mg (44%) from **6**, yellow oil; IR ($CHCl_3$): ν = 2952, 1596 and 1558 cm^{-1} (Ar); ^1H NMR ($CDCl_3$) δ 6.79 (dd, J_1 = 0.6 Hz, J_2 = 3.3 Hz, 1H), 7.36-7.61 (m, 9H), 7.83 (s, 1H), 7.99 (m,

2H), 9.07 (d, J = 0.6 Hz, 1H); ^{13}C NMR ($CDCl_3$) δ 102.4, 102.9, 124.4, 125.1, 127.0, 127.3, 127.9, 128.6, 129.5, 129.9, 138.6, 140.7, 140.7, 143.8, 150.6; ESMS *m/z* 271 (MH^+). Anal. Calcd for $C_{19}H_{14}N_2$: C: 84.42, H: 5.22, N: 10.36. Found: C: 84.37, H: 5.21, N: 10.42.

2,4-Dimethyl-1,6-diphenylpyrrolo[3,2-*c*]pyridine 8. Yield 45 mg (15%), white crystal, mp 179-181 °C; IR ($CHCl_3$): ν = 3065, 2922, 1593 and 1552 cm^{-1} (Ar); ^{1}H NMR ($CDCl_3$) δ 2.32 (d, J = 0.6 Hz, 3H), 2.83 (s, 3H), 6.47 (d, J = 0.6 Hz, 1H), 7.23 (s, 1H), 7.29-7.60 (m, 8H), 7.93 (m, 2H); ^{13}C NMR ($CDCl_3$) δ 13.4, 22.1, 100.2, 100.4, 122.8, 126.9, 127.4, 127.7, 128.3, 128.5, 129.7, 137.0, 137.9, 141.2, 142.6, 149.3, 150.4; ESMS *m/z* 299 (MH^+). Anal. Calcd for $C_{21}H_{18}N_2$: C: 84.53, H: 6.08, N: 9.39. Found: C: 84.49, H: 6.10, N: 9.41.

5-(*o*-Aminophenyl)-2-phenyl-4-phenylaminopyridine 10. Yield 122 mg (36%), white crystal, mp 99-101 °C; IR ($CHCl_3$): ν = 3397 (NH and NH_2), 3063, 1588 and 1557 cm^{-1} (Ar); ^{1}H NMR ($CDCl_3$) δ 3.79 (s, 2H), 6.31 (s, 1H), 6.86 (d, J = 8.1 Hz, 1H), 6.92 (td, J_1 = 0.9 Hz, J_2 = 7.2 Hz, 1H), 7.13 (t, J = 7.5 Hz, 1H), 7.19-7.47 (m, 9H), 7.55 (s, 1H), 7.91 (m, 2H), 8.39 (s, 1H); ^{13}C NMR ($CDCl_3$) δ 104.1, 115.8, 119.3, 120.0, 120.3, 122.2, 124.1, 126.9, 128.6, 128.8, 129.6, 129.8, 131.6, 139.8, 139.8, 144.5, 149.1, 151.3, 157.9; ESMS *m/z* 338 (MH^+). Anal. Calcd for $C_{23}H_{19}N_3$: C: 81.87, H: 5.68, N: 12.45. Found: C: 81.95, H: 5.65, N: 12.40.

ACKNOWLEDGMENTS

This work was supported by the Spanish DGICYT (PB94-0483 and PB97-0589) and the Universidad de La Rioja (API-98/B05). One of us (E.A.) would like to thank the Ministerio de Educación y Ciencia (Spain) for a fellowship.

REFERENCES AND NOTES

1. Sondhi, S. M.; Magan, A.; Sahu, R.; Mahesh, V. K.; Shukla, R.; Patnaik, G. K. *Synthesis* **1994**, *11*, 1175-1180.
2. Cho, N.; Harada, M.; Imaeda, T.; Imada, T.; Matsumoto, H.; Hayase, Y.; Sasaki, S.; Furuya, S.; Suzuki, N.; Okubo, S.; Ogi, K.; Endo, S.; Onda, H.; Fujino, M. *J. Med. Chem.* **1998**, *41*, 4190-4195.

3. Henry, J. R.; Rupert, K. C.; Dodd, J. H.; Turchi, I. J.; Wadsworth, S. A.; Cavender, D. E.; Fahmy, B.; Olini, G. C.; Davis, J. E.; Pellegrino-Gensey, J. L.; Schafer, P. H.; Siekierka, J. J. *J. Med. Chem.* **1998**, *41*, 4196-4198.

4. Marot, C.; Chavatte, P.; Morin-Allory, L.; Viaud, M. C.; Guillaumet, G.; Renard, P.; Lesieur, D.; Michel, A. *J. Med. Chem.* **1998**, *41*, 4453-4465.

5. See, for example: Hands, D.; Bishop, B.; Cameron, M.; Edwards, J. S.; Cottrell, I. F.; Wright, S. H. B. *Synthesis* **1996**, 877-882; and references therein cited.

6. See, for example: (a) Marzinzik, A. L.; Rademacher, P. *Synthesis* **1995**, 1131-1134. (b) Bremmer, D. H.; Dunn, A. D.; Wilson, K. A.; Sturrock, K. R.; Wishart, G. *Synthesis* **1998**, 1095-1097; and references therein cited.

7. (a) Campos, P. J.; Tan, C.-Q.; González, J. M.; Rodríguez, M. A. *Tetrahedron Lett.* **1993**, *34*, 5321-5324. (b) Campos, P. J.; Tan, C.-Q.; Añón, E.; Rodríguez, M. A. *J. Org. Chem.* **1996**, *61*, 7195-7197. (c) Campos, P. J.; Añón, E.; Malo, M. C.; Tan, C.-Q.; Rodríguez, M. A. *Tetrahedron* **1998**, *54*, 6929-6938.

8. (a) Campos, P. J.; Tan, C.-Q.; González, J. M.; Rodríguez, M. A. *Synthesis* **1994**, 1155-1157. (b) Campos, P. J.; Añón, E.; Malo, M. C.; Rodríguez, M. A. *Tetrahedron* **1998**, *54*, 14113-14122.

9. Hoberg, H.; Barluenga, J. *Synthesis* **1970**, 142-144. Barluenga, J.; Losada, C. P.; Olano, B. *Tetrahedron Lett.* **1993**, *34*, 5497-5498.

10. Barluenga, J.; Jardón, J.; Gotor, V. *J. Org. Chem.* **1985**, *50*, 802-804.

11. Goldstein, S. W.; Overman, L. E.; Rabinowitz, M. H. *J. Org. Chem.* **1992**, *57*, 1179-1190.

12. Salez, H.; Wardani, A.; Demeunynck, M.; Tatibouet, A.; Lhomme, J. *Tetrahedron Lett.* **1995**, *36*, 1271-1274.