SYNTHESIS OF 2-ARYL- AND 6-HETEROARYL-1,3-DI(4-PYRIDYL)AZULENES BY KATRITZKY’S PYRIDYLATION OF 2-ARYL- AND 6-HETEROARYL AZULENES†

Taku Shoji, a* Akifumi Maruyama, a Shunji Ito, b Tetsuo Okujima, c Masafumi Yasunami (the late), d Junya Higashi, e and Noboru Morita e

a Department of Chemistry, Faculty of Science, Shinshu University, Matsumoto, 390-8621, Japan. E-mail: tshoji@shinshu-u.ac.jp
b Graduate School of Science and Technology, Hirosaki University, Hirosaki 036-8561, Japan
c Department of Chemistry and Biology, Graduate School of Science and Engineering, Ehime University, Matsuyama 790-8577, Japan
d Department of Chemical Biology and Applied Chemistry, College of Engineering, Nihon University, Koriyama 963-8642, Japan
e Department of Chemistry, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan

Abstract – Preparation of 2-aryl- and 6-heteroarylanzulenes 2–6 and 8–10 was established by the palladium-catalyzed cross-coupling reaction of the corresponding haloazulenes with lithium aryl- and heteroaryl magnesium ate complexes, which were readily prepared from the corresponding aryl and heteroaryl halides. The reaction of 2–6 and 8–10, except for 3 and 8, with pyridine in the presence of Tf₂O, followed by treatment with KOH in MeOH afforded the corresponding 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes 11–16 in good yields.

INTRODUCTION
Azulene (C_{10}H_{8}) has attracted the interest of many research groups owing to its unusual properties as well as its beautiful blue color. † To construct the electrochromic materials, we have developed the synthetic

† Dedicated to the late Professor Alan R. Katritzky for his long-mentioned contribution to heterocyclic chemistry.
procedures for several 2- and 6-arylazulene derivatives by utilizing transition-metal-catalyzed cross-coupling reactions (e.g., Suzuki–Miyaura and Stille cross-coupling reactions) of 2- and 6-azulenyl metal reagents. Although the azulenyl metal reagents might be useful for the preparation of polyaromatic systems with multiple 2- and 6-azulenyl groups, preparation of the metal reagents for the transition-metal-catalyzed reactions sometimes causes difficulty and the most promising azulenylborane reagents are relatively unstable and undergo easy hydrolysis to afford hydrocarbon derivatives. As another subject of the procedures, instability of 1- and/or 3-haloazulenes, the promising precursors for the functionalization at the 1- and/or 3-positions of azulenes by the transition-metal-catalyzed reactions, sometimes causes problems for the synthesis of 1- and/or 3-arylazulenes by such a method. For the reasons described above, development of a general and an efficient method for the preparation of functionalized azulene derivatives with multiple aryl and/or heteroaryl groups from readily available reagents would have great importance because functionalized azulene derivatives should become a promising candidate for the production of advanced materials.

Herein, we report the details of the palladium-catalyzed cross-coupling reaction of 2- and 6-haloazulenes with aryl- and heteroarylmagnesium lithium ate complexes (lithium aryl- and heteroarylmagnesate reagents), which were prepared in situ from the corresponding aryl and heteroaryl halides, to afford 2-aryl- and 6-heteroarylazulenes. Furthermore, we also describe the synthesis of 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes by Katritzky’s pyridylation reaction of 2-aryl- and 6-heteroarylazulenes with pyridine in the presence of trifluoromethanesulfonic anhydride (Tf₂O), followed by treatment with KOH in MeOH. Characteristic properties of the 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes were also clarified by NMR, absorption spectroscopy, and theoretical calculations.

RESULT AND DISCUSSION
SYNTHESIS: In 2003, Mongin et al. reported a one-pot procedure for the preparation of quinolinylmagnesium lithium ate complexes by a halogen-metal exchange reaction of bromoquinolines, followed by subsequent palladium-catalyzed cross-coupling of the ate complexes with heteroaryl halides to give 2-, 3-, and 4-heteroarylquinolines. Previously, we have also reported the preparation of azulenyllithium and -magnesium reagents utilizing halogen–metal exchange reaction and their reactivity toward several electrophiles have been clarified. Thus, the lithium aryl- and heteroarylmagnesate reagents were prepared in situ under the similar reaction conditions reported by literatures to examine the reactivity of the 2- and 6-haloazulenes with the reagents under the palladium-catalyzed cross-coupling conditions.

To a solution of n-butylmagnesium chloride (n-BuMgCl) in diethyl ether was added n-butyllithium (n-BuLi) in hexane at 0 °C to give a lithium tri(n-butyl)magnesate reagent. After the mixture was stirred
at the same temperature for 30 min, bromobenzene was added dropwise to the mixture at the same
temperature. Then, to the cooled mixture a solution of 2-iodoazulene (1) and 5 mol% of PdCl₂(PPh₃)₂ in
diethyl ether was added dropwise at 0 °C (Scheme 1). The mixture was warmed to room temperature
and stirred for 24 h to complete the cross-coupling reaction. The crude product was isolated and purified
by the usual workup procedure to afford 2-phenylazulene (2) in 89% yield (Table 1, Entry 1).

To examine the generality of the reaction, the cross-coupling reaction of 1 with several aryl and
heteroaryl halides was conducted under the similar reaction conditions. The magnesate reagents prepared
from 2- and 3-bromopyridines were reacted readily with 1 to afford cross-coupling products 3 (99%) and 4 (72%), respectively (Table 1, Entries 2 and 3). The 2-(3-quinolyl)azulene (5) was also obtained in
high yield (80%) by the reaction of 1 with 3-bromoquinoline under the similar reaction conditions as
summarized in Table 1 (Entry 4). The magnesate reagent prepared from 1 was also reacted with 1 to give
2,2’-biazulene (6) in 71% yield, as less soluble green crystals (Table 1, Entry 5).

The cross-coupling reaction of 6-bromoazulene (7) with heteroarylmagnesate reagents was also
conducted under the similar reaction conditions employed for the cross-coupling reaction of 1 (Scheme 2).
The cross-coupling product, 6-(2-pyridyl)azulene (8) was obtained by the reaction of 7 with
2-pyridylmagnesate reagent in 93% yield (Table 2, Entry 1). The magnesate reagents prepared from
3-bromopyridine and 3-bromoquinoline were readily reacted with 7 to afford the corresponding
cross-coupling products 9 and 10 in 70% and 80% yields, respectively (Table 2, Entries 2 and 3).

In 2001, Katritzky et al. have discovered the reaction of carbonyl compounds with
\[ N-[(trifluoromethyl)sulfonyl]pyridinium trifluoromethanesulfonate (TPT), \] followed by the base induced
aromatization, to give the corresponding 4-(2-oxoalkyl)pyridine derivatives. Corey and Tian have

---

**Table 1. Synthesis of 2-arylazulenes 2–6**

<table>
<thead>
<tr>
<th>Entry</th>
<th>Aryl</th>
<th>X</th>
<th>Product</th>
<th>Yield [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>phenyl</td>
<td>Br</td>
<td>2</td>
<td>89</td>
</tr>
<tr>
<td>2</td>
<td>2-pyridyl</td>
<td>Br</td>
<td>3</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>3-pyridyl</td>
<td>Br</td>
<td>4</td>
<td>72</td>
</tr>
<tr>
<td>4</td>
<td>3-quinolyl</td>
<td>Br</td>
<td>5</td>
<td>80</td>
</tr>
<tr>
<td>5</td>
<td>2-azulenyl</td>
<td>I</td>
<td>6</td>
<td>71</td>
</tr>
</tbody>
</table>

**Table 2. Synthesis of 6-heteroarylazulenes 8–10**

<table>
<thead>
<tr>
<th>Entry</th>
<th>HeteroAr</th>
<th>Product</th>
<th>Yield [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2-pyridyl</td>
<td>8</td>
<td>93</td>
</tr>
<tr>
<td>2</td>
<td>3-pyridyl</td>
<td>9</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>3-quinolyl</td>
<td>10</td>
<td>80</td>
</tr>
</tbody>
</table>
extended the reaction of the electron-rich aromatic compound with pyridine derivatives in the presence of 
Tf₂O to give the corresponding 4-aryldihydropyridines, which could be convertible to the corresponding 
4-arylpyridines.⁵ We have applied the procedure to the heteroarylation of azulene derivatives at 1-, 2-, 3-, 
5-, and 7-positions.¹⁶ The methodology using the triflate of nitrogen-containing heterocycles opened a 
new two-step strategy for the heteroarylation of aliphatic and aromatic compounds. In this study, we have 
applied the synthetic procedure of 1,3-di(4-pyridyl)azulenes via 1,3-bis(1,4-dihydropyrid-4-yl)azulenes to 
the synthesis of 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes (Scheme 3). The results on the 
preparation of 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes ¹¹–¹⁶ by utilizing the synthetic 
procedure are summarized in Table 3. The reaction of 2 with pyridine in the presence of 2.4 equiv. Tf₂O, 
followed by the treatment of KOH in MeOH without an isolation of the intermediately produced product, 
1,3-bis(1,4-dihydropyrid-4-yl)-2-phenylazulene, gave ¹¹ in 77% yield (Table 3, Entry 1).

A series of 2-heteroaryl- and 6-heteroary lazulenes ³–⁶ and ⁸–¹⁰ were subjected to the sequential 
electrophilic aromatic substitution reaction under the similar reaction conditions to explore the scope of 
the methodology. The synthesis of ¹² and ¹³ were established by the reaction of ⁴ and ⁵ with pyridine in 
the presence of Tf₂O, similar to the procedure described above in 81% and 80% yields, respectively, after 
the treatment of KOH in MeOH (Table 3, Entries 3 and 4). 1,1′,3,3′-Tetra(4-pyridyl)-2,2′-biazulene (¹⁴) 
was obtained in 72% yield, by the reaction of ⁶ with pyridine in the presence of 6-fold molar excess Tf₂O, 
followed by the base-induced aromatization (Entry 5). Although the compound ⁶ is less soluble in the 
common organic solvent (e.g., CH₂Cl₂, CHCl₃ etc.) as also shown in the literature, tetrapyridyl product ¹⁴ 
possesses relatively high solubility. It should be concluded to the steric effect of substituted pyridine 
moieties that inhibit the intermolecular π–π stacking, effectively.

The similar reaction of 6-heteroary lazulenes ⁸–¹⁰ with triflate of pyridine was also investigated to 
introduce the pyridine moieties into the azulene ring. The reaction of ⁹ and ¹⁰ with pyridine in the 
presence of Tf₂O, followed by treatment with KOH in MeOH afforded ¹⁵ and ¹⁶ in 82% and 75% yields, 
respectively (Table 3, Entries 7 and 8). However, the sequential electropholic-aromatic substitution 
reaction of ³ and ⁸, having a 2-pyridyl moiety, did not afford the presumed 2-(2-pyridyl)- and 
6-(2-pyridyl)-1,3-di(4-pyridyl)azulenes owing to the decomposition of the substrates under the reaction 
conditions (Table 3, Entries 2 and 6).

Table 3. Synthesis of 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes ¹¹–¹⁶

<table>
<thead>
<tr>
<th>Entry</th>
<th>Substrate</th>
<th>Product</th>
<th>Yield [%]</th>
<th>Entry</th>
<th>Substrate</th>
<th>Product</th>
<th>Yield [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>²</td>
<td>¹¹</td>
<td>77</td>
<td>5</td>
<td>⁶</td>
<td>¹⁴</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>³</td>
<td>–</td>
<td>decomp.</td>
<td>⁶</td>
<td>⁸</td>
<td>–</td>
<td>decomp.</td>
</tr>
<tr>
<td>³</td>
<td>⁴</td>
<td>¹²</td>
<td>81</td>
<td>⁷</td>
<td>⁹</td>
<td>¹⁵</td>
<td>82</td>
</tr>
<tr>
<td>⁴</td>
<td>⁵</td>
<td>¹³</td>
<td>80</td>
<td>⁸</td>
<td>¹⁰</td>
<td>¹⁶</td>
<td>75</td>
</tr>
</tbody>
</table>
SPECTROSCOPIC PROPERTIES: All new compounds reported herein were fully characterized by spectroscopic data as shown in the Experimental Section. The high resolution mass spectra of all compounds ionized by FAB or ESI showed the correct molecular ion peaks. These results are consistent with the structures of these products. The $^1$H NMR spectra of 12 were measured both in acetone-$d_6$ and in 10% CF$_3$CO$_2$D/acetone-$d_6$. The spectra of 12 are represented in Figure 1. Most of the proton signals for the pyridine moieties of 12 were observed in downfield regions in 10% CF$_3$CO$_2$D/acetone-$d_6$ relative to those in pure acetone-$d_6$, which should be consistent with the generation of 12a$^{3+}$ by the protonation of all nitrogen atoms in the pyridine moieties on the azulene ring (Scheme 4). Significant shifts for the ring protons of azulene moiety were also observed on the $^1$H NMR spectra, when the solvent was changed from acetone-$d_6$ to 10% CF$_3$CO$_2$D/acetone-$d_6$. These results should be attributable to the contribution of the tropylium cationic form 12b$^{3+}$ in Scheme 4 by the resonance effect between azulene and pyridinium moieties.

The absorption maxima and their coefficients in the UV-Vis spectra for the 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes 11–16 are shown in the Experimental Section. The UV-Vis spectra of 12 in CH$_2$Cl$_2$ and in 10% CF$_3$CO$_2$H/CH$_2$Cl$_2$ are shown in Figure 2. The 2-aryl- and
6-heteroaryl-1,3-di(4-pyridyl)azulenes in CH$_2$Cl$_2$ showed characteristic weak absorption bands in the visible region arising from the azulene system, as well as those of 2-(2- and 3-pyridyl)azulenes 3 and 4 reported by Wakabayashi et al. The UV-Vis spectra of 12 showed weak absorption bands at $\lambda_{\text{max}} = 368$ nm sh ($\log \varepsilon = 3.86$) and $\lambda_{\text{max}} = 583$ nm ($\log \varepsilon = 2.62$) in CH$_2$Cl$_2$. When the solvent was changed to 10% CF$_3$CO$_2$H/CH$_2$Cl$_2$, the longest wavelength absorption band exhibited a hypsochromic shift [$\lambda_{\text{max}} = 401$ nm ($\log \varepsilon = 4.04$) and $\lambda_{\text{max}} = 554$ nm ($\log \varepsilon = 2.90$)] relative to that in CH$_2$Cl$_2$. The blue-shift should be concluded to the formation of tricationic spices 12a$^{3+}$, that could be drawn as a tropylium cationic form 12b$^{3+}$ by the protonation of the pyridine nitrogen as illustrated in Scheme 4.

Scheme 4. Protonation of 12 in CF$_3$CO$_2$H (or CF$_3$CO$_2$D)

To elucidate the nature of the absorption bands of 12 and protonated species 12a$^{3+}$, theoretical calculations were carried out on time-dependent density functional theory (TD-DFT) calculations at the B3LYP/6-31G** level. The frontier Kohn-Sham orbitals of 12 and 12a$^{3+}$ are shown in Figures 3 and 4. Judging from a comparison between the experimental and the theoretical UV-Vis spectra, the absorption maxima of 12 at $\lambda_{\text{max}} = 583$ nm should be considered as the $\pi$–$\pi^*$ transition (HOMO to LUMO) of the substituted azulene-ring itself. The absorption maxima at $\lambda_{\text{max}} = 368$ nm (sh) is also assigned to the transitions, which originated from the HOMO–1 delocalized on the both azulene and 3-pyridyl moiety at the 2-position to the LUMO located on the azulenyln group (Figure 3). Although the HOMO–1 and HOMO are slightly distributed over two 4-pyridyl groups at the 1,3-positions, contribution to the transitions is relatively small.
Theoretical calculations of $12a^{3+}$ showed the absorption band at $\lambda_{\text{max}} = 554$ nm can be considered as the transition, which originated from the HOMO located on the azulanyl group to the LUMO mainly located on the pyridinium moiety at the 2-position (Figure 4 and Table 4). The broad absorption of $12a^{3+}$ at around $\lambda_{\text{max}} = 400$ nm confirmed that the absorption band arose from the overlapping of HOMO to LUMO+1, LUMO+2, LUMO+3, and LUMO+4. Therefore, the blue-shift of the longest wavelength absorption band in $12a^{3+}$ should be concluded to the CT transition from azulene to three pyridinium groups.

![Figure 3](image.png)

**Figure 3.** Frontier Kohn–Sham orbitals of 12 at the B3LYP/6-31G** level

![Figure 4](image.png)

**Figure 4.** Frontier Kohn–Sham orbitals of $12a^{3+}$ at the B3LYP/6-31G** level
Similar color changes were also observed for the other 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes upon changing the solvent from CH₂Cl₂ to 10% CF₃CO₂H/CH₂Cl₂. The longest wavelength absorption band of compound 11 showed a hypsochromic shift in 10% CF₃CO₂H/CH₂Cl₂ (λₘₐₓ = 546 nm) due to the protonation of the two pyridine moieties, compared to that in CH₂Cl₂ (λₘₐₓ = 583 nm). When the UV-Vis spectra were measured in CH₂Cl₂, compound 13 exhibited absorption band at λₘₐₓ = 585 nm. In contrast, the same compound showed a hypsochromic shift of the absorption band to λₘₐₓ = 556 nm in 10% CF₃CO₂H/CH₂Cl₂, arising from the protonation of both quinoline and pyridine moieties. The longest wavelength absorption band of 2,2'-biazulene derivative 14 in 10% CF₃CO₂H/CH₂Cl₂ (λₘₐₓ = 573 nm) showed a hypsochromic shift compared with that in CH₂Cl₂ (λₘₐₓ = 595 nm). Compounds 15 and 16 also showed a hypsochromic shift (15: 616 nm; 16: 606 nm) in 10% CF₃CO₂H/CH₂Cl₂ due to the protonation of the pyridine and quinoline moieties, respectively, compared with those in CH₂Cl₂ (15: 562 nm; 16: 551 nm).

**Table 4.** Electronic transitions for 12 and 12a³⁺ derived from the computed values based on B3LYP/6-31G** method and experimental values

<table>
<thead>
<tr>
<th>Sample</th>
<th>Experimental</th>
<th>Computed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>λₘₐₓ (log ε)</td>
<td>λₘₐₓ (strength)</td>
<td>Composition of band (amplitude)</td>
</tr>
<tr>
<td>12</td>
<td>583 (2.69)</td>
<td>533 (0.0109)</td>
</tr>
<tr>
<td></td>
<td>368 sh (3.86)</td>
<td>370 (0.0120)</td>
</tr>
<tr>
<td></td>
<td>554 (2.90)</td>
<td>572 (0.0221)</td>
</tr>
<tr>
<td>12a³⁺</td>
<td>401 sh (4.04)</td>
<td>449 (0.0281)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In conclusion, we have described an efficient synthetic method for 2-aryl- and 6-heteroarylazulenes. 2-Iodo- and 6-bromoazulenes 1 and 7 reacted with aryl- and heteroarylmagnesate regents in the presence of a palladium catalyst to afford the corresponding 2-aryl and 6-heteroarylazulenes 2–6 and 8–10 under mild reaction conditions. Several 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes 11–16 were also prepared by utilizing Katritzky’s procedure consisting of the electrophilic substitution reaction of the 2-aryl- and 6-heteroarylazulenes with the triflate of pyridine, followed by the base-induced aromatization of the initially formed dihydropyridine derivatives. The longest wavelength absorption band on UV-Vis spectra of the 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes 11–16 in 10% CF₃CO₂H/CH₂Cl₂ exhibited a hypsochromic shift, relative to that in CH₂Cl₂ due to the protonation of substituted-heterocycles to develop the intramolecular CT absorption bands.
Nitrogen-containing heterocyclics act as a highly versatile functional group in organic synthesis. Thus, there are a large number of reports for the synthesis of functional molecules, starting from nitrogen-containing heterocycles to date. Recently, we have also reported the synthesis of azulene-substituted polymethines, bi- and terazulene derivatives, which exhibit significant solvatochromism and intramolecular CT, from 1-(4-pyridyl)- and 1,3-di(4-pyridyl)azulenes. Thus, 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes reported in this paper might be convertible to functionalized azulene derivatives.

To evaluate the scope of this class of molecules investigated by this research, molecular transformation of the reported compounds is currently under investigation in our laboratory.

**EXPERIMENTAL**

Melting points were determined with a Yanagimoto MPS3 micro melting apparatus and are uncorrected. Mass spectra were obtained with a Bruker APEX II instrument. IR and UV-Vis spectra were measured with JASCO FT/IR-4100 and Shimadzu UV-2550 spectrophotometers, respectively. \(^1\)H and \(^{13}\)C NMR spectra were recorded with a Bruker AVANCE400 spectrometer (at 400 MHz and 100 MHz, respectively), or a JEOL ECA500 spectrometer (at 500 MHz and 125 MHz, respectively). Elemental analyses were performed at the Research and Analytical Center for Giant Molecules, Graduate School of Science, Tohoku University.

**General procedure for the synthesis of 2-aryl- and 6-heteroarylanazulenes**

To a solution of \(n\)-BuMgCl (0.9 M in THF, 1.4 mL) in Et\(_2\)O (10 mL) was added \(n\)-BuLi (1.6 M in hexane, 1.5 mL) at 0 °C. After the mixture was stirred at the same temperature for 30 min, aryl or heteroaryl halides (1.10 mmol) was added dropwise. The resulting mixture was stirred at the same temperature for 1 h. To the mixture was added dropwise a solution of 1 or 7 (1.00 mmol) and PdCl\(_2\)(PPh\(_3\))\(_2\) (35 mg, 0.05 mmol) in Et\(_2\)O (20 mL) at 0 °C, and the mixture was stirred at room temperature for 24 h. The reaction mixture was poured into water and extracted with hexane. The organic layer was washed with brine, dried with Na\(_2\)SO\(_4\), and concentrated under reduced pressure. The residue was purified by column chromatography on alumina with CH\(_2\)Cl\(_2\) to give the corresponding products. Yield of the products is summarized in Tables 1 and 2.

**2-Phenylazulene (2)**\(^{11}\): mp 228.0–230 °C (lit. 231–232 °C); \(^1\)H NMR (500 MHz, CDCl\(_3\)): \(\delta_H = 8.29\) (d, 2H, \(J = 10.0\) Hz, 4,8-H), 7.96 (d, 2H, \(J = 7.3\) Hz, H of o-Ph), 7.68 (s, 2H, 1,3-H), 7.51 (t, 1H, \(J = 10.0\) Hz, 6-H), 7.46 (dd, 2H, \(J = 7.3, 7.3\) Hz, H of m-Ph), 7.46 (dd, 1H, \(J = 7.3\) Hz, H of p-Ph), 7.16 (t, 2H, \(J = 10.0\) Hz, 5,7-H) ppm.
2-(2-Pyridyl)azulene (3): mp 114.5–115.0 °C (CH₂Cl₂/MeOH, lit. 116–118 °C); ¹H NMR (400 MHz, CDCl₃): δ_H = 8.74 (d, 1H, J = 4.8 Hz, 6'-H of Py), 8.34 (d, 2H, J = 10.0 Hz, 4,8-H), 7.99 (dd, 1H, J = 4.8, 1.2 Hz, 3'-H of Py), 7.97 (s, 2H, 1,3-H), 7.48 (dd, 1H, J = 4.8, 1.2 Hz, 5'-H of Py), 7.41 (t, 1H, J = 10.0 Hz, 6-H), 7.22 (dd, 1H, J = 4.8, 1.2 Hz, 4'-H of Py), 7.16 (t, 2H, J = 10.0 Hz, 5,7-H) ppm.

2-(3-Pyridyl)azulene (4): mp 180.0–182.0 °C, decomp. (lit. 182–183 °C); ¹H NMR (400 MHz, CDCl₃): δ_H = 9.21 (d, 1H, J = 1.6 Hz, 2'-H of Py), 8.57 (dd, 1H, J = 4.8, 1.6 Hz, 6'-H of Py), 8.32 (d, 2H, J = 10.0 Hz, 4,8-H), 8.18 (dd, 1H, J = 4.8, 1.6 Hz, 5'-H of Py), 7.67 (s, 2H, 1,3-H), 7.56 (t, 1H, J = 10.0 Hz, 6-H), 7.37 (dd, 1H, J = 4.8, 1.6 Hz, 4'-H of Py), 7.19 (t, 2H, J = 10.0 Hz, 5,7-H) ppm.

2-(3-Quinolyl)azulene (5): mp 184.0–185.0 °C (CH₂Cl₂/MeOH); IR (KBr): ν_max = 3006 (m), 1574 (m), 1531 (m), 1476 (m), 1469 (m), 1406 (m), 1350 (m), 1207 (w), 1020 (w), 951 (m), 906 (m), 812 (s), 729 (m), 669 (w), 578 (w), 474 (w) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ε) = 286 (4.68), 308 sh (4.79), 316 (4.83), 340 (4.32), 379 (4.32), 575 (2.66), 618 (2.64), 676 sh (2.29) nm; ¹H NMR (400 MHz, CDCl₃): δ_H = 9.53 (d, 1H, J = 1.6 Hz, 2'-H of Quinoline), 8.62 (d, 1H, J = 1.6 Hz, 4'-H of Quinoline), 8.12 (d, 1H, J = 8.4 Hz, 8'-H of Quinoline), 7.90 (d, 1H, J = 8.4 Hz, 5'-H of Quinoline), 7.80 (s, 2H, 1,3-H), 7.69 (dd, 1H, J = 8.4, 1.2 Hz, 6'-H of Quinoline), 7.59–7.53 (m, 2H, 6-H and 7'-H of Quinoline), 7.25 (t, 2H, J = 10.0 Hz, 5,7-H) ppm; ¹³C NMR (100 MHz, CDCl₃): δ_C = 150.24, 147.64, 146.10, 141.40, 137.28, 136.70, 133.50, 129.60, 129.45, 129.26, 128.31, 128.21, 127.06, 124.21, 114.46 ppm; HRMS (ESI, positive): calcd for C₁₉H₁₃N + Na⁺ [M + Na⁺] = 278.0941, found: 278.0941. Anal. Calcd for C₁₉H₁₃N: C, 89.38; H, 5.13; N, 5.49. Found: C, 89.08; H, 5.25; N, 5.44.

2,2'-Biazulene (6): mp >300 °C (lit. >300 °C); MS (EI, 70 eV): m/z (relative intensity, %) = 254 (100).

Although low solubility of compound 6 hampered the ¹H NMR measurement, effective formation of compound 14 from the product should provide the criterion of the structure of compound 6.

6-(2-Pyridyl)azulene (8): mp 113.5–114.0 °C (CH₂Cl₂/MeOH); IR (KBr): ν_max = 3088 (w), 3078 (w), 3024 (w), 1576 (s), 1552 (w), 1475 (s), 1444 (m), 1419 (m), 1400 (m), 1365 (m), 1327 (w), 1304 (m), 1304 (w), 1226 (m), 1199 (m), 1107 (m), 1053 (m), 1024 (s), 972 (s), 844 (s), 802 (s), 754 (w), 750 (w), 713 (s), 671 (m), 621 (m), 572 (m), 555 (w), 501 (w), 488 (w), 418 (w), 403 (m) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ε) = 290 (4.74), 298 (4.75), 340 sh (3.78), 352 (3.84), 370 (3.85), 600 (2.56), 650 sh (2.48), 730 sh (1.96) nm; ¹H NMR (400 MHz, CDCl₃): δ_H = 8.75 (dd, 1H, J = 4.8, 1.2 Hz, 6'-H of Py), 8.45 (d, 2H, J = 10.8 Hz, 4,8-H), 7.93 (t, 1H, J = 4.0 Hz, 2-H), 7.80–7.74 (m, 4H, 5,7-H and 3',5'-H of Py), 7.41 (d, 2H, J = 4.0 Hz, 1,3-H), 7.28 (t, 1H, J = 4.8, 1.2 Hz, 4'-H of Py) ppm; ¹³C NMR (100 MHz, CDCl₃): δ_C =
161.07, 150.08, 148.08, 138.18, 137.29, 136.23, 123.19, 123.03, 118.80, 107.86 ppm; HRMS (ESI, positive): calcd for C$_{15}$H$_{11}$N + Na$^+$ [M + Na]$^+$ 228.0784, found: 228.0784. Anal. Calcd for C$_{15}$H$_{11}$N·1/5H$_2$O: C, 86.27; H, 5.50; N, 6.71. Found: C, 86.57; H, 5.51; N, 6.49.

6-(3-Pyridyl)azulene (9): mp 119.0−120.0 °C (CH$_2$Cl$_2$/MeOH); IR (KBr): $\nu_{\text{max}} = 3024$ (w), 3005 (w), 1576 (s), 1552 (w), 1475 (s), 1444 (m), 1419 (m), 1400 (m), 1365 (m), 1327 (w), 1304 (m), 1226 (m), 1199 (m), 1107 (m), 1053 (m), 1024 (s), 972 (s), 844 (s), 802 (s), 754 (w), 750 (w), 713 (s), 671 (m), 621 (m), 572 (m), 555 (m), 501 (m), 488 (w), 418 (m), 403 (m) cm$^{-1}$; UV-Vis (CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 298 (4.82), 336 sh (3.72), 368 (3.81), 588 (2.56), 634 sh (2.48), 710 sh (2.00) nm; $^1$H NMR (400 MHz, CDCl$_3$): $\delta_H = 8.90$ (d, 1H, $J = 1.6$ Hz, 2'-H of Py), 8.65 (d, 1H, $J = 4.8$, 1.6 Hz, 6'-H of Py), 8.41 (d, 2H, $J = 10.0$ Hz, 4,8-H), 8.36 (d, 1H, $J = 4.8$, 1.6 Hz, 4'-H of Py), 8.18 (d, 1H, $J = 8.0$ Hz, 8'-H of Py), 7.96 (t, 1H, $J = 4.0$ Hz, 2-H), 7.90 (d, 1H, $J = 8.0$ Hz, 5'-H of Py), 7.76 (t, 1H, $J = 8.0$ Hz, 7'-H of Quinoline), 7.56 (t, 1H, $J = 8.0$ Hz, 6'-H of Quinoline), 7.47–7.44 (m, 4H, 1,3,5,7-H) ppm; $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta_C = 149.30$, 148.99, 147.07, 140.78, 139.12, 137.72, 135.85, 135.61, 123.36, 123.01, 118.93 ppm; HRMS (ESI, positive): calcd for C$_{15}$H$_{11}$N + Na$^+$ [M + Na]$^+$ 228.0784, found: 228.0784. Anal. Calcd for C$_{15}$H$_{11}$N: C, 87.77; H, 5.40; N, 6.82. Found: C, 87.72; H, 5.48; N, 6.76.

6-(3-Quinolyl)azulene (10): mp 162.0−164.0 °C (CH$_2$Cl$_2$/MeOH); IR (KBr): $\nu_{\text{max}} = 3080$ (w), 3055 (w), 1618 (w), 1578 (s), 1491 (m), 1442 (m), 1400 (s), 1352 (w), 1228 (w), 1126 (w), 1053 (w), 978 (w), 970 (w), 965 (w), 945 (w), 908 (m), 856 (m), 837 (s), 785 (m), 746 (w), 728 (m), 705 (m), 638 (m), 574 (w), 480 (m), 463 (m), 451 (m), 420 (m) cm$^{-1}$; UV-Vis (CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 284 (4.65), 300 sh (4.60), 308 sh (4.60), 352 (3.91), 370 (3.95), 590 (2.48), 638 sh (2.40), 710 sh (1.91) nm; $^1$H NMR (400 MHz, CDCl$_3$): $\delta_H = 9.22$ (d, 1H, $J = 1.6$ Hz, 2'-H of Quinoline), 8.45 (d, 2H, $J = 10.0$ Hz, 4,8-H), 8.36 (d, 1H, $J = 1.6$ Hz, 4'-H of Quinoline), 8.18 (d, 1H, $J = 8.0$ Hz, 8'-H of Quinoline), 7.96 (t, 1H, $J = 4.0$ Hz, 2-H), 7.90 (d, 1H, $J = 8.0$ Hz, 5'-H of Quinoline), 7.76 (t, 1H, $J = 8.0$ Hz, 7'-H of Quinoline), 7.56 (t, 1H, $J = 8.0$ Hz, 6'-H of Quinoline), 7.47–7.44 (m, 4H, 1,3,5,7-H) ppm; $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta_C = 150.88$, 147.86, 147.54, 139.54, 138.37, 138.19, 136.34, 135.44, 130.38, 129.67, 128.61, 128.12, 127.71, 123.73, 119.45 ppm; HRMS (ESI, positive): calcd for C$_{19}$H$_{13}$N + Na$^+$ [M + Na]$^+$ 278.0941, found: 278.0941. Anal. Calcd for C$_{19}$H$_{13}$N·1/10H$_2$O: C, 88.76; H, 5.17; N, 5.45. Found: C, 88.71; H, 5.39; N, 5.46.

**General procedure for the synthesis of 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes**

Tf$_2$O (2.4 equiv.) and pyridine (20 equiv.) in CH$_2$Cl$_2$ were added at room temperature to a solution of 2–5 and 8–10 in CH$_2$Cl$_2$. In the case of the reaction of compound 6, 6.0 equiv. Tf$_2$O and 40 equiv. pyridine were used as reagents. The resulting mixture was stirred at the same temperature for 30 min. The solvent
was removed under reduced pressure. 5 equiv. KOH was added to a solution of the crude product in MeOH at room temperature, and the resulting mixture was stirred at the same temperature for 3 h. The reaction mixture was poured into water, extracted with CH₂Cl₂, and dried with Na₂SO₄. The solvent was removed under reduced pressure and the residue was purified by column chromatography on alumina with CH₂Cl₂ to give the corresponding 2-aryl- and 6-heteroaryl-1,3-di(4-pyridyl)azulenes. Yield of the products is summarized in Table 3.

2-Phenyl-1,3-di(4-pyridyl)azulene (11): mp 266.0–268.0 °C (sublimation); IR (KBr): ν_max = 3027 (w), 1589 (s), 1572 (m), 1536 (w), 1499 (w), 1428 (m), 1403 (m), 1295 (w), 1258 (w), 1214 (w), 1069 (w), 1029 (w), 992 (m), 916 (w), 866 (w), 854 (m), 836 (m), 822 (w), 807 (w), 791 (m), 764 (w), 743 (s), 721 (m), 709 (m), 698 (s), 676 (w), 659 (w) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ε) = 258 (4.42), 318 (4.69), 325 sh (4.68), 370 sh (2.37) nm; UV-Vis (10% CF₃CO₂H/CH₂Cl₂): λ_max (log ε) = 260 (4.40), 300 sh (4.35), 334 (4.51), 407 sh (4.14), 546 (3.20) nm; ¹H NMR (500 MHz, CDCl₃): δ_H = 8.55 (d, 4H, J = 6.3 Hz, 2',6'-H of Py), 8.39 (d, 2H, J = 9.8 Hz, 4,8-H), 7.67 (t, 1H, J = 9.8 Hz, 6-H), 7.27 (t, 2H, J = 9.8 Hz, 5,7-H), 7.23–7.15 (m, 7H, 3',5'-H of Py, m-Ph, and p-Ph), 6.98 (d, 2H, J = 8.6 Hz, o-Ph) ppm; ¹³C NMR (125 MHz, CDCl₃): δ_C = 149.72 (C-2',6' of Py), 148.33 (ipso-Ph), 144.14 (C-3a,8a), 139.12 (C-6), 137.98 (C-4', Py), 135.88 (C-4,8), 135.16 (C-2), 131.13 (o-Ph), 128.28 (C-1,3), 127.58 (m-Ph), 126.35 (C-3',5' of Py), 126.24 (p-Ph), 125.72 (C-5,7) ppm; HRMS (EI, positive): calcd for C₂₆H₁₈N₂⁺ [M⁺] 358.1465, found: 358.1470. Anal. Calcd for C₂₆H₁₈N₂: C, 87.12; H, 5.06; N, 7.82. Found: C, 87.03; H, 5.18; N, 7.79.

2-(3-Pyridyl)-1,3-di(4-pyridyl)azulene (12): mp 242.0–244.0 °C (CH₂Cl₂/MeOH); IR (KBr): ν_max = 3032 (w), 1590 (s), 1572 (w), 1539 (w), 1505 (w), 1429 (m), 1402 (m), 1390 (w), 1310 (w), 1269 (w), 1213 (w), 1196 (w), 1114 (w), 1040 (w), 1024 (m), 991 (m), 961 (w), 883 (w), 856 (m), 838 (m), 824 (m), 793 (m), 771 (w), 757 (s), 730 (w), 709 (s), 676 (w), 666 (w), 658 (w) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ε) = 252 (4.30), 315 (4.64), 323 sh (4.62), 368 sh (3.86), 583 (2.62), 623 (2.59), 694 sh (2.19) nm; UV-Vis (10% CF₃CO₂H/CH₂Cl₂): λ_max (log ε) = 258 (4.24), 295 sh (4.40), 317 (4.45), 401 sh (4.04), 554 (2.90) nm; ¹H NMR (500 MHz, CDCl₃): δ_H = 8.59 (d, 4H, J = 4.6 Hz, 2',6'-H of Py), 8.46 (d, 1H, J = 4.9 Hz, 6''-H of Py), 8.41 (d, 2H, J = 9.9 Hz, 4,8-H), 8.27 (s, 1H, 2''-H of Py), 7.73 (t, 1H, J = 9.9 Hz, 6-H), 7.33 (dd, 1H, J = 4.9, 1.8 Hz, 4'-H of Py), 7.32 (t, 2H, J = 9.9 Hz, 5,7-H), 7.17 (d, 4H, J = 4- Hz, 3',5'-H of Py), 7.13 (dd, 1H, J = 4.9, 1.8 Hz, 5''-H of Py) ppm; ¹³C NMR (125 MHz, CDCl₃): δ_C = 151.39 (C-2'' of Py), 149.97 (C-2',6' of Py), 148.60 (C-6'' of Py), 143.95 (C-3'' of Py), 143.56 (C-3a,8a), 139.87 (C-6), 138.11 (C-4'' of Py), 138.00 (C-4' of Py), 136.62 (C-4,8), 131.28 (C-2), 126.44 (C-1,3), 126.30 (C-3',5' of Py), 126.00 (C-5,7), 123.08 (C-5'' of Py) ppm; HRMS (EI, positive): calcd for C₂₅H₁₈N₃⁺ [M⁺]
1,3-Di(4-pyridyl)-2-(3-quinolyl)azulene (13): mp > 300 °C (CH$_2$Cl$_2$/MeOH); IR (KBr): $\nu_{\text{max}}$ = 3028 (w), 2965 (w), 1592 (s), 1573 (w), 1540 (w), 1504 (m), 1434 (m), 1410 (m), 1376 (w), 1273 (w), 1217 (m), 1132 (w), 1067 (w), 1008 (w), 990 (w), 977 (w), 949 (w), 916 (m), 872 (w), 855 (w), 826 (m), 797 (s), 763 (s), 756 (s), 732 (w), 726 (w), 711 (s), 678 (w), 668 (w), 658 (w) cm$^{-1}$; UV-Vis (CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 269 (4.60), 330 (4.92), 396 sh (3.77), 585 (2.85), 623 (2.83), 694 sh (2.44) nm; UV-Vis (10% CF$_3$CO$_2$H/CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 257 (4.54), 285 sh (4.60), 333 (4.77), 410 sh (4.17), 556 (3.09) nm; $^1$H NMR (500 MHz, CDCl$_3$): $\delta_H$ = 8.57 (d, 4 H, $J = 5.3$ Hz, 2',6'-H of Py), 8.57 (s, 1 H, 2"-H of Quinoline), 8.44 (d, 2H, $J = 9.8$ Hz, 4,8-H), 8.03 (d, 1H, $J = 8.4$ Hz, 8"-H of Quinoline), 7.76 (s, 1H, 4"-H of Quinoline), 7.70 (t, 1H, $J = 9.8$ Hz, 6-H), 7.70 (dd, 1H, $J = 8.6$, 8.6 Hz, 7"-H of Quinoline), 7.56 (d, 1H, $J = 8.6$ Hz, 5''-H of Quinoline), 7.49 (dd, 1H, $J = 8.6$, 8.6 Hz, 6"-H of Quinoline), 7.33 (t, 2H, $J = 9.8$ Hz, 5,7-H), 7.20 (d, 4H, $J = 4.6$ Hz, 3',5'-H of Py) ppm; $^{13}$C NMR (125 MHz, CDCl$_3$): $\delta_C$ = 152.02 (C-2" of Quinoline), 150.06 (C-2',6' of Py), 146.90 (C-4a" or C-8a" of Quinoline), 143.81 (C-4" of Quinoline), 143.64 (C-4' of Py), 139.90 (C-6), 138.11 (C-4a" or C-8a" of Quinoline), 137.81 (C-3a,8a), 136.60 (C-4,8), 130.12 (C-7" of Quinoline), 129.38 (C-8" of Quinoline), 128.51 (C-2), 128.05 (C-5" of Quinoline), 127.41 (C-3" of Quinoline), 127.13 (C-6" of Quinoline), 126.61 (C-3',5' of Py), 126.07 (C-5,7) ppm; HRMS (EI, positive): calcd for C$_{29}$H$_{19}$N$_3$ $[M]^+$ 409.1574, found: 409.1585. Anal. Calcd for C$_{29}$H$_{19}$N$_3$: C, 85.06; H, 4.68; N, 10.26. Found: C, 84.98; H, 4.78; N, 10.24.

1,1',3,3'-Tetra(4-pyridyl)-2,2'-biazulene (14): mp > 300 °C (CH$_2$Cl$_2$/MeOH); IR (KBr): $\nu_{\text{max}}$ = 3061 (w), 2999 (w), 1594 (s), 1573 (m), 1541(w), 1504 (w), 1430 (m), 1370 (m), 1312 (w), 1303 (w), 1221 (w), 1125 (w), 1067 (w), 993 (w), 912 (w), 878 (w), 859 (w), 825 (m), 782 (m), 746 (m), 728 (s), 686 (s), 670 (w), 659 (w) cm$^{-1}$; UV-Vis (CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 311 sh (4.59), 342 (4.88), 414 (3.99), 595 (2.91), 635 (2.89), 706 sh (1.71) nm; UV-Vis (10% CF$_3$CO$_2$H/CH$_2$Cl$_2$): $\lambda_{\text{max}}$ (log $\varepsilon$) = 257 (4.45), 350 (4.72), 362 sh (4.71), 403 sh (4.37), 573 (3.22) nm; $^1$H NMR (500 MHz, CDCl$_3$): $\delta_H$ = 8.34 (d, 4H, $J = 9.7$ Hz, 2',6'-H of Py), 8.26 (dd, 8H, $J = 1.6$, 4.5 Hz, 2',6'-H of Py), 7.70 (t, 2H, $J = 9.7$ Hz, 6-H), 7.28 (t, 4H, $J = 9.7$ Hz, 5,7-H), 6.58 (d, 8H, $J = 1.6$, 4.5 Hz, 3',5'-H of Py) ppm; $^{13}$C NMR (125 MHz, CDCl$_3$): $\delta_C$ = 149.44 (C-2',6' of Py), 143.27 (C-3a,8a), 142.19 (C-2), 140.07 (C-6), 137.77 (C-4' of Py), 136.14 (C-4,8), 127.24 (C-1,3), 126.17 (C-5,7), 125.23 (C-3',5' of Py) ppm; HRMS (FAB, positive): calcd for C$_{40}$H$_{26}$N$_4$ $[M + H]^+$ 563.2231, found: 563.2257. Anal. Calcd for C$_{40}$H$_{26}$N$_4$: C, 85.38; H, 4.66; N, 9.96. Found: C, 85.35; H, 4.70; N, 9.95.
6-(3-Pyridyl)-1,3-di(4-pyridyl)azulene (15): mp 218.0–220.0 °C (CH₂Cl₂/MeOH); IR (KBr): v_max = 3015 (m), 2969 (m), 1591 (m), 1507(w), 1275 (w), 1267 (w), 1228 (s), 1216 (s), 1095 (w), 990 (w), 814 (m), 767 (s), 749 (s), 699 (w), 670 (w), 658 (m) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ϵ) = 242 sh (4.32), 310 sh (4.54), 337 (4.69), 371 sh (4.13), 398 sh (3.79), 567 sh (2.49), 616 (2.58), 670 sh (2.48), 758 sh (1.95); UV-Vis (10% CF₃CO₂H/CH₂Cl₂): λ_max (log ϵ) = 256 (4.25), 287 sh (4.03), 327 sh (4.49), 348 (4.54), 400 (4.33), 419 sh (4.27), 562 (2.83) nm; 1H NMR (500 MHz, CDCl₃): δ_H = 8.72 (d, 1H, J = 4.6 Hz, 6”-H of Py), 8.68–8.66 (m, 6H, 4,8-H and 2’,6’-H of Py), 8.13 (s, 1H, 2-H), 7.91 (d, 2H, J = 10.8 Hz, 5,7-H), 7.80–7.79 (m, 2H, 2”,4”-H of Py), 7.51 (d, 4H, J = 5.8 Hz, 3’,5’-H of Py), 7.15 (dd, 1H, J = 4.6, 4.6 Hz, 5”-H of Py) ppm; 13C NMR (125 MHz, CDCl₃): δ_C = 159.38 (C-6), 150.59 (C-3” of Py), 150.22 (C-2’,6’ of Py), 150.07 (C-6” of Py), 144.28 (C-3a,8a), 137.41 (C-2), 137.23 (C-2” or C-4” of Py), 135.68 (C-4,8), 128.19 (C-1,3), 125.60 (C-5,7), 124.31 (C-3’,5’ of Py), 123.39 ppm. The signal for C-4” of pyridine could not be observed probably due to the overlapping with the other signal. HRMS (EI, positive): calcd for C₂₅H₁₇N₃+ [M]+ 359.1417, found: 359.1416. Anal. Calcd for C₂₅H₁₇N₃·1/5H₂O: C, 82.71; H, 4.83; N, 11.57. Found: C, 82.65; H, 4.85; N, 11.60.

1,3-Di(4-pyridyl)-6-(3-quinolyl)azulene (16): mp >300 °C (CH₂Cl₂/MeOH); IR (KBr): ν_max = 3030 (w), 1594(s), 1577(m), 1550 (w), 1504 (w), 1491 (w), 1431 (m), 1370 (m), 1334 (w), 1312 (w), 1251 (w), 1220 (w), 1131 (w), 1033 (w), 992 (m), 916 (w), 854 (m), 815 (s), 783 (m), 742 (m), 720 (w), 700 (m), 685 (w), 679 (w), 658 (m) cm⁻¹; UV-Vis (CH₂Cl₂): λ_max (log ϵ) = 239 sh (4.47), 311 (4.56), 343 (4.75), 377 sh (4.33), 442 sh (2.92), 560 sh (2.55), 606 (2.65), 658 sh (2.55), 740 sh (2.04) nm; UV-Vis (10% CF₃CO₂H/CH₂Cl₂): λ_max (log ϵ) = 254 (4.37), 286 (4.20), 327 sh (4.53), 360 (4.67), 418 sh (4.38), 551 (3.03) nm; 1H NMR (500 MHz, CDCl₃): δ_H = 9.24 (d, 1H, J = 2.3 Hz, 2”-H of Quinoline), 8.72 (d, 2H, J = 11.0 Hz, 4,8-H), 8.41 (d, 1H, J = 2.3 Hz, 4”-H of Quinoline), 8.21 (s, 1H, 2-H), 8.20 (d, 1H, J = 8.6 Hz, 8”-H of Quinoline), 7.93 (d, 1H, J = 8.6 Hz, 5”-H of Quinoline), 7.79 (dd, 1H, J = 8.6, 8.6 Hz, 7”-H of Quinoline), 7.64 (dd, 1H, J = 8.6, 8.6 Hz, 6”-H of Quinoline), 7.61 (d, 2H, J = 11.0 Hz, 5,7-H), 7.59 (d, 4H, J = 6.3 Hz, 3’,5’-H of Py) ppm; 13C NMR (125 MHz, CDCl₃): δ_C = 150.29 (C-2’,6’ of Py), 150.19 (C-6), 149.92 (C-2” of Quinoline), 148.01 (C-4a” or C-8a” of Quinoline), 144.11 (C-3a,8a), 137.31 (C-2), 136.88 (C-8” of Quinoline), 135.76 (C-4,8), 135.08 (C-4” of Quinoline), 130.40 (C-7” of Quinoline), 129.52 (C-4’ of Py), 128.89 (C-6” of Quinoline), 128.27 (C-5” of Quinoline), 127.68 (C-4a” or C-8a” of Quinoline), 127.56 (C-1,3), 125.88 (C-5,7), 124.24 (C-3’,5’ of Py) ppm. The signal for C-3” of quinoline could not be observed probably due to the overlapping with the other signal. HRMS (EI, positive): calcd for C₂₉H₁₉N₃+ [M]+ 409.1574, found: 409.1585. Anal. Calcd for C₂₉H₁₉N₃·1/3H₂O: C, 83.83; H, 4.77; N, 10.11. Found: C, 83.85; H, 4.73; N, 10.11.
ACKNOWLEDGEMENTS

This work was partially supported by a Grant-in-Aid for Research (Grant No. 25810019 to T.S.) from the Ministry of Education, Culture, Sports, Science, and Technology, Japan.

REFERENCES AND NOTES


6. A part of this study was reported previously in preliminary form: T. Shoji, S. Kikuchi, S. Ito, and N. Morita, Heterocycles, 2005, 66, 91.


10. To obtain the product in high yield, 5 mol% of palladium catalyst was required at least (see reference 6).


17. $^1$H NMR measurement was performed in acetone-$d_6$, owing to the insolubility of cationic species of $^{12}$.

18. The B3LYP/6-31G** time-dependence density functional calculations were performed with Spartan’10, Wavefunction, Irvine, CA.
