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One-Pot Synthesis of *N*-Substituted Diaza[12]annulenes

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ABSTRACT

***N*-Substituted diaza[12]annulenes are obtained by one -pot reaction of *N*-(2,4-dinitrophenyl)pyridinium chloride with amines in moderate to high yields. The ^{1}H NMR spectrum reveals that diamagnetic ring current is generated in the diaza[12]annulene ring. The *N*-substituted diaza[12]annulenes are electrochemically active in solution.**

Annulenes have attracted much attention since the first report on [8]annulene in 1911.[1] Many efforts have been devoted to probing the (anti)aromaticity of [4*n*]annulenes by using NMR spectroscopy and computational methods.[2−4] The addition of π-electrons to the [4*n*]annulenes that are anti-aromatic in the Hückel sense has been carried out to alter their aromaticity and magnetic properties.[5−8] Among the [4*n*]-annulenes, studies on [12]annulenes and hetero[12]annulenes are very limited due to their decreased thermal stability.[6,9−11] Stevenson reported that [12]annulenes show diamagnetic properties.[10a]

To our knowledge, the subtraction of two π-electrons from a [4*n*]annulene to provide a dicationic [4*n*]annulene containing $(4n - 2)\pi$ electrons has no precedent. The aromaticity and chemical properties of dicationic [4*n*]annulenes and hetero[4*n*]annulenes remain elusive.

The introduction of a substituent on the nitrogen atoms of a diaza[12]annulene will give a dicationic species. It is known that the thermal and electronic properties of *N*-substituted aza[4*n* + 1]annulenes ($n = 2$, 3, and 4) vary depending on the *N*-substituent.[12−14] Investigation of the aromaticity and chemical properties of the *N*-substituted diaza[12]annulenes will provide new information about hetero[4*n*]annulenes. However, there is only one report on such a diaza[12]annulene,[11] and its *N*-substitution reaction to generate a dicationic species has not yet been performed.

Herein, we report the one-pot synthesis of *N*-substituted diaza[12]annulenes and an investigation of their aromaticity and their structural, optical, and electrochemical properties. A plausible reaction pathway is also reported.

N-Substituted diaza[12]annulenes (**3**) were obtained by a 2:2 reaction of *N*-(2,4-dinitrophenyl)pyridinium chloride (**1**) with substituted amines[15] (**2**) in 40−83% yields (Scheme 1).

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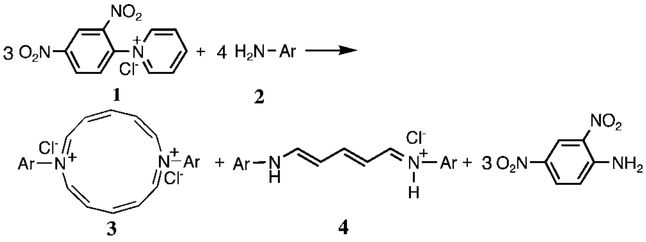
Scheme 1. Reaction of *N*-(2,4-Dinitrophenyl)pyridinium Chloride (**1**) with Amine (**2**)



The results of these reactions are summarized in Table 1. Reaction of **1** with 4-haloaniline (entries 4−7) gave a mixture of *N*-halophenyl diaza[12]annulene dichloride and *N*-halophenylpenta-2,4-dienylidene-1-*N*-halophenylinium chloride (**4**).[16] The diaza[12]annulenes obtained were soluble in water and polar aprotic solvents such as *N*,*N*-dimethylformamide, dimethyl sulfoxide (DMSO), and *N*-methyl-2-pyrrolidinone. The structures of **3** and **4** were confirmed by FAB-MS, ^{1}H and ^{13}C NMR spectroscopy, and elemental analysis.

Table 1. Results of Reaction of *N*-(2,4-Dinitrophenyl)pyridinium Chloride (**1**) with Amines (**2**)

			yield, %	
entry[a]	**2**	Ar	**3**[b]	**4**[c]
1	**2a**	2,5-Me-C_6H_3	**3a**, 40	0
2	**2b**	*p*-MeO-C_6H_4	**3b**, 83	0
3	**2c**	*p*-F-C_6H_4	**3c**, 62	0
4	**2d**	*p*-Cl-C_6H_4	**3d**, 73	**4d**, 6
5	**2e**	*p*-Br-C_6H_4	**3e**, 76	**4e**, 3
6	**2f**	*p*-I-C_6H_4	**3f**, 46	**4f**, 3
7	**2g**	*n*-hexyl	**3g**, 40	0

[a] Ethanol solution of **1** and **2** in a 1:2 molar ratio was refluxed for 12 h under nitrogen. [b] Isolated yield. [c] Estimated from ^{1}H NMR spectrum of a mixture of **3** and **4**.

Figure 1 depicts the ^{1}H NMR spectrum of **3a** in DMSO-d_6. Peaks at δ 9.29, 8.83, and 8.33 are assigned to H^a, H^c, and H^b of the diaza[12]annulene ring, respectively. Observation of these three signals of the diaza[12]annulene ring in a 2:1:2 integral ratio suggests that the diaza[12]annulene ring has a C_2-symmetric conformation. As judged from the coupling constants, $J_{H_a-H_b} = 5.9$ Hz and $J_{H_b-H_c} = 6.6$ Hz, the diaza[12]annulene ring may form an all-cis geometrical structure at 20 °C, as shown in Figure 1. ^{13}C NMR data also support this structure.[17] A previous report predicted the all-cis structure to be the most stable of the six geometries of [12]annulene isomers.[18]

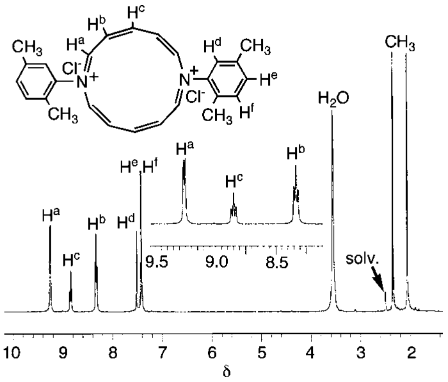


Figure 1. ^{1}H NMR spectrum of **3a** in DMSO-d_6 at 20 °C.

The ^{1}H NMR peak positions and *J* values corresponding to the hydrogen atoms of the diaza[12]annulene ring of **3a**−**g** were essentially the same, independent of the structure of the *N*-substituent. The appearance of the ^{1}H NMR peaks of the diaza[12]annulene ring at lower magnetic field positions by about 2−3 ppm compared with those of the outer hydrogens of the [12]annulenes[9b] and hetero[12]annulenes[11,19] has been ascribed to the generation of diamagnetic ring currents in the diaza[12]annulene ring. Such a downfield shift of the ^{1}H NMR peak induced by diamagnetic ring current was also observed in the [12]annulene anion.[6]

The diaza[12]annulenes give rise to two absorption bands in the ranges of 255−284 and 351−396 nm, and their relative intensities vary depending on the structures of the *N*-substituents, as summarized in Table 2. It is reported that *N*-substituted aza[9]annulenes exhibit two absorption bands and their intensities are affected by the structures of the *N*-substituents.[12] Diaza[12]annulene **3b** exhibited absorptions at longer wavelengths than those exhibited by **3a**, probably

Table 2. Absorption and Electrochemical Oxidation Potential Data of Diaza[12]annulene Dichloride (**3**)

entry	**3**	absorption,[a] nm (log ϵ, $M^{-1}\,cm^{-1}$)	E_a,[c] V (vs Ag^+/Ag)
1	**3a**	255 (3.95), 351 (2.85)	0.79
2	**3b**	264 (5.56), 333 (5.18),[b] 396 (4.51)	0.77
3	**3c**	268 (4.53), 297 (3.88)	1.15
4	**3d**	266 (4.79), 365 (3.92)	1.07
5	**3e**	284 (4.01)	1.00
6	**3f**	269 (4.51), 292 (4.56), 369 (4.05)	0.99
7	**3g**	258 (4.17), 336 (3.58), 395 (3.31)	0.73

[a] In EtOH. [b] Shoulder peak. [c] In DMSO solution including Et_4NBF_4 (0.1 M). Sweep rate was 50 mV s^{-1}.

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(15) Reactions of **1** with 4-nitroaniline and with 4-aminoacetophenone did not give both **3** and **4**. A possible reason for the results is that low basicity of the amines prevents nucleophilic addition to the pyridinium ring of **1**.

(16) It was reported that reaction of **1** with amine in a 1:1 molar ratio gave *N*-arylpenta-2,4-dienylidene-1-*N*-arylinium chloride. See: Becher, J. *Synthesis* **1980**, 589.

(17) Three ^{13}C NMR signals due to the diaza[12]annulene ring were observed at δ 142.2, 146.1, and 142.0.

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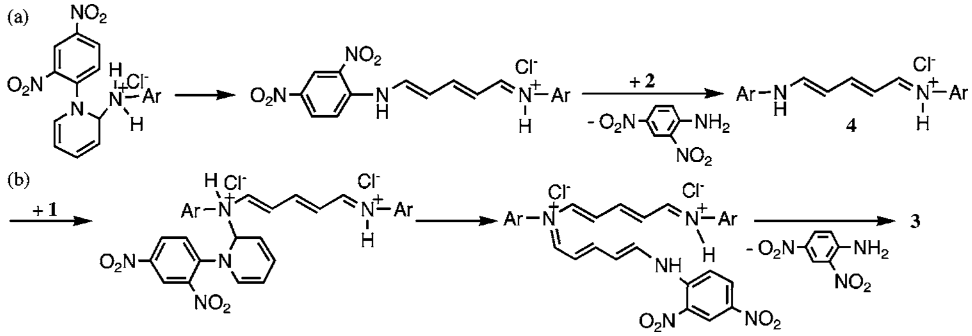
Scheme 2. Possible Reaction Mechanism for *N*-Substituted Diaza[12]annulene Dichloride



due to the expansion of the π-conjugation system from the diaza[12]annulene ring to the 4-methoxyphenyl groups.

The steric effect of the methyl group at the 2-position of the 2,4-dimethylphenyl ring of **3a** may hinder the expansion of the π-conjugation system. The absorption data often give valuable information in predicting the planarity of the annulene ring. The reported tetrabenzodiaza[12]annulene has a nonplanar ring structure, and exhibits absorptions at 235 and 300 nm.[11] The diaza[12]annulene ring of **3** seems to have a more planar structure than that of tetrabenzodiaza[12]annulene, as judged from the absorption data.

Cyclic voltammetry measurements suggested that the diaza[12]annulenes underwent electrochemical oxidation in a DMSO solution including Et_4NBF_4. Figure 2 depicts CV curves of **3a** and **3g**. As summarized in Table 2, the oxidation potential is dependent on the *N*-substituent; **3g** with electron-donating *n*-hexyl substituents (entry 7) shows a peak at a lower oxidation potential than the compounds with electron-withdrawing substituents, **3c**−**f** (entries 3−6).

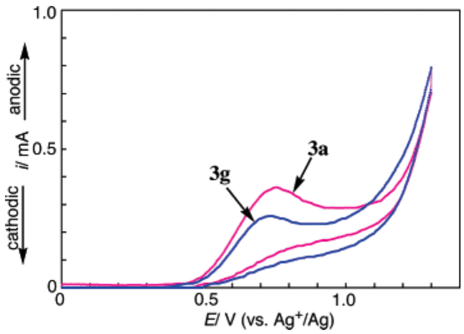


Figure 2. CV curves of **3a** and **3g** in a DMSO solution including Et_4NBF_4 (0.1 M). Sweep rate was 50 mV s^{-1}.

Scheme 2 shows a plausible preparation mechanism for the diaza[12]annulene dichloride (**3**) and *N*-arylpenta-2,4-dienylidene-1-*N*-arylnium chloride (**4**), where nucleophilic addition of amine to the pyridinium ring of **1** occurs first, followed by ring-opening of the dihydropyridyl ring and elimination of 2,4-dinitroaniline by reaction of the ring-opening compound with **2** to provide **4** (path a). The reaction of *N*-(2,4-dinitrophenyl)penta-2,4-dienylidene-1-*N*-arylinium chloride with amine to give **4** has been reported.[20] The **3**:**4** preparative ratios obtained by reaction of **1** with aromatic amines depend on the basicity of the amine. These results indicate that the nucleophilic addition of the NH group of **4** to the pyridinium ring of **1** is a crucial step for generation of the diaza[12]annulene ring.

In summary, *N*-substituted diaza[12]annulenes were obtained in moderate to high yields by the one-pot reaction of *N*-(2,4-dinitrophenyl)pyridinium chloride with amines. The ^{1}H NMR spectra of the products revealed that a diamagnetic ring current was generated in the diaza[12]annulene ring. Cyclic voltammetry analysis indicated that the diaza[12]annulenes were electrochemically active in solution. Diaza[12]annulenes with 4-halophenyl substituents would be a useful starting material for functional compounds and polymers. These approaches are under investigation in our laboratory.

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Supporting Information Available: Experimental procedures and compound characterization data. This material is available free of charge via the Internet at http://pubs.acs.org.

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