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SYNTHETIC STUDIES OF NOVEL 6-AZA- AND 6,7-DIAZAAZULENO[1,2-a]AZULENES[1]

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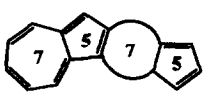
Summary: The title compounds were synthesized by thermal reaction of [(azulen-2-yl)imino]phosphorane and [(1-azaazulen-2-yl)imino]phosphorane with 2-bromotropone or by alternative methods.

The elucidation of π-conjugation mode of cata-condensed non-alternant polycyclic π-systems having more than one (4n+2)π conjugation loop is an important subject. Hess and Schaad have predicted that twelve isomers of cata-condensed azulenoazulene possess fairly large resonance energy per electron.[2] In the last decade, three types of compounds, such as azuleno[1,2-f]azulene[3] and azuleno[2,1-e]azulene[4] of 7-5-7-5 ring system (1) and azuleno[1,2-b]azulene (2)[5] of 7-5-5-7 ring system, have been synthesized. Another 7-5-5-7 ring system, azuleno[1,2-a]azulene (3), has not been synthesized so far. In this communication, we wish to report the synthetic studies of 6-aza- and 6,7-diazaazuleno[1,2-a]azulenes (4 and 5), which are aza- and diaza-analogues of 3.



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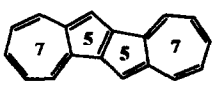

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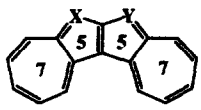


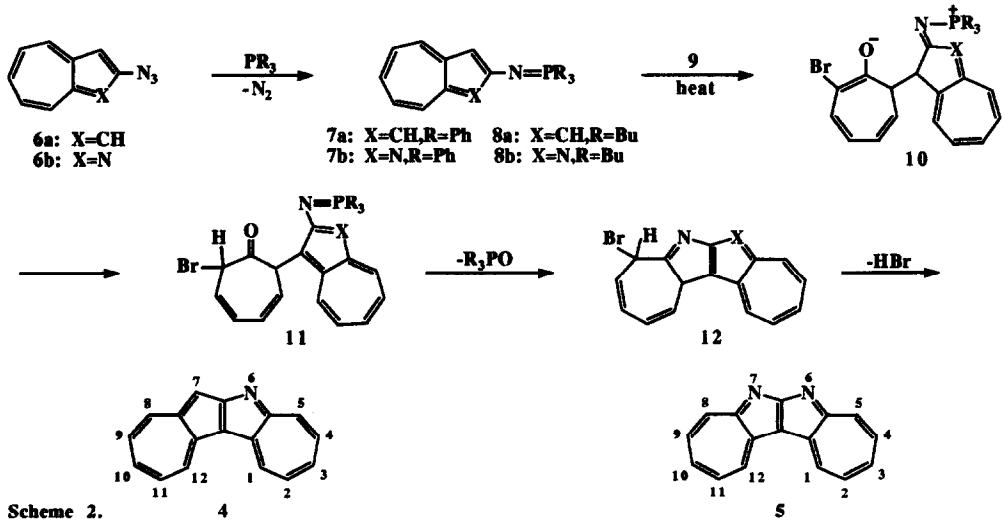
3: X=Y=CH 4: X=CH ; Y=N
5: X=Y=N

Scheme 1.

During the course of our studies in the field of (vinylimino)phosphorane, we were confronted with the preparation of 1-azaazulene[6] and its vinylogues,[7] conveniently obtained by an enamine-type alkylation and then by following aza-Wittig reaction of several (vinylimino)phosphoranes with 2-halotropones and 3,8-methano[11]annulenone. Thus, our synthetic procedure for 4 and 5 was at first based upon 1-azaazulene-annulation by using [(azulen-2-yl)imino]phosphorane, [(1-azaazulen-2-yl)imino]phosphorane and 2-bromotropone. The desired 2-azidoazulene (6a) was prepared in 32% yield by the reaction of 2-azulenehydrazine[8] with $NaNO_2$ in 1N H_2SO_4 and ether at 0 °C for 2 h, followed by usual workup.[9,10] Similarly, 2-azido-1-azaazulene (6b) was prepared in 52% yield by the reaction of 2-hydrazino-1-azaazulene[11] with $NaNO_2$ in 2N CH_3CO_2H at room tempearture for 0.5 h, followed by usual workup.[9,10] The reaction of 6a and 6b with an equivalent amount of triphenylphosphine in dry benzene accompanied with nitrogen evolution was completed in 30 min at room temperature (Staudinger reaction[12]) to give [(azulen-2-yl)imino]triphenylphoshorane (7a) and [(1-azaazulen-2-yl)imino]triphenylphos-

phorane (7b) quantiatively.[9,10] The reaction of 6a and 6b with tributylphosphine in a similar manner gave [(azulen-2-yl)imino]tributylphosphorane (8a) and [(1-azaazulen-2-yl)-imino]tributylphosphorane (8b) (Scheme 2).[9,10] Although the compounds 8a and 8b were unstable under workup conditions and not isolated as pure form, satisfactory ^{1}H NMR spectra were obtained.[10] The signals of protons at C-1 and C-3 of azulene appear at δ 7.24,[13] while those of 7a and 8a appear at δ 6.65 and δ 6.69, respectively.[10] The signals of protons at C-3 in 7b and 8b appear at higher field of δ 6.50 and δ 6.38, respectively, than that of 1-azaazulene (δ 7.69).[9] These chemical shifts of 7b and 8b are similar to that of 2-amino-1-azaazulene.[14] The upfield shift suggests high electron density and large π-HOMO coefficient, thereby fascilitating nucleophilic attack at C-1 and/or C-3 of 7a,b and 8a,b. Since the formation of 7a,b and 8a,b was confirmed, the annulation reactions were carried out conveniently under one-flask operations.

After a solution of 6a (1.0 mmol) and triphenylphosphine (1.2 mmol) in dry toluene (3 ml) was stirred at room temperature for 30 min ("in-situ" preparation of 7a), 2-bromotropone (9) (1.2 mmol) and triethylamine (1.2 mmol) were added, and the mixture was heated under reflux for 3 h to give 4 [9,10] in 18% yield (based on 6a) after separation by TLC (AcOEt/EtOH: 10/1) (Scheme 2). The reaction of 8a with 9 in toluene in a similar manner was completed in 45 min under reflux to give 4 in 46% yield. In a similar fashion, a solution of 6b (1 mmol) and tributylphosphine (0.75 mmol) in dry toluene (6 ml) was stirred at room temperature for 30 min, 9 (2 mmol) and triethylamine (3 mmol) were



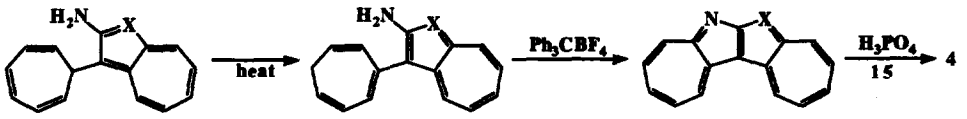
Scheme 2.

added, and the mixture was heated under reflux for 19 h to give the expected compound 5 in 9% yield[9,10] (based on tributylphosphine used) after separation by TLC (AcOEt/EtOH: 5/3) (Scheme 2). On the contrary, the reaction of 7b with 9 in a similar way gave no product except intractable tars.

The postulated pathways for the formation of 4 and 5 are also shown in Scheme 2.[9]

The enamine-type alkylation of 7a and 8a,b on C-7 of 9 gives the intermediate 10. The hydrogen migration of 10 regenerates iminophosphorane 11, which undergoes intramolecular aza-Wittig reaction and then dehydrobromination to give 4 and 5. Since the replacement of -N=PPh_3 with more electron-donating -N=PBu_3 seems to accelerate the enamine-type alkylation, the reaction of 8a resulted in the better yield of 4 as compared with that of 7a. Similarly, the replacement of -N=PPh_3 in 8b by more electron-donating -N=PBu_3 effected the expected reaction to give 5. The reaction of 7b and 8b is not clean and the yield of 5 is low. This is possibly due to the introduction of the nitrogen atom at 1-position, which could also intervene in the nucleophilic attack onto 9. The compounds 7a and 8a,b are unique iminophosphoranes, the double bond of which is contained in an aromatic ring, to intervene in the 1-azaazulene-annulation reaction. The enhanced reactivity as compared with, for example, phenyl-substituted iminophosphorane, which undergoes no enamine-type alkylation, is ascribed to a low resonance energy of azulene (16.1 kcal/mol; REPE: 1.61 kcal/mol) as well as 1-azaazulene compared with that of benzene (26.1 kcal/mol; REPE: 4.35 kcal/mol)[16].

Alternative synthetic methods of 4 and 5 were also explored. The 1,5-hydrogen migration of 2-amino-1-(2,4,6-cycloheptatrienyl)-3-ethoxycarbonylazulene (13a)[16] in dry xylene was carried out under reflux for 3 h to give 2-amino-1-(1,3,6-cycloheptatrienyl)-3-ethoxycarbonylazulene (14a) in 70% yield. The hydride abstraction of 14a with trityl tetrafluoroborate in dry acetonitrile at room temperature for 30 h gave 15 in 86% yield. The demethoxycarbonylation of 15 in 100% phosphoric acid[17] was completed in 1 h at 100 °C to give 4 quantitatively. Similarly, a solution of 2-amino-1-azaazulene,[11] which was easily obtained by acid-catalyzed hydrolysis of 7b, and 7-ethoxy-1,3,5-cycloheptatriene in ethanol containing trace of HCl was heated under reflux for 1 h to give 2-amino-3-(2,4,6-cycloheptatrienyl)-1-azaazulene (13b) in 73% yield. The 1,5-hydrogen migration of 13b in refluxing xylene for 5 h gave 2-amino-3-(1,3,5-cycloheptatrienyl)-1-azaazulene (14b)[9,10] in 62% yield. The hydride abstraction of 14b with trityl tetrafluoroborate in acetonitrile under reflux for 30 h gave 5 in 14% yield.



13a: X=CCO_2Et 14a: X=CCO_2Et 15: X=CCO_2Et
Scheme 3. 13b: X=N 14b: X=N 5: X=N

Unequivocal proton assignment for 4 was made by 2D ^1H-^1H and 2D ^1H-^{13}C NMR spectra.[10] Compound 5 exhibits a symmetric structure and the proton assignment was made by 2D ^1H-^1H NMR spectrum and by using $Eu(fod)_3$.[10] In addition, observed coupling constants between neighboring protons of 4 and 5 indicates the bond alternations of azulene and azaazulene moieties of 4 as well as two azaazulene moieties of 5. The chemical and structural properties including PPP-type MO calculation are described in the following paper.[18]

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References

1. Part 23 of the reaction of (vinylimino)phosphoranes and related compounds. This paper is dedicated to Professor Harold Hart for the celebration of his 70th birthday.
2. B. A. Hess, Jr., and L. J. Schaad, J. Org. Chem., 36, 3418 (1971).
3. C. Jutz, H. G. Peuker, and W. Kosbahn, Synthesis, 1976, 673.
4. Z. Yoshida, M. Shibata, E. Ogino, and T. Sugimoto, Tetrahedron Lett., 25, 3343 (1984).
5. T. Toda, N. Shimazaki, T. Mukai, and C. Kabuto, Tetrahedron Lett., 21, 4001 (1980); A. Tajiri, M. Hatano, T. Toda, N. Shimazaki, and T. Mukai, Chem. Phys. Lett., 81, 251 (1981); S. Kuroda, S. Hirooka, H. Iwaki, M. Ikeda, T. Nakao, M. Ogisu, M. Yasunami, and K. Takase, Chem. Lett., 1986, 2039.
6. M. Nitta and T. Kobayashi, Chem. Lett., 1986, 463; M. Nitta, Y. Iino, and K. Kamata, Heterocycles, 29, 1655 (1989); M. Nitta, Y. Iino, E. Hara, and T. Kobayashi, J. Chem. Soc., Perkin Trans. 1, 1989, 51.
7. M. Nitta, N. Kanomata, and M. Tada, Tetrahedron Lett., 31, 1291 (1990).
8. T. Nozoe, S. Seto, and S. Matsumura, Bull. Chem. Soc. Jpn., 35, 1990 (1962).
9. Satisfactory high resolution mass spectral data are obtained for new compounds except 8a,b.
10. Physical data of new compounds: 4: dark brown prisms; mp 170-171 °C (EtOH); ^{1}H NMR ($CDCl_3$, 400 MHz) δ=7.23 (1H, dd, J=10.6, 8.8 Hz, H-9), 7.32 (1H, dd, J=10.6, 8.8 Hz, H-11), 7.36 (1H, s, H-7), 7.41 (1H, dd, J=10.6, 8.8 Hz, H-10), 7.70 (1H, dd, J=10.3, 9.2 Hz, H-3), 7.71 (1H, dd, J=10.3, 9.2 Hz, H-2), 7.82 (1H, dd, 10.3, 9.2 Hz, H-4), 8.23 (1H, d, J=10.6 Hz, H-8), 8.51 (1H, d, J=8.8 Hz, H-12), 8.65 (1H, d, J=10.3 Hz, H-5), 8.79 (1H, d, J=9.2 Hz, H-19). 5: red plates; mp 177-178 °C; ^{1}H NMR ($CDCl_3$, 400 MHz) δ=7.92-7.98 (4H, m, H-2,3,10,11), 8.01-8.06 (2H, m, H-4,9), 8.91 (2H, d, J=10.3 Hz, H-5,8), 9.00-9.04 (2H, m, H-1,12). 6a: violet plates; mp 75-76 °C (hexane); ^{1}H NMR ($CDCl_3$, 60 MHz) δ=6.79 (2H, s, H-1,3), 7.15-7.55 (3H, m, H-5,6,7), 8.02-8.25 (2H, m, H-4,8). 6b: mp 75-76 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ=6.70 (1H, s, H-3), 7.40-7.70 (3H, m, H-5,6,7), 8.00-8.40 (2H, m, H-4,8); IR ($CHCl_3$) 2125 cm^{-1}. 7a: orange powder; mp 88-91 °C (hexane-benzene); ^{1}H NMR ($CDCl_3$, 90 MHz) δ=6.65 (2H, s, H-1,3), 6.80-7.00 (3H, m, H-5,6,7), 7.20-7.50 (9H, m, Ph), 7.50-7.85 (8H, m, H-4,8 and Ph). 7b: mp 129-130 °C; ^{1}H NMR ($CDCl_3$, 90 NHz) δ=6.50 (1H, s, H-3), 7.10-7.24 (3H, m, H-5,6,7), 7.35-7.55 (9H, m, Ph), 7.63-8.00 (8H, m, H-4,8, Ph). 8a: ^{1}H NMR ($CDCl_3$, 60 MHz) δ=0.82-2.10 (27H, m), 6.69 (2H, s, H-1,3), 6.85-7.10 (3H, m, H-5,6,7), 7.60-7.80 (2H, m, H-4,8). 8b: ^{1}H NMR ($CDCl_3$, 90 MHz) δ=0.80-2.30 (27H, m, Bu), 6.38 (1H, s, H-3), 6.99-7.39 (3H, m, H-5,6,7), 7.53-7.74 (2H, m, H-4,8). 14a: oil; ^{1}H NMR ($CDCl_3$, 60 MHz) δ=1.45 (3H, t, J=7.0 Hz, CH_3), 2.46 (2H, t, J=6.8 Hz, H-5'), 4.45 (2H, q, J=7.0 Hz, $-CH_2-$), 5.30-5.75 (2H, m, H-4',6'), 6.00-6.45 (4H, m, H-3',7', and NH_2), 6.73 (1H, d, J=5.8 Hz, H-2'), 7.05-7.35 (3H, m, H-5,6,7), 7.75-8.00 (1H, m, H-4), 8.75-9.00 (1H, m, H-8). 14b: mp 120-121 °C; ^{1}H NMR ($CDCl_3$, 60 MHz) δ=2.3-3.9 (2H, m, H-5'), 5.3-5.9 (2H, m, H-4',6'), 6.1-6.5 (2H, m, H-3',7'), 6.8-6.9 (3H, m, H-2', NH_2),7.1-7.5 (3H, m, H-5,6,7), 7.8-8.2 (2H, m, H-4,8). 15: dark brown prisms; mp 113-114 °C (CCl_4); ^{1}H NMR ($CDCl_3$, 90 MHz) δ=1.52 (3H, t, J=7.0 Hz, CH_3)m 4.58 (2H, q, J=7.0 Hz, $-CH_2-$), 7.45-7.90 (6H, m, H-2,3,4,9,10,11), 8.60-8.85 (3H, m, H-1,5,12), 9.55-9.72 (1H, m, H-8).
11. T. Nozoe, S. Seto, S. Matsumura, and T. Terasawa, Chem. Ind., 1959, 1357.
12. Yu. G. Gololobov, I. V. Zhumurova, and L. F. Kasukin, Tetrahedron, 37, 437 (1981).
13. J. -R. Llinas, D. Road, M. Derbesy, and E. -J. Vincent, Can. J. Chem., 53, 2911 (1975).
14. 2-Amino-1-azaazulene: ^{1}H NMR ($CDCl_3$, 400 MHz) δ=5.5 (2H, broad s, NH_2), 6.49 (1H, s, H-3), 7.27-7.36 (2H, m), 7.42-7.48 (1H, m), 7.87-7.92 (2H, m); ^{13}C NMR ($CDCl_3$, 100.6 MHz) δ=168.0 (C-2), 158.0 (C-8a), 148.6 (C-3a), 128.0-130.5 (C-4,5,6,7,8), 99.1 (C-3).
15. W. R. Roth, M. Bohm, H. -W. Lennartz, and E. Vogel, Angew. Chem. Int. Ed. Engl., 22, 1007 (1983).
16. T. Nozoe, T. Toda, T. Asao, and A. Yamanouti, Bull. Chem. Soc. Jpn., 41, 2935 (1968).
17. M. Yasunami, T. Amemiya, and K. Takase, Tetrahedron Lett., 24, 69 (1983).
18. M. Nitta, Y. Iino, T. Sugiyama, and A. Toyota, Tetrahedron Lett., following paper.

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