Synthesis of Thiophene Derivatives of 1,3-Diazabicyclo[3,1,0]hex-3-ene

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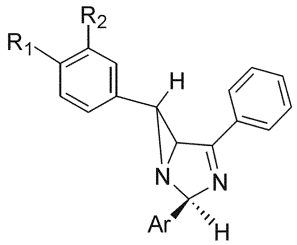
Phtochromism is defined as the reversible conversion induced by light of a substance A (photochrome) into product B differing in absorption spectrum (color) and internal energy, dielectric constant and other physico-chemical parameters.

$$A \underset{h\nu_2}{\overset{h\nu_1}{\rightleftharpoons}} B$$

Photochromic materials are used widely. In recent times they are being considered as extremely promising systems to store information. Study of photochromic materials has drawn great attention to their significant application in optical data storage, holographic storage, solar cells, and sensitizes. Typical photochromic optical switching devices include ophthalmic and sunglass lenses.[1-3] Various photochromic dyes have been developed to improve major photochromic properties such as reversibility and stability. The thiophene substitution plays an important role in the structure of gated photochromism and dual-mode photochromism compounds.[4-6]

Recently we became interested in the Photochromism and Photoreproduction of 1,3-diazabicyclo[3,1,0]hex-3-ene derivatives with various substitutions.[7] The synthesis of several fluorescence emission producers based on symmetrical and unsymmetrical trisannelated benzene constructions were attempted.[8,9]

We herein present two new thiophenyl derivatives of 1,3-diazabicyclo[3,1,0]hex-3-enes **1** and **2** (Scheme 1). The UV spectroscopical properties of **1** and **2** are intresting and specify that they are capable of acting as an intelligent materials. These compounds were prepared by a slight modification of an accessible procedure by Heine-Padwa methods.[10,11] The molecular cause of the color produced upon exposure of the light is quite remarkable. Irradiation with 254 nm light of colorless **1a** and **2a** in ethanol with UV light after 20 min causes heterolytic cleavage of the aziridine ring broken which in a such case is in conrotatory fashion and opening to form a zwitterionic (double charged imine ylide) highly colored (bluish-purple for **1b** and pale yellow for **2b**) highly conjugated species **1b**, **2b** (Scheme 2).



1 $R_1 = NO_2$, R_2= H, Ar = thiophen-2-yl
2 R_1 = H, R_2= NO_2, Ar = thiophen-2-yl

Scheme 1

The evidences for such a (σ2s + n2s) ring opening and the zwitterionic species are base on the red shift in UV and photochromism behaviour of **1** and **2**. The stability of the colored intermediates is strongly influenced by both electronic and steric change in the structure of the aziridines. Thus, removal of the nitro group, or shifting it to a meta position reduced markedly the photochromic sensitivity of compound **2** in comparison to **1** and blue-shifted the absorption spectrum of the coloured species. Irradiation of compound **1a** produced a bluish-purple coloration, that either faded in dark room after 1 day or at 60 ^oC in dark room after 30 min. The structures of **1b** and **2b** were assigned based upon their UV-Visible absorption spectra in ethanol solution. A reversible change in color is not the only alteration in physical property; obviousley there are also changes in refractive index, dielectric constant and oxidation/reduction potentials.[14] Examination of the AM1 model of **1a** together with the small to larg steric course of the reaction, *i.e*., preparation of **5** and **6** mixture (*ca* 2 : 1), leaves little doubt that the proton at C_2 lies below the plane of the imidazoline ring.[4] In contrast to the mixture of **5** and **6** the ^{1}H NMR of **7** and **8** consisting of virtually pure single crystals of these compounds. The ^{1}H NMR of **7** confirms that the *i*-Bu group is certainly above the plane of the imidazoling ring (Scheme 3).

The aziridines **3** and **4** were prepared starting with electrophilic addition of bromide to the double bond of trans-chalcone.[11,12] The stereochemistry of the addition is anti based on $J_{H2\text{-}H3} \sim 11$ Hz.

In the typical procedure for the preparation of **1a** and **2a** instead of the more traditional 1 mmol gaseous ammonia and 1 mmol NH_4Br in absolute ethanol, we found that 5 mmol NH_4OCOCH_3 and 1 mmol NH_4Br in absolute ethanol also work very well. In this case, the reaction was completed in less than 4 days instead of 1 week.

The UV-visible spectrum of **1**, after 20 min of irradiation

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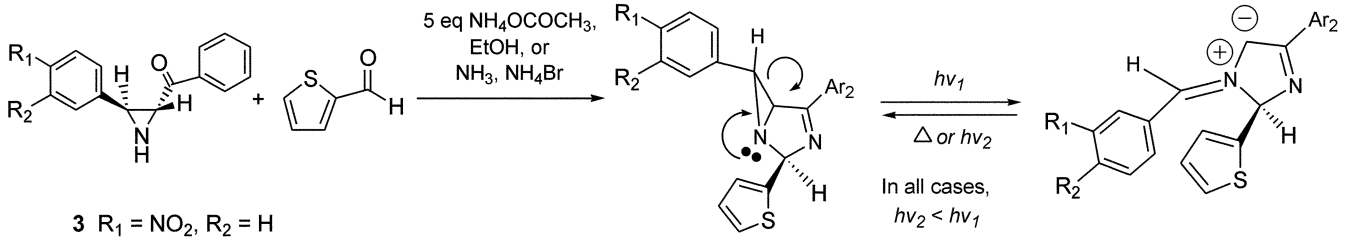
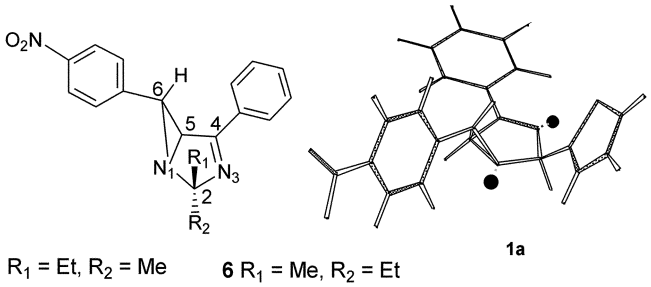


3 $R_1 = NO_2$, $R_2 = H$
4 $R_1 = H$, $R_2 = NO_2$

1a $R_1 = NO_2$, $R_2 = H$
2a $R_1 = H$, $R_2 = NO_2$

1b Ar_1 = 4-nitrophenyl, Ar_2 = phenyl
2b Ar_1 = 3-nitrophenyl, Ar_2 = phenyl

Scheme 2



1a

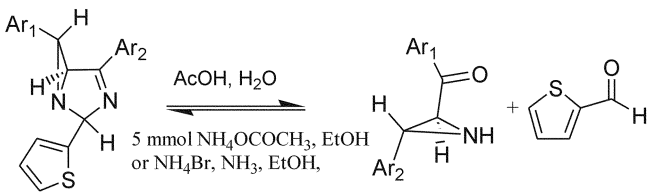
R_1 = Et, R_2 = Me
R_1 = i-Bu, R_2 = Me

6 R_1 = Me, R_2 = Et
8 $R_1 = R_2$ = n-Pr

Scheme 3

under UV light in ethanol solution exhibits absorption maxima at 285 nm for **1a** and 279 nm for **2a**, respectively. By comparison, for the zwiterionic double charged imine ylide, UV irradiation causes absorption maximum in the visible range at 285, 408 nm for **1b**, and at 279, 365 nm for **2b**, respectively due to the breaking of the aziridine ring and forming a conjugated system. Absorption spectra changes of colorless of **1a**, **2a** (1.4×10^{-4} mol^{-1} dm^{-3} in EtOH; cell length 1 cm), irradiation time/min, 0, 0.5, 1, 5, 10, 15, and 20 were obtained immediately after 254-nm light irradiation. Both spectra afforded the photostationary states, respectively.

The ^{13}C NMR of recrystallized of **1a** and **2a** showed 16 and 18 peaks, correspondingly. Considering the ^1H NMR spectra proton-proton coupling between hydrogens on C_5 and C_6 in aziridine ring in such a rigid system is about 0 Hz (in accord with the vicinal Karplus correlation presumably the $\phi \sim 90^o$. However, direct "reading off" of the angle from the magnitude of the *J* value is risky).



1a Ar_1 = p-NO_2-phenyl, Ar_2 = phenyl
2a Ar_1 = m- NO_2-phenyl, Ar_2 = phenyl

3 Ar_1 = p-NO_2-phenyl, Ar_2 = phenyl
4 Ar_1 = m-NO_2-phenyl, Ar_2 = phenyl

Scheme 4

The compounds **1a** and **2a** in wet acetic acid for almost 3 days at room temperature retreat to trans-2-benzoyl-3-(4-nitrophenyl)aziridine **3** and trans-2-benzoyl-3-(3-nitrophenyl) aziridine **4**, respectively. As a result, the separation of the starting *trans*-aziridines **3** and **4** assigns that the hydrogens at C_5 and C_6 in the related 1,3-diazabicyclo[3.1.0]hex-3-enes **1a** and **2a** were also *trans* to each other and that no epimerization occurred in the synthesis of the bicyclic aziridines (Scheme 4).

In the upfield region of ^1H NMR for compounds **1a**, **2a** and **5-8** just two singlets for C_5 and C_6 protons were observed.

Experimental Section

Chemicals were purchased from Fluka, Merck, and Aldrich. Products were characterized by comparison with authentic samples (IR, NMR, GC, TLC, and m.p.). Yields refer to isolated pure center cut from column chromatography or material scratched from preparative TLC plates. Melting points are uncorrected and were determined on a Mettler Fp5 melting point apparatus. IR spectra were obtained on a Shimadzu IR-470. All NMR data were recorded in $CDCl_3$ on a Bruker FT-500 MHz spectrometer, using TMS as internal reference. The UV/Vis spectra were recorded on a Shimadzu UV-2100. The 4-nitrochalcone and 2,3-dibromo-4-nitrochalcone were prepared according to a standard procedure.[12] The structure of the intermediates and the final products were consistent with their Shimadzu 470 (KBr disks), Bruker 500 MHz ^1H NMR and 125 MHz ^{13}C NMR.

Synthesis of 2-benzoyl-3-(4-nitrophenyl)aziridine (3; $C_{15}H_{12}N_2O_3$): A Typical Procedure. A total of 3 mL solution of concentrated ammonia was added to a solution of 2,3-dibromo-4-nitrochalcone (0.413 g, 1 mmol)[12] in 6 mL of 96% EtOH with stirring at room temperature. After 4 days, the reaction mixture was filtered. The solid was washed with methanol and dried in the air and the resulting residue was purified on a silica gel column and recrystallized from ethanol to give orange solid: 0.196 g (73%), m.p 139-140 °C (lit[13] = 136.8-137 °C). IR (KBr): 3260, 3050, 1662, 1600, 1512, 1445, 1343, 1265, 1230, 1020, 825, 747, 710 cm^{-1}; ^1H NMR ($CDCl_3$): δ 2.8 (br t, *J* = 8.5 Hz, 1H), 3.28 (dd, *J* = 2.0, 9.2 Hz, 1H), 3.54 (dd, *J* = 2.1, 8.1 Hz, 1H), 7.52-7.58 (m, 4H), 7.67 (t, *J* = 7.4 Hz, 1H), 8.01 (d, *J* = 7.5 Hz, 2H), 8.24 (d, *J* = 8.6 Hz, 2H).

Synthesis of 2-benzoyl-3-(3-nitrophenyl)aziridine (4; $C_{15}H_{12}N_2O_3$). A total of 3 mL solution of concentrated ammonia was added to a solution of 2,3-dibromo-3-nitrochalcone (0.413 g, 1mmol)[12] in 7 mL of 96% EtOH with stirring at room temperature. After 3 days, the reaction mixture was filtered. The pale-yellow solid was washed with cold methanol and dried in the air and the resulting residue was purified on a silica gel column and recrystallized from ethanol to give needle-like colorless solid: 0.185 g (69%), m.p 97-98 °C. IR (KBr): 3260, 3050, 1660, 1590, 1580, 1520, 1450, 1400, 1350, 1260, 1220, 1080, 1010, 920, 840, 805, 770, 730, 705, 680 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$): δ 2.79 (br t, J = 8.6 Hz, 1H), 3.29 (dd, J = 2.0, 9.3 Hz, 1H), 3.55 (dd, J = 2.1, 8.0 Hz, 1H), 7.50-7.57 (m, 4H), 7.65 (t, J = 7.4 Hz, 1H), 7.74 (d, J = 7.7 Hz, 1H), 8.01 (d, J = 7.6 Hz, 1H), 8.17 (d, J = 8.2 Hz, 1H), 8.25 (s, 1H) ppm.

Preparation of 6-(4-nitrophenyl)-4-phenyl-2-thiophen-2-yl-1,3-diazabicyclo[3.1.0]hex-3-ene (1a; $C_{20}H_{15}N_3O_2$). 2-Benzoyl-3-(4-nitrophenyl)aziridine **3** (0.536 g, 2 mmol), NH_4Br (0.1 g, 1 mmol) and thiophene-2-carbaldehyde (2 mmol, 0.23 g, 0.2 mL) were dissolved in 16 mL of absolute ethanol and stirred at room temperature. The anhydrous gaseous ammonia is gently blown into the reaction mixture for 6 hours. The color of the reaction mixture changes to pink. Alternatively instead of 1 mmol gaseous ammonia, 5 mmol NH_4OCOCH_3 (10 mmol, 0.78 g) was used, in this case the reaction was completed after 4 days instead of 1 week. The reaction mixture was filtered, washed with ethanol, and some impurity left on the filter paper. The filtrate was diluted with EtOH and extracted with ether and solvent evaporated and dried in the air and the resulting solid recovered 0.405 g (56%), which was purified by silicagel column chromatography and recrystallized from ethanol 0.31 g (43%), mp = 177-178 °C, IR (KBr): 3050, 1595, 1508, 1440, 1340, 1010, 970, 880, 790, 760, 740, 700, 690 cm^{-1}, ^1H NMR ($CDCl_3$): δ 2.72 (s, 1H), 3.83 (s, 1H), 6.9 (s, 1H), 7.02 (t, J = 4.8, 3.7 Hz, 1H), 7.17 (d, J = 3.2, 1H), 7.29 (d, J = 5.2 Hz, 1H), 7.47 (d, J = 8.6 Hz, 2H), 7.53 (t, J = 7.6,7.4 Hz, 2H), 7.58 (t, J = 7.3 Hz, 1H), 8.01 (d, J = 7.4 Hz, 2H), 8.21 (J = 8.6 Hz, 2H), ^{13}C NMR ($CDCl_3$): δ 42.90, 58.62, 93.50, 124.22, 126.09, 126.33, 127.50, 127.98, 129.13, 129.43, 131.77, 132.56, 140.95, 145.69, 147.94, 171.49, Exact mass: (M+) calcd. 361.0885, found 361.0882, UV-Vis (EtOH): λ_a max/nm = 285 for **1a** and 408 for **1b**.

Preparation of 6-(3-nitrophenyl)-4-phenyl-2-thiophen-2-yl-1,3-diazabicyclo[3.1.0]hex-3-ene (2a; $C_{20}H_{15}N_3O_2$). 2-Benzoyl-3-(3-nitrophenyl)aziridine **4** (0.536 g, 2 mmol), NH_4OCOCH_3 (10 mmol, 0.78 g) were dissolved in 14 mL of absolute ethanol. The reaction mixture was stirred for 2 hours. The thiophene-2-carbaldehyde (2 mmol, 0.23 g, 0.2 mL) was added to the reaction mixture at room temperature and stirred vigorously. After 30 min a yellowish white precipitate was formed. The reaction mixture was stirred for additional 25 hours. The reaction mixture was filtered and washed with 5 mL cold EtOH. The colorless solid was dried at 60 °C. The resulting solid recovered 0.36 g (50%), purified by silica gel column chromatography and recrystallized from ethanol 0.25 g (33%), mp = 140-141 °C, IR (KBr): 3065, 2890, 1600, 1525, 1345, 1278, 765, 695 cm^{-1}, ^1H NMR ($CDCl_3$): δ 2.71 (s, 1H), 3.8 (d, J = 0.58 Hz, 1H), 6.87 (s, 1H), 7.0 (dd, J = 3.6, 3,7 Hz, 1H), 7.15 (dd, J = 0.8, 1.3 Hz, 1H), 7.26 (d, J = 5.4 Hz, 1H), 7.47 (d, J = 3.5, 1H), 7.49 (d, J = 2.8 Hz, 1H), 7.51 (d, J = 2.4 Hz, 1H), 7.56 (t, J = 7.5, 7.0 Hz, 1H), 7.62 (d, J = 7.7 Hz, 1H), 7.98 (d, J = 7.6 Hz, 2H), 8.11, J = (dd, J = 1.3, 0.9 Hz, 1H), 8.15 (s, 1H), ^{13}C NMR ($CDCl_3$): δ 42.67, 58.36, 93.45, 122.18, 123.08, 126.08, 126.36, 127.51, 129.13, 129.42.129.93, 131.82, 132.52, 133.30, 140.56, 141.02, 148.96, 171.55, Exact mass: (M+) calcd. 361.0885, found 361.0881, UV-Vis (EtOH): λ_a max/nm = 279 for **2a** and 365 for **2b**.

Conversion of 6-(4-nitrophenyl)-4-phenyl-2-thiophen-2-yl-1,3-diazabicyclo [3.1.0]hex-3-ene 1a into the 2-benzoyl-3-(4-nitrophenyl) aziridine 3. A mixture of 362 mg (1 mmol) of **1a** and 10 mL of commercial acetic acid was kept at room temperature for 3 days. The acetic acid was evaporated and the gummy residue treated with 10 mL of methanol. The 2-benzoyl-3-(4-nitrophenyl)aziridine **3** (85%), was recovered (262 mg) and recrystallized from 95% EtOH to give compounds: mp = 140-141 °C, which was identical with an authentic sample.

Synthesis of 2-ethyl-2-methyl-6-(4-nitro-phenyl)-4-phenyl-1,3-diaza-bicyclo[3,1,0]hex-3-ene (mixture of 5 and 6; $C_{19}H_{19}N_3O_2$). A similar procedure to that used for **1a** was applied, the resulting solid recovered (85%), was recrystallized from ethanol 0.273 g (59% yield) mixture of *ca*, 2/1 of **5** : **6**. m.p. = 136-137 °C; IR (KBr): 3100, 3080, 2980, 2920, 1600, 1570, 1510, 1450, 1340, 1160, 1100, 930, 860, 820, 770, 740, 690 cm^{-1}; ^1H NMR ($CDCl_3$) δ: 1.03 (t, J = 7.5 Hz, 3H), 1.13 (t, J = 7.5 Hz, 3H), 1.56 (s, 6H), 1.69-1.74 (m, 1H), 1.87-2.02 (m, 3H), 2.62 (s, 2H), 3.52 (d, J = 1.4 Hz, 1H), 3.6 (d, J = 1.2 Hz, 1H), 7.44-7.53 (m, 10H), 7.88 (d, J = 7.2 Hz, 4H), 8.2 (d, 2H, J = 8.6, 4H). UV-Vis (EtOH): λmax/nm = 280, 405 nm.

Synthesis of 2-isobutyl-2-methyl-6-(4-nitrophenyl)-4-phenyl-1,3-diaza-bicyclo[3,1,0]hex-3-ene (7; $C_{21}H_{23}N_3O_2$). A similar procedure to that used for **1a** was applied, the resulting solid recovered, (65%), was recrystallized from ethanol 0.143 g (41% yield), m.p. = 147-148 °C; IR (KBr): 3050, 2990, 2900, 2850, 1600, 1570, 1510, 1440, 1340, 1100, 940, 860, 760, 740, 695 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 1.03 (d, J = 6.6 Hz, 3H), 1.07 (d, J = 6.6 Hz, 3H), 1.57 (s, 3H), 1.77-1.87 (m, 2H), 1.94-1.98 (m, 1H), 2.64 (s, 1H), 3.52 (s, 1H), 7.44-7.53 (m, 5H), 7.87 (d, J = 7.4 Hz, 2H), 8.2 (d, J = 8.6 Hz, 2H). UV-Vis (EtOH): λmax/nm = for **7a**, 281 nm, for **7b**, 401 nm.

Synthesis of 6-(4-nitrophenyl)-4-phenyl-2,2-dipropyl-1,3-diaza-bicyclo[3,1,0]hex-3-ene (8; $C_{22}H_{25}N_3O_2$). A similar procedure to that used for **1a** was applied, the resulting solid recovered, (85%), was recrystallized from ethanol 0.222 g (61% yield), m.p. = 138-140 °C; IR (KBr): 3100, 3080, 2950, 2920, 2880, 1600, 1570, 1510, 1440, 1340, 1240, 1140, 960, 860, 830, 760, 740 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 0.93-0.99 (tt, J = 7, 7.3 Hz, 6H), 1.28-1.36 (m, 1H), 1.51-1.57 (m, 2H), 1.65-1.7 (m, 2H), 1.88-

1.94 (m, 3H), 2.65 (s, 1H), 3.54 (s, 1H), 7.45-7.54 (m, 5H), 7.89 (d, J = 7.5 Hz, 2H), 8.23 (d, J = 8.5 Hz, 2H). UV-Vis (EtOH): λmax/nm = for **8a**, 245 and shoulder at 290 nm, for **8b**, 406 nm.

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