Pergamon

Tetrahedron 58 (2002) 3613–3618

TETRAHEDRON

Synthesis of new stable arylthiopyridinium *N*-arylimide zwitterions. Part 20: Fused azolium salts☆

András Messmer, Péter Kövér, Zsuzsanna Riedl, Ágnes Gömöry and György Hajós*

[a]*Chemical Research Center, Central Research Institute for Chemistry, Hungarian Academy of Sciences, P.O. Box 17, H-1525 Budapest, Hungary*

Received 1 January 2002; revised 11 February 2002; accepted 7 March 2002

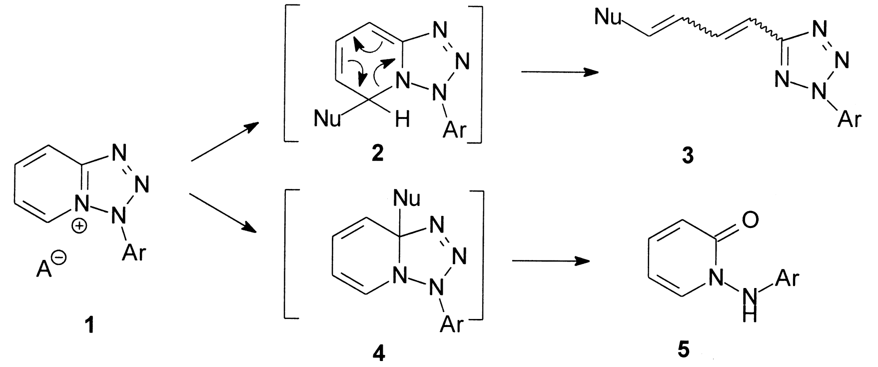
Abstract—3-Aryltetrazolopyridinium salts react with thiophenolates to afford stable arylthio substituted pyridinium *N*-arylimide zwitterions as red crystals. The angularly fused tetrazolo[1,5-*a*]quinolinium salt react analogously and also yielded a blue zwitterionic product. The new zwitterions underwent solvolysis in methanol to give *N*-anilinopyridones, their alkylation yielding stable *N*-alkyl substituted salts and their reaction with dipolarophiles results in the formation of stable cycloadducts. © 2002 Elsevier Science Ltd. All rights reserved.

Earlier studies[2–5] on reactivity of azolopyridinium salts revealed that these ring systems (e.g. tetrazolopyridinium salt **1**) readily react with nucleophiles and, in most cases, undergo ring opening reactions. In these transformations (see Scheme 1), two major types of reactions of **1** have been observed: secondary amines, most alkoxides or carbon nucleophiles attack the pyridine-carbon atom adjacent to the bridgehead nitrogen atom to give an intermediate addition product (**2**), which rapidly undergoes a retro-electrocyclization to afford a tetrazolyldiene (**3**).

With other nucleophiles (like hydroxide ion or some alkoxide reagents in a side-reaction) the attack of the nucleophile takes place at the bridgehead carbon atom (i.e. at the other carbon centre adjacent to the positively charged bridgehead nitrogen atom). The first addition product (**4**) formed in this way undergoes nitrogen elimination and results in the formation of *N*-anilinopyridones (**5**).

In this paper we report a novel extension of these studies and describe the reactivity of **1** with thiophenolates.

Reaction of the bicyclic salt **1** with sodium thiophenolates (generated from thiophenols with sodium hydride in tetrahydrofuran) under mild conditions (−35°C) yielded arylthio substituted pyridinium *N*-arylimides (**7**) (Scheme 2). Upon addition of the reagent the color of the reaction mixture



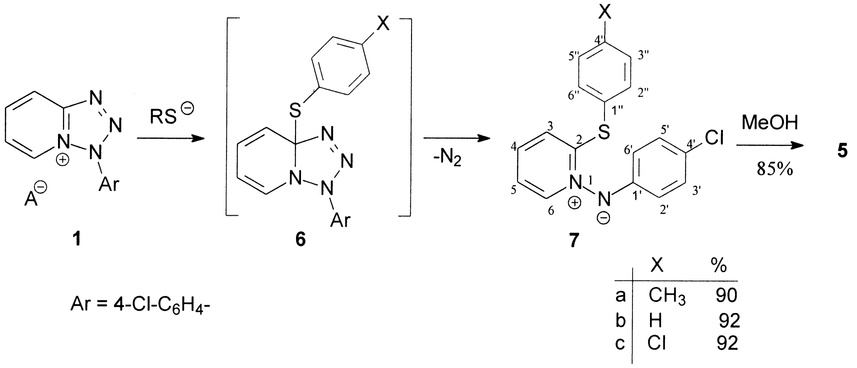
Scheme 1.

☆ For part XIX, see Ref. 1.

Keywords: 1,3-dipolar cycloaddition; zwitterion; ring opening; nitrogen elimination.

* Corresponding author. Tel.: +36-1-3257-550; fax: +36-1-3257-683; e-mail: ghajos@chemres.hu

PII: S0040-4020(02)00293-4



	X	%
a	CH_3	90
b	H	92
c	Cl	92

Scheme 2.

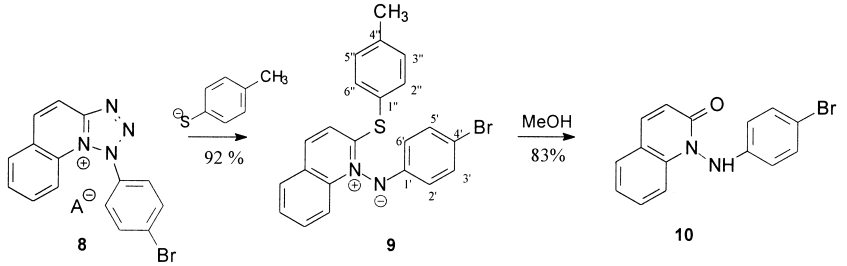
turned to deep red, gas evolution was observed and finally the red crystalline product was isolated in good yield by addition of ether to the filtered and evaporated reaction mixture.

Comparison of this finding with our earlier results suggests that, similar to the formation of **4**, the thiophenolates first form an addition product (**6**) which undergoes nitrogen elimination to yield **7**. The highly polarized zwitterionic structure of the product was found to be in accordance with the NMR spectra (e.g. appearance of the proton and carbon peaks: 8.61 ppm (H-6) and 151.2 ppm (C-2), respectively). When the new zwitterions were treated with methanol, solvolysis took place and *N*-anilinopyridone (**5**) was formed in good yield. Transformation of **7** to **5** is most probably accounted for by the high sensitivity of the arylthio group in **7** towards nucleophiles and traces of water in methanol resulting in hydrolysis to yield **5**.

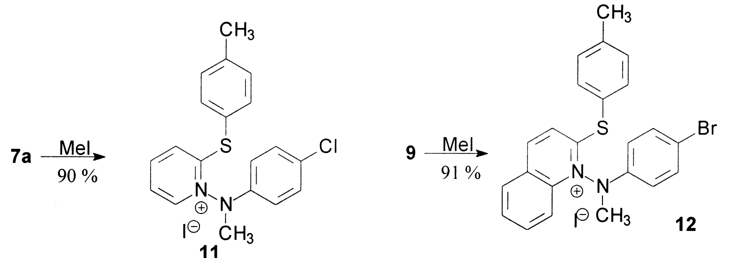
Similar to the reactivity of **1**, its angularly fused benzologue: tetrazolo[1,5-*a*]quinolinium salt (**8**) also reacted with sodium *p*-tolylthiophenolate to give the blue zwitterion **9** (Scheme 3). This zwitterion when dissolved in methanol also yielded the quinolone derivative **10**, the same compound obtained earlier from **8** by addition of tetramethylammonium hydroxide.[4]

Extensive literature has already appeared[6,7] on the synthesis of pyridinium arylimide zwitterions. Most of these procedures imply quaternization of a pyridine derivative and a subsequent deprotonation of the quaternary salt. An entirely different method was applied by Huisgen and Temme.[8–12] These authors carried out a Zincke reaction of *N*-dinitrophenyl-pyridinium salts using arylhydrazines. The majority of the zwitterionic derivatives published in the literature proved to be fairly unstable and could only be isolated in the form of their adducts. Our new crystalline zwitterions proved to be relatively stable upon storing in the solid state. Their solutions, however, gradually decomposed on storage.

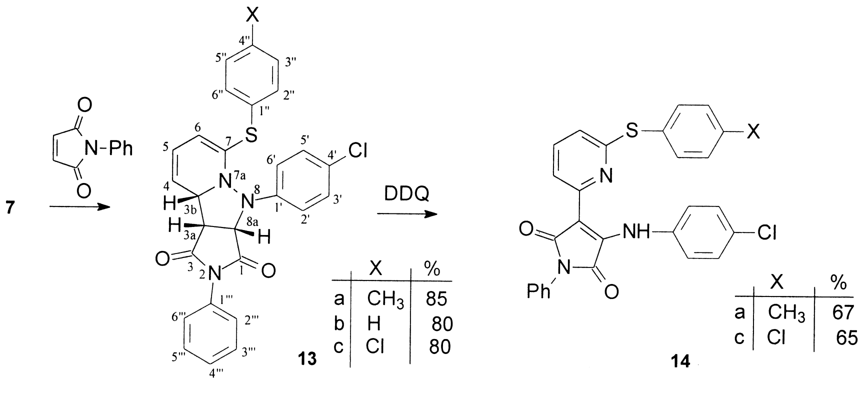
The new zwitterions could be easily alkylated with methyl iodide. Thus, the red pyridinium arylimide **7** and its blue quinoline analogue **9** yielded stable *N*-methyl salts (**11** and **12**, respectively) as yellow crystals in good yields (Scheme 4).



Scheme 3.



Scheme 4.



	X	%
a	CH_3	85
b	H	80
c	Cl	80

	X	%
a	CH_3	67
c	Cl	65

Scheme 5.

In accordance with some recent publications[8–12] on related pyridinium arylimide zwitterions we have also found that the new products can participate in 1,3-dipolar cycloadditions. Thus, **7** when treated with *N*-phenylmaleinimide at room temperature yielded the stable cycloadduct **13** (Scheme 5). DNOE experiment revealed that 3a, 3b, and 8a protons in this compound are situated on the same side of the polycyclic skeleton. Oxidation of **13** with 2,6-dichloro-3,5-dicyanoquinone (DDQ) resulted in aromatization of the pyridine moiety accompanied by the cleavage of the N–N bond to give **14**.

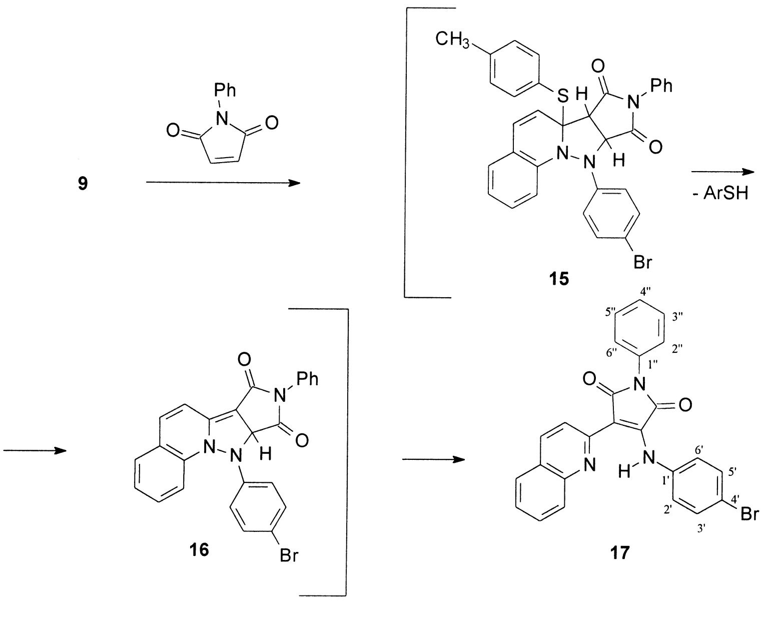
Although quinolinium *N*-arylimide **9** also reacted with *N*-phenylmaleinimide, an essentially different course of reaction was observed. Thus, a 2-substituted quinoline derivative (**17**) was isolated in poor yield (10%). This is interpreted by formation of the cycloadduct **15**, a subsequent elimination of thiophenol to give a second intermediate **16**, and the final aromatization step involving N–N bond cleavage to form the end product **17** (Scheme 6). The difference between the behavior of the pyridinium and quinolinium zwitterions (**7** and **9**, respectively) is caused by the different regioselectivity of the two compounds: in the case of **7** the sterically less hindered carbon atom of the pyridine ring participates in the transformation and the cycloaddition is terminated in the form of the cycloadduct (**13**). In the benzologue case (i.e. with **9**), only the other C-atom is available for the cycloaddition reaction because the other carbon atom is a bridgehead atom. In this cycloadduct (i.e. **15**) elimination of thiophenol molecule is possible allowing the formation of a second intermediate (**16**) and, subsequently, the final product **17**.

Detailed investigation of the reaction of the fused tetrazolium salts with phenolates as well as the reactivity of the new zwitterions in dipolar cycloaddition reactions is in progress.

1. Experimental

1.1. General

Melting points were determined by a Büchi apparatus and are uncorrected. The IR spectra were recorded with a Nicolet Magna 750 FT-IR, spectrophotometers; the NMR spectra were recorded with a Varian UNITY INOVA spectrometer (400 MHz for ^1H and 100 MHz for ^{13}C). The



Scheme 6.

mass spectra were measured on a VG ZAB2-SEQ tandem mass spectrometer using FAB and EI techniques for ionization. For Cl and Br containing molecules the high-resolution mass measurements were carried out using ^{35}Cl or ^{79}Br isotopic peaks.

1.1.1. *N*-Anilinopyridin-2(1*H*)one (5). A solution of phenol (639 mg, 6.8 mmol) in tetrahydrofuran (10 mL) was added to a suspension of sodium hydride (314 mg—calculated for a 50% dispersion, 6.5 mmol) in tetrahydrofuran (10 mL) with vigoros stirring and ice cooling. The mixture was refluxed for 10 min, cooled down to −35°C and, then, a solution of tetrazolopyridinium salt **1**[4] (1.9 g, 6 mmol) in acetonitrile (25 mL) was added dropwise. The whole manipulation was executed under an argon atmosphere. The reaction mixture was allowed to warm up to room temperature. The solvent was removed in vacuo, and the residue was dissolved in methanol, some impurities were removed by filtration, the filtrate was evaporated, and the redish solid residue was treated with ether. The resulting solid was filtered off, and crystallized from ethanol to afford white crystals. 927 mg (70%) mp: 209–213°C (lit.[4] 198°C). The product proved to be identical (NMR, TLC) with an authentic sample obtained by a previous procedure.

1.2. General procedure for preparation of pyridinium and quinolinium *N*-arylimides

A solution of the appropriate thiophenol (6.8 mmol) in tetrahydrofuran (10 mL) was added to a suspension of sodium hydride (314 mg, 6.5 mmol, calculated for a 50% dispersion with respect to NaH) in tetrahydrofuran (20 mL) with vigorous stirring and ice cooling. The mixture was refluxed for 10 min, then it was cooled down to −35°C and a solution of the appropriate tetrazolium salt (6 mmol) in acetonitrile (25 mL) was added dropwise. The whole manipulation was executed under an argon atmosphere. The reaction mixture was allowed warm up to room temperature. The solvent was removed in vacuo, and the residue was dissolved in dichloromethane. This mixture was filtered from the insoluble inorganic material (sodium tetrafluoroborate), the filtrate was evaporated again, and the residue was treated with ether. The resulting solid was filtered off and washed with ether.

1.2.1. 2-(4-Tolylthio)pyridinium-*N*-(4-chloro)phenylimide (7a, Ar=4-chlorophenyl, X=CH_3). This compound was isolated as red crystals, 1.76 g (90%), mp 138–140°C; UV λ (nm) log ϵ in acetonitrile: 224 (4.226), 288 (4.095), 444 (3.761); ν_{max} (KBr): 3020, 1573, 1490, 1477, 1467, 1312, 1253, 1225, 829, 810, 743, 501 cm^{-1}; δ_H ($CDCl_3$): 2.42 (s, 3H, H–Me), 6.60 (m, 1H, H-3), 6.92 (m, 1H, H-4), 6.93 (m, 1H, H-5), 6.94 (m, 2H, H-2′, H-6′), 7.15 (m, 2H, H-3′, H-5′), 7.31 (m, 2H, H-3″, H-5″), 7.50 (m, 2H, H-2″, H-6″), 8.61 (m, 1H, H-6); δ_C ($CDCl_3$): 21.6 (C–Me), 116.5 (C-4″ or C-4′), 117.7 (C-2′, C-6′), 120.6 (C-5), 123.4 (C-3), 126.2 (C-4), 128.8 (C-4′ or C-4″), 129.7 (C-3′, C-5′), 131.3 (C-3″, C-5″), 134.8 (C-6), 136.1 (C-2″, C-6″), 141.1 (C-1″), 151.3 (C-2), 151.8 (C-1′); HRMS (FAB) for $C_{18}H_{15}N_2ClS$ $[M+H]^+$ found: 327.0714, calcd: 327.0723.

1.2.2. 2-(Phenylthio)pyridinium-*N*-(4-chloro)phenylimide (7b, Ar=4-chlorophenyl, X=H). This compound was isolated as red crystals, 1.72 g, (92%); mp: 90–92°C; ν_{max} (KBr): 3020, 1577, 1477, 1468, 1420, 1305, 1255, 1228, 1170, 829, 747, 689, 503 cm^{-1}; δ_H ($CDCl_3$): 6.58 (m, 1H, H-3), 6.91 (m, 1H, H-4), 6.93 (m, 1H, H-5), 6.95 (m, 2H, H-2′, H-6′), 7.15 (m, 2H, H-3′, H-5′), 7.50 (m, 3H, H-3″, H-4″, H-5″), 7.65 (m, 2H, H-2″, H-6″), 8.60 (m, 1H, H-6); δ_C ($CDCl_3$): 117.8 (C-2′, C-6′), 120.7 (C-5), 123.3 (C-3), 123.5 (C-4′), 125.6 (C-4), 129.7 (C-3′, C-5′), 130.0 (C-1″), 130.5 (C-3″, C-5″), 130.6 (C-4″), 134.2 (C-6), 136.2 (C-2″, C-6″), 150.8 (C-2), 151.4 (C-1′); HRMS (FAB) for $C_{17}H_{12}N_2ClS$ $[M+H]^+$ found: 313.0565, calcd: 313.0566.

1.2.3. 2-(4-Chlorophenylthio)pyridinium-*N*-(4-chloro)-phenylimide (7c, Ar=4-chlorophenyl, X=Cl). This compound was isolated as red crystals, 1.5 g (92%) mp 141–142°C; ν_{max} (KBr): 3070, 1576, 1480, 1472, 1420, 1307, 1255, 1170, 1092, 1013, 836, 751, 503 cm^{-1}; δ_H ($CDCl_3$): 6.55 (dd, 1H, *J*=8, 2 Hz, H-3), 6.86 (ddd, 1H, *J*=8.5, 8, 1.5 Hz, H-4), 6.91 (ddd, 1H, *J*=8.5, 7, 2 Hz, H-5), 6.96 (m, 2H, H-2″, H-6″), 7.16 (m, 2H, H-3″, H-5″), 7.19 (m, 2H, H-2′, H-6′), 7.25 (m, 2H, H-3′, H-5′), 8.57 (dd, 1H, *J*=7, 1.5 Hz, H-6); δ_C ($CDCl_3$): 117.9, 120.5, 122.8, 123.4, 124.1, 128.6, 129.5, 130.4, 132.6, 136.8, 137.2, 148.5, 151.1; HRMS (FAB) for $C_{17}H_{12}N_2Cl_2S$ $[M+H]^+$ found: 347.0177, calcd: 347.0176.

1.2.4. 2-(4-Tolylthio)quinolinium-*N*-(4-bromo)phenylimide (9). This compound was isolated as blue crystals, 2.32 g (92%) mp: 159–161°C; UV λ (nm) log ϵ in acetonitrile: 224 (4.408), 266 (4.463), 326 (4.254), 588 (3.025); ν_{max} (KBr): 3027, 3010, 1587, 1574, 1560, 1472, 1301, 1252, 1169, 806, 505 cm^{-1}; δ_H ($CDCl_3$): 2.42 (s, 3H, H–Me), 6.08 (b, 2H, H-2′, H-6′), 6.88 (d, 1H, *J*=9 Hz, H-3), 7.06 (m, 2H, H-3′, H-5′), 7.32 (m, 2H, H-3″, H-5″), 7.49 (m, 2H, H-2″, H-6″), 7.58 (ddd, 1H, *J*=8.5, 7.5, 1 Hz, H-7), 7.72 (ddd, 1H, *J*=9, 7.5, 1 Hz, H-6), 7.87 (dd, 1H, *J*=9, 1 Hz, H-8), 7.91 (dd, *J*=9, 1 Hz, H-4), 8.24 (ddd, 1H, *J*=8.5, 1, 1 Hz, H-5); δ_C ($CDCl_3$): 21.3, 103.5, 111.9, 119.5, 120.4, 125.8, 127.1, 127.5, 129.2, 131.1, 131.5, 132.8, 134.6, 135.5, 141.2, 142.0, 156.4, 164.3; HRMS (FAB) for $C_{22}H_{17}N_2BrS$ $[M]^+$ found: 420.0272, calcd: 420.0296.

1.3. Reaction of 2-(4-chlorophenylthio)-pyridinium *N*-(4-chlorophenyl)imide (7c) with methanol

Crystalline **7c** (400 mg, 1.15 mmol) was suspended in methanol (10 mL). The mixture was refluxed for 1 h, the solvent was evaporated, the residue was treated vith ether, and the precipitated solid was filtered off. The crude product was crystallized from methanol to yield *N*-(4-chloro)anilinopyridin-2(1*H*)one (**5**) as white crystals: 216 mg (85%), mp: 209–212°C (lit.,[4] 198°C).

1.3.1. *N*-(4-Bromoanilino)quinolin-2(1*H*)one (10). 2-(4-Tolylthio)quinolinium *N*-(4-bromophenyl)imide **9** (300 mg, 0.71 mmol) was added to methanol (10 mL), whereupon a fast reaction occurred indicated by the disappearance of the blue color of the starting compound. The solvent was removed, the residue was treated with ether, and the precipitated solid was filtered off. Recrystallization from methanol afforded colorless crystals. Yield: 186 mg (83%), mp: 176–178°C (lit.,[4] 196°C). Physical data (TLC, NMR spectra) of the product proved to be identical with that of the authentic sample.

1.3.2. 2-(4-Tolylthio)-*N*-methyl-*N*-(4-chloroanilino)pyridinium iodide (11). A mixture of 2-(4-tolylthio)pyridinium-*N*-(4-chlorophenyl)imide **7a** (200 mg, 0.61 mmol), methyliodide (0.5 mL) and acetonitrile (3 mL) was stirred at room temperature for 1 h. The solvent was removed, the residue was treated with ether, and the precipitated solid material was filtered off to yield the product, 250 mg (90%), mp: 136–138°C, yellow crystals; $\nu_{\max}$ (KBr): 3017, 2983, 1601, 1557, 1493, 1464, 1279, 1092, 816, 811 cm^{-1}; δ_H (CDCl$_3$): 2.50 (s, 3H, H–Me), 3.80 (s, 3H, H–N–Me), 7.01 (m, 2H, H-2′, H-6′), 7.13 (dd, 1H, *J*=9, 2 Hz, H-3), 7.37 (m, 2H, H-3′, H-5′), 7.44 (m, 2H, H-3″, H-5″), 7.64 (m, 2H, H-2″, H-6″), 7.91 (ddd, 1H, *J*=7, 6.5, 2 Hz, H-5), 8.34 (ddd, 1H, *J*=9, 7, 1 Hz, H-4), 9.42 (dd, 1H, *J*=6.5, 1 Hz); δ_C (CDCl$_3$): 21.7, 42.6, 119.3, 120.6, 125.8, 126.0, 130.4, 131.3, 136.2, 143.6, 144.0, 145.3, 146.3, 166.0; HRMS (FAB) for $C_{19}H_{18}N_2ClS$ [M−I]$^+$ found: 341.0881, calcd: 341.0879.

1.3.3. 2-(4-Tolylthio)-*N*-methyl-*N*-(4-bromoanilino)quinolinium iodide (12). A mixture of 2-(4-tolylthio)quinolinium *N*-(4-bromo)phenylimide **9** (200 mg, 0.47 mmol), methyliodide (0.5 mL) and acetonitrile (3 mL) was stirred at room temperature for 1 h. The solvent was removed, the residue was treated with ether, and the precipitated solid material was filtered off to yield the product, 244 mg (91%), mp: 119–121°C; $\nu_{\max}$ (KBr): 3032, 2970, 1613, 1592, 1561, 1488, 1447, 1141, 814, 762 cm^{-1}; δ_H (CDCl$_3$): 2.48 (s, 3H, H–Me), 3.91 (s, 3H, H–N–Me), 6.53 (m, 2H, H-2′, H-6′), 7.24 (d, 1H, *J*=9 Hz, H-3), 7.43 (m, 2H, H-3″, H-5″), 7.45 (m, 2H, H-3′, H-5′), 7.53 (dd, 1H, *J*=9, 1 Hz, H-8), 7.72 (m, 2H, H-2″, H-6″), 7.76 (ddd, 1H, *J*=8, 7, 1 Hz, H-6), 7.92 (ddd, 1H, *J*=9, 7, 2 Hz, H-7), 8.47 (ddd, 1H, *J*=8, 2, 1 Hz, H-5), 9.14 (dd, 1H, *J*=9, 1 Hz, H-4); δ_C (CDCl$_3$): 21.8, 39.6, 114.2, 115.6, 116.6, 120.1, 121.0, 128.6, 129.6, 132.4, 132.6, 133.5, 136.2, 136.6, 139.6, 142.8, 143.9, 146.5, 173.1; HRMS (FAB) for $C_{23}H_{20}N_2BrS$ [M−I]$^+$ found: 435.0502, calcd: 435.0530.

1.4. General procedure for cycloaddition of the zwitterion with *N*-phenylmaleimide

To a solution of the appropriate pyridinium-*N*-arylimide (1.5 mmol) in dichloromethane (10 mL) was added *N*-phenyl-maleimide (294 mg, 1.7 mmol). The reaction mixture was stirred at room temperature for 15 min. A fast reaction occured indicated by disappearence of the red color. The solvent was removed, the residue was treated with ether and the resulting solid was filtered off.

1.4.1. 8-(4-Chlorophenyl)-2-phenyl-7-*p*-tolylthio-3a,3b,8,8a-tetrahydro-2,7a,8-triaza-cyclopenta[*a*]indene-1,3-dione (13a, Ar=4-chlorophenyl, X=CH$_3$). This compound was obtained as colorless crystals, 636 mg (85%); mp: 140–141°C; $\nu_{\max}$ (KBr): 3057, 2920, 1786, 1725, 1546, 1491, 1387, 1192, 1175, 820, 810, 751 cm^{-1}; δ_H (CDCl$_3$): 2,30 (s, 3H, H–Me), 3.60 (dd, 1H, *J*=8, 7.5 Hz, H-3a), 4.39 (dd, 1H, *J*=7.5, 5 Hz, H-3b), 4.44 (dd, 1H, *J*=6, 1 Hz, H-6), 4.65 (d, 1H, *J*=8 Hz, H-8a), 5.74 (ddd, 1H, *J*=9.5, 5, 1 Hz, H-4), 5.98 (dd,1H, *J*=9.5, 6 Hz, H-5), 7.03 (m, 2H, H-3″, H-5″), 7.17 (m, 2H, H-2″, H-6″), 7.19 (m, 2H, H-3′, H-5′), 7.25 (m, 2H, H-2′, H-6′), 7.33 (m, 2H, H-2‴, H-6‴), 7.43 (m, 1H, H-4‴), 7.49 (m, 2H, H-3‴, H-5‴); δ_C (CDCl$_3$): 21.4 (C–Me), 54.4 (C-3a), 62.5 (C-3b), 65.1 (C-8a), 98.0 (C-6), 113.9 (C-4), 116.2 (C-2′, C-6′), 125.0 (C-5), 126.2 (C-2‴, C-6‴), 126.4 (C-4′), 127.4 (C-1″), 129.0 (C-4‴), 129.3 (C-3‴, C-5‴), 129.5 (C-3′, C-5′), 130.2 (C-3″, C-5″), 135.7 (C-2″, C-6″), 139.7 (C-4″), 148.0 (C-1′), 151.4 (C-7), 172.0 (C-3), 172.3 (C-1); LRMS (FAB): 500, 499; HRMS (FAB) for $C_{28}H_{22}N_3ClO_2S$ [M]$^+$ found: 499.1082, calcd: 499.1121.

1.4.2. 8-(4-Chlorophenyl)-2-phenyl-7-*p*-phenylthio-3a,3b,8,8a-tetrahydro-2,7a,8-triaza-cyclopenta[*a*]indene-1,3-dione (13b, Ar=4-chlorophenyl, X=H). This compound was obtained as colorless crystals, 544 mg (80%); mp: 103–105°C; $\nu_{\max}$ (KBr): 3057, 2970, 1785, 1720, 1593, 1540, 1488, 1379, 1175, 826, 810, 749 cm^{-1}; δ_H (CDCl$_3$): 3.62 (dd, 1H, *J*=8, 7.5 Hz, H-3a), 4.40 (dd, 1H, *J*=7.5, 5 Hz, H-3b), 4.48 (dd, 1H, *J*=6, 1 Hz, H-6), 4.66 (d, 1H, *J*= 8 Hz, H-8a), 5.76 (ddd, 1H, *J*=9.5, 5, 1 Hz, H-4), 5.98 (dd, 1H, *J*=9.5, 6 Hz, H-5), 7.18 (m, 2H, H-2′, H-6′), 7.24 (m, 2H, H-3′, H-5′), 7.25–7.34 (m, 7H, H-2″, H-3″, H-4″, H-5″, H-6″, H-2‴, H-6‴), 7.42 (m, 1H, H-4‴), 7.49 (m, 2H, H-3‴, H-5‴); δ_C (CDCl$_3$): 54.2, 62.2, 65.0, 98.4, 114.0, 116.0, 124.8, 126.0, 127.2, 129.1, 129.2, 129.3, 130.0, 131.8, 135.3, 147.7, 150.6, 171.8, 172.0; HRMS (FAB) for $C_{27}H_{20}N_3ClO_2S$ [M]$^+$ found: 485.0941, calcd: 485.0965.

1.4.3. 8-(4-Chlorophenyl)-2-phenyl-7-*p*-4-chlorophenylthio-3a,3b,8,8a-tetrahydro-2,7a,8-triaza-cyclopenta[*a*]indene-1,3-dione (13c, Ar=4-chlorophenyl, X=Cl). This compound was obtained as colorless crystals, 624 mg (80%); mp: 132–134°C; $\nu_{\max}$ (KBr): 3061, 2900, 1789, 1719, 1547, 1488, 1387, 1192, 1174, 1092, 826, 753 cm^{-1}; δ_H (CDCl$_3$): 3.63 (dd, 1H, *J*=8, 7.5 Hz, H-3a), 4.38 (dd, 1H, *J*=7.5, 5 Hz, H-3b), 4.53 (dd, 1H, *J*=6, 1 Hz, H-6), 4.65 (d,1H, *J*= 8 Hz, H-8a), 5.78 (ddd, 1H, *J*=9.5, 5, 1 Hz, H-4), 6.00 (dd, 1H, *J*=9.5, 6 Hz, H-5), 7.13 (m, 1H, H-2′, H-6′), 7.17 (m, 4H, H-2″, H-3″, H-5″, H-6″), 7.24 (m, 2H, H-3′, H-5′), 7.30 (m, 2H, H-2‴, H-6‴), 7.44 (m, 1H, H-4‴), 7.49 (m, 2H, H-3‴, H-5‴); δ_C (CDCl$_3$): 54.2, 62.1, 64.9, 98.9, 114.5, 115.8, 124.6, 125.7, 127.3, 128.4, 128.7, 129.1, 129.2, 129.3, 131.6. 135.4, 136.3, 147.5, 149.7, 171.6, 171.9; HRMS (FAB) for $C_{27}H_{19}N_3Cl_2O_2S$ [M]$^+$ found: 519.0590, calcd: 519.0575.

1.5. General procedure for oxidation of cycloadduct 13 with dicyanodichloroquinone (DDQ)

A suspension of the appropriate derivative of **13** (1.5 mmol), DDQ (409 mg, 1.8 mmol) in toluene (10 mL) was refluxed for two hours. The solvent was removed, the residue was mixed with dichloromethane (40 mL), and some impurities were removed by filtration. Alumina (2 g) was added to the filtrate, the mixture was stirred for a few minutes, and the mixture was filtered. The organic solvent was evaporated, and the residue was crystallized from acetonitrile.

1.5.1. 3-(4-Chloroanilino)-1-phenyl-4-(6-*p*-tolylthiopyridin-2-yl)-pyrrole-2,5-dione (14a). This compound was obtained as orange crystals, 499 mg (67%); mp: 191–193°C; $\nu_{\max}$ (KBr): 2920, 1757, 1711, 1636, 1545, 1497, 1399, 1161, 1096, 799, 752 cm^{-1}; δ_H (CDCl$_3$): 2.08 (s, 3H, H–Me), 6.92 (m, 2H, H-2″, H-6″), 6.93 (m, 2H, H-2′, H-6′), 6.96 (m, 2H, H-3″, H-5″), 6.98 (dd, 1H, *J*=8, 1 Hz, H-3), 7.23 (m, 2H, H-3′, H-5′), 7.24–7.31 (m, 2H, H-2‴, H-6‴), 7.35–7.4 (m, 3H, H-3‴, H-4‴, H-5‴), 7.56 (dd, 1H, *J*=8, 8 Hz, H-4), 8.17 (dd, 1H, *J*=8, 1 Hz, H-5), 10.7 (b, 1H, N–H); δ_C ($CDCl_3$): 21.3, 99.7, 118.5, 119.2, 126.6, 126.8, 127.7, 128.8, 129.0, 130.6, 131.6, 132.3, 134.7, 136.3, 137.4, 139.6, 144.6, 152.7, 158.7, 163.9, 168.7; HRMS (FAB) for $C_{28}H_{20}N_3ClO_2S$ $[M+H]^+$ found: 498.1052, calcd: 498.1043.

1.5.2. 3-(4-Chloroanilino)-1-phenyl-4-(6-*p*-chlorophenylthiopyridin-2-yl)-pyrrole-2,5-dione (14c). This compound was obtained as orange crystals: 505 mg (65%); mp: 225–227°C; ν_{max} (KBr): 3089, 3057, 1767, 1708, 1627, 1570, 1495, 1387, 1157, 1091, 802, 760 cm^{-1}; δ_H (DMSO-d$_6$): δ_H (DMSO-d$_6$): 7.04 (m, 2H, H-2′, H-6′), 7.12 (dd, 1H, *J*=8, 1 Hz, H-3), 7.29 (m, 2H, H-3′, H-5′), 7.32 (m, 2H, H-3″, H-5″), 7.35–7.40 (m, 3H, H-3‴, H-4‴, H-5‴), 7.46 (m, 2H, H-2‴, H-6‴), 7.49 (m, 2H, H-2″, H-6″), 7.79 (dd, 1H, *J*=8, 8 Hz, H-4), 7.98 (dd, 1H, *J*=8, 1 Hz, H-5), 10.34 (b, 1H, N–H); δ_C (DMSO-d$_6$): 99.4, 118.9, 119.4, 125.7, 126.9, 127.5, 128.2, 128.6, 128.9, 129.7, 130.1, 131.7, 134.2, 135.5, 136.4, 137.9, 143.8, 151.7, 156.9, 163.7, 168.5; HRMS (FAB) for $C_{27}H_{17}N_3SCl_2O_2$ $[M+H]^+$ found: 518.0524, calcd: 518.0497.

1.5.3. 3-(4-Bromophenylamino)-1-phenyl-4-quinolin-2-yl-pyrrole-2,5-dione (17). A mixture of quinolinium *N*-arylimide derivative **9** (1 g, 2.4 mmol), *N*-phenylmaleimidine (420 mg, 2.4 mmol) and acetonitrile (6 mL) was stirred at room temperature for three days. A precipitate was formed which was filtered off and was submitted to flash vacuum chromatography (chloroform:cyclohexane=2:1, neutral alumina). The collected fraction at R_f=0.8 was evaporated, treated with ether, the resulting solid was filtered off and crystallized from acetonitrile to give dark blue crystals, 120 mg (10%); mp: 263–265°C; UV λ (nm) log ε in acetonitrile: 234 (4.178), 356 (3.676), 482 (3.457), 676 (3.724); ν_{max} (KBr): 3062, 3034, 2960, 1700, 1632, 1605, 1558, 1501, 1460, 1408, 1382, 1167, 982, 817, 767, 726, 625 cm^{-1}; δ_H ($CDCl_3$): 6.48 (m, 2H, H-2′, H-6′), 7.13 (m, 2H, H-3′, H-5′), 7.21 (m, 2H, H-2″, H-6″), 7.33 (m, 1H, H-4″), 7.38 (ddd, 1H, *J*=8, 7, 1 Hz, 6-H), 7.42 (m, 2H, H-3″, H-5″), 7.51 (d, 1H, *J*=9 Hz, H-3), 7.57 (ddd, 1H, *J*=8.5, 7, 1 Hz, H-7), 7.62 (dd, 1H, *J*=8, 1 Hz, H-5), 7.65 (d, 1H, *J*=9 Hz, H-4), 8.11 (dd, 1H, *J*=8.5, 1 Hz, H-8), 10.9 (s, 1H, N–H); δ_C ($CDCl_3$): 91.9, 113.2, 115.7, 117.2, 122.2, 125.3, 125.9, 126.2, 127.1, 127.6, 127.9, 128.8, 131.6, 132.3, 132.7, 134.5, 141.2, 142.5, 153.5, 166.1, 166.9; HRMS (EI) for $C_{25}H_{16}N_3BrO_2$ $[M]^+$ found: 469.0418, calcd: 469.0426.

Acknowledgements

Research fund OTKA 35176 is gratefully appreciated.

References

1. For part XIX: Béres, M.; Hajós, Gy.; Riedl, Zs.; Soós, T.; Timári, G.; Messmer, A. *J. Org. Chem.* **1999**, *64*, 5499–5503.
2. Gelléri, A.; Messmer, A. *Tetrahedron Lett.* **1973**, *14*, 4295–4298.
3. Gelléri, A.; Messmer, A.; Nagy, S.; Radics, L. *Tetrahedron Lett.* **1980**, *21*, 663–666.
4. Messmer, A.; Gelléri, A.; Hajós, Gy. *Tetrahedron* **1986**, *42*, 4827–4836.
5. Messmer, A.; Hajós, Gy.; Timári, G. *Tetrahedron* **1992**, *48*, 8451–8458.
6. Timpe, H. J. *Adv. Heterocycl. Chem.* **1974**, *17*, 213–253.
7. Tamamura, Y.; Ikeda, M. *Adv. Heterocycl. Chem.* **1981**, *29*, 73–139.
8. Bast, K.; Durst, T.; Huisgen, R.; Lindner, K.; Temme, R. *Tetrahedron* **1998**, *54*, 3745–3764.
9. Huisgen, R.; Palacios-Gambra, F.; Polborn, K.; Boeckh, D. *Heterocycles* **1999**, *50*, 353–364.
10. Temme, R.; Huisgen, R. *J. Heterocycl. Chem.* **1998**, *35*, 643–647.
11. Huisgen, R.; Durst, T.; Temme, R. *J. Heterocycl. Chem.* **1998**, *35*, 637–642.
12. Huisgen, R.; Temme, R. *Heteroatom. Chem.* **1999**, *10*, 79–88.