Pergamon

Tetrahedron 58 (2002) 7583–7588

TETRAHEDRON

Reactions of 6-(dichloromethylene)cyclohexa-2,4-dien-1-alkylimines with amines

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Received 14 May 2002; revised 20 June 2002; accepted 19 July 2002

Abstract—Chlorination of 2,1-benzisothiazoline 2,2-dioxides (benzosultams) with hexachloroethane under phase-transfer catalysis condition in the presence of 50% aqueous NaOH and tetraalkylammonium salt gives 3,3-dichlorobenzosultams in good yields. Thermal extrusion of SO_2 from 3,3-dichloropyridosultams generates dichloro derivatives of aza-*ortho*-xylylenes which do not enter [4+2] cycloaddition reactions, but add amines to form amidines. With aromatic diamines and aminophenols, benzimidazole and benzoxazole derivatives are formed in good yields. © 2002 Published by Elsevier Science Ltd.

1. Introduction

6-Methylenecyclohexa-2,4-dien-1-imines, known as aza-*ortho*-xylylenes or *ortho*-quinone methide imines, are potential building blocks for the construction of heterocyclic systems.[1] We have developed a method of generation of these reactive intermediates by thermal extrusion of SO_2 from 2,1-benzisothiazoline 2,2-dioxides (benzosultams).[2–6] These 1-azadienes enter [4+2] cycloaddition with dienophiles leading to 1,2,3,4-tetrahydroquinoline derivatives.[2,3,6] Without dienophile, the aza-*ortho*-xylylenes undergo [1,5]-hydrogen shift leading to 2-vinylanilines[4,5] or Schiff bases.[3] In the presence of nucleophilic agents an addition to the exocyclic C=CH_2 bond occurs leading to 2-aminobenzyl derivatives.[7,8]

It was interesting how the replacement of hydrogen atoms in the methylene group of aza-*ortho*-xylylene by heteroatoms would influence the reactivity of these 1-azadienes. The only known derivatives of that type are difluoromethylene quinone imines generated by a base-induced elimination of HF from *ortho*-(trifluoromethyl)anilines.[9] These difluoroxylylenes do not enter Diels–Alder reactions, but can add nucleophiles. The characteristic feature of these reactions is a recurrence of elimination of HF and addition of nucleophiles resulting in a replacement of all fluorine atoms in the trifluoromethyl group by the nucleophile.

In this paper we report results of our studies on the reactions of 6-(dichloromethylene)cyclohexa-2,4-dien-1-imines (dichloroxylylenes) generated from 1-alkyl-3,3-dichloro-1,3-dihydro-2,1-benzisothiazole 2,2-dioxides.

Keywords: nucleophilic addition; imidochlorides; amidines; benzosultams; benzimidazoles; benzoxazoles; 2-arylperimidine.

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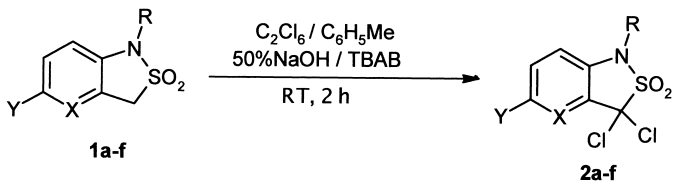
2. Results and discussion

One method of introduction of the halogen atoms α to the sulfonyl group involves chlorination of carbanions of sulfones with perhalogenoalkanes, usually tetrachloro- or tetrabromomethane.[10] Since in these reactions trihalomethyl anions are formed as a side product, which can decompose to a reactive dihalocarbene, we decided to use hexachloroethane as the halogen source. The chlorination of starting benzosultams with hexachloroethane in the catalytic two-phase system employing 50% aqueous sodium hydroxide in the presence of tetrabutylammonium bromide proceeded smoothly and the expected 1-alkyl-3,3-dichloro-2,1-benzisothiazoline 2,2-dioxides **2** were obtained in good yields (Scheme 1).

Our attempts to intercept the dichloroxylylene generated from the dichlorosultam **2a** by Diels–Alder reaction with *N*-phenylmaleimide (NPMI) were unsuccessful. Under standard reaction conditions in boiling 1,2-dichlorobenzene (180°C) or 1,2,4-trichlorobenzene (215°C) the extrusion of SO_2 from the dichlorosultam **2a** proceeded rapidly. After 15 min starting material disappeared, but in the reaction mixture no cycloaddition products were detected. Supposing that the expected [4+2] cycloaddition product might be thermally unstable we decreased the reaction temperature and have found that the sultam **2a** loses SO_2 slowly in boiling toluene (110°C). However, under these conditions also no cycloaddition of the generated aza-*ortho*-xylylene to NPMI occurred.

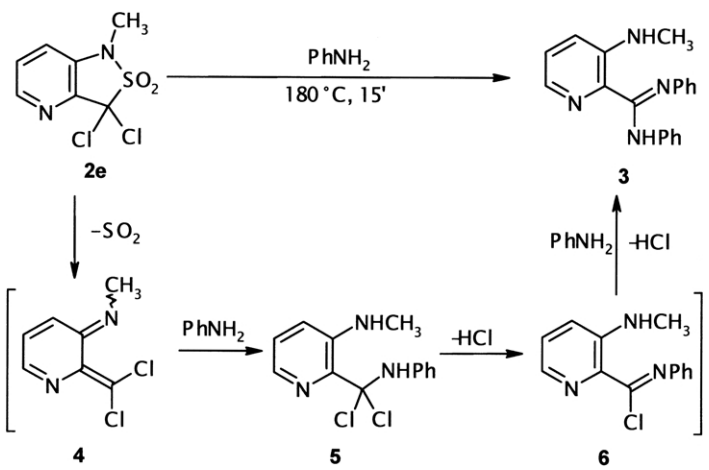
Aza-*ortho*-xylylenes can be effectively trapped by nucleophiles.[7–9,11] We decomposed the sultam **2e** in boiling dichlorobenzene in the presence of an excess of aniline. The reaction led to amidine **3** in 44% yield. A plausible way of formation of **3** is shown in Scheme 2. The reaction consists

0040–4020/02/$ - see front matter © 2002 Published by Elsevier Science Ltd.
PII: S0040-4020(02)00862-1



	X	Y	R	Yield (%)
a	C-H	H	CH_3	69
b	C-H	H	C_2H_5	59
c	C-H	H	i-C_3H_7	47
d	C-H	CH_3	CH_3	82
e	N	H	CH_3	62
f	N	H	n-C_3H_7	80

Scheme 1.



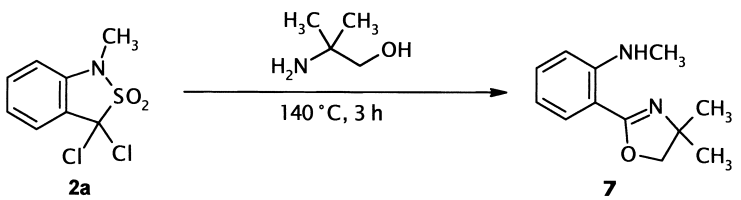
Scheme 2.

in a nucleophilic addition of aniline to the dichloroxylylene **4** followed by an elimination of hydrogen chloride from the adduct **5** and consecutive nucleophilic substitution of chlorine in the intermediate imidochloride **6** by another molecule of aniline.

The sultams **2a** and **d** reacted similarly. The corresponding amidines were detected in the reaction mixture, however their isolation and purification proved impossible. Attempts to introduce aliphatic monoamines into this reaction were unsuccessful and they led to intractable reaction mixtures from which no amidines were isolated. Only in the reaction of xylylene generated from benzosultam **2a** with 2-amino-2-methylpropanol was the expected dihydrooxazol-2-ylaniline **7** obtained in moderate yield (Scheme 3).

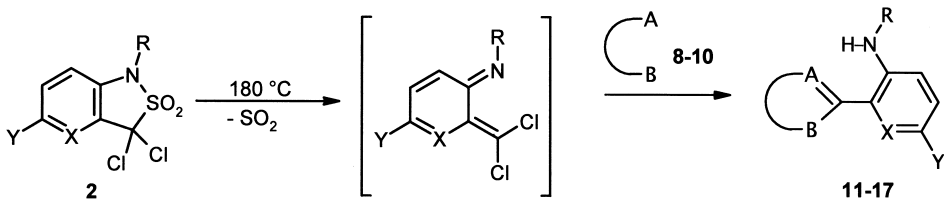
In an analogous reaction with *ortho*-phenylenediamine (**8**) the benzosultam **2a** was transformed into 2-arylbenzimidazole **9** in good yield (Table 1, entry 1). Dichloroxylylenes generated from sultams **2c** and **e** reacted with phenylenediamine similarly giving the expected benzimidazoles **13** and **16**, respectively. The reaction of benzosultam **2c** with 1,8-diaminonaphthalene (**10**) led to 2-arylperimidine derivative **15**. Dichloroxylylenes reacted also with 2-aminophenol (**9**) to form benzoxazole derivatives **12**, **14**, and **17**. The results are summarized in Table 1.

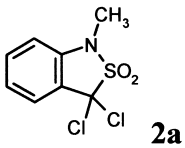
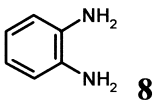
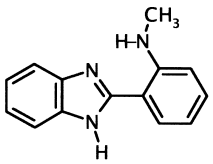
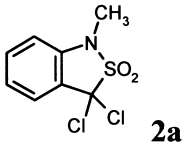
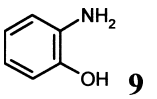
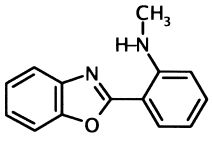
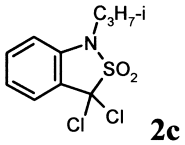
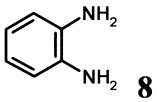
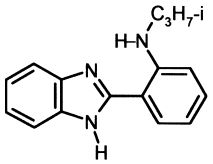
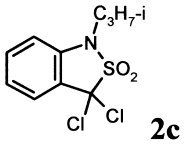
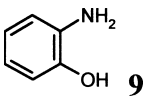
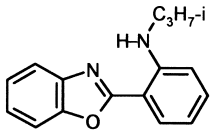
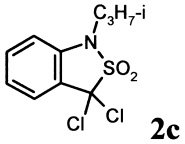
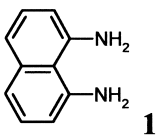
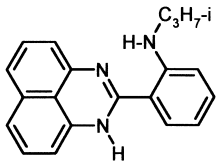
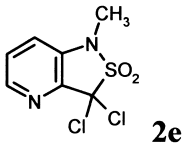
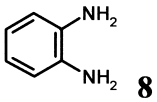
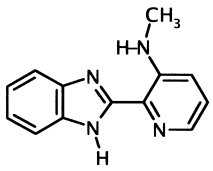
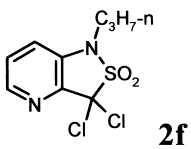
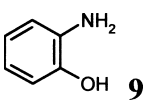
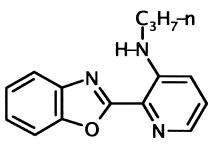
The reactions of dichloroxylylene resemble the transformations of difluoro-aza-*ortho*-xylylenes [6-(difluoromethylene)cyclohexa-2,4-diene-1-imines] generated via a base-induced 1,4-elimination of hydrogen fluoride from 2-(trifluoromethyl)anlilines, which were extensively studied by



Scheme 3.

Table 1. Formation of condensed heterocycles from dichloroxylylenes and nucleophiles



	Sultam		Product	Yield (%)
1.	 **2a**	 **8**	 **11**	70
2.	 **2a**	 **9**	 **12**	51
3.	 **2c**	 **8**	 **13**	65
4.	 **2c**	 **9**	 **14**	47
5.	 **2c**	 **10**	 **15**	45
6.	 **2e**	 **8**	 **16**	45
7.	 **2f**	 **9**	 **17**	66

Kiselyov and Strekowski.[9] These difluoroxylylenes also did not enter into [4+2] cycloaddition reactions with dienophiles, but with 2-aminophenol and 2-aminothiophenol gave the corresponding benzoxazole and benzothiazole derivatives.[12] The addition of other nucleophiles to the difluoroxylylenes resulted in diverse heterocyclic systems, usually in good yields.[9] The known methods of synthesis of 2-(2-aminophenyl) substituted derivatives of benzimidazole,[13] benzoxazole[14,15] and perimidine[16] deal with the reactions of anthranilic acid or isatoic anhydride[13,15–17] with the corresponding 1,2-phenylenediamines or 2-aminophenols.

3. Experimental

3.1. General

Melting points are uncorrected. ^{1}H and ^{13}C NMR and spectra were obtained with Varian Mercury 400 BB (400 MHz) and Varian Gemini (200 MHz) instruments in $CDCl_3$ with TMS as internal standard. Coupling constants J are given in Hz. IR were obtained using a Perkin–Elmer 2000 FTIR instrument. Mass spectra (electron impact, 70 eV) were obtained on AMD 604 (AMD Intectra GmbH, Germany) instrument. HRMS were measured in the presence of perfluorokerosene as the reference compound. Column chromatography was performed using silica gel 240–400 mesh (Merck). Benzosultams **1a–d** were obtained from the corresponding *N*-alkyl-2-chloro-*N*-(methanesulfonyl)anilines following the procedure described by Bunnett.[18] Pyridosultams **1e**,**f** were prepared according to the procedure described earlier.[5]

3.1.1. 3,3-Dichloro-1-methyl-1,3-dihydro-2,1-benzisothiazole 2,2-dioxide (2a). Typical procedure. Benzosultam **1a** (2.7 mmol) and hexachloroethane (1.42 g, 6.0 mmol) in toluene (5 mL) were stirred vigorously with 50% aqueous sodium hydroxide (5 mL) and tetrabutylammonium bromide (100 mg) until the starting benzosultam disappeared (15–30 min, TLC control). Then the reaction mixture was poured into saturated aqueous solution of ammonium chloride (100 mL) and product was extracted with dichloromethane (3×20 mL). The combined extracts were dried over $MgSO_4$. After evaporation of solvent the product was recrystallized from a mixture of hexane and ethyl acetate. Colorless crystals. Mp 66–67°C. ^{1}H NMR (400 MHz): δ=3.28 (s, 3H), 6.83 (br d, J=8.2 Hz, 1H), 7.20 (ddd, J=8.2, 7.6, 1.0 Hz, 1H), 7.49 (ddd, J=8.2, 7.6, 1.4 Hz, 1H), 7.70 (ddd, J=8.2, 1.4, 0.8 Hz, 1H). ^{13}C NMR (100 MHz): δ=28.7, 88.4, 110.8, 123.9, 125.3, 126.2, 132.9, 138.1. IR (KBr) ν: 2938, 1604, 1481, 1470, 1342, 1319, 1302, 1197, 1162, 1118, 1057. MS (EI 70 eV, *m*/*z*, %): 251 (34, M^+), 216 (7), 187 (24), 153 (10), 152 (100), 133 (12), 125 (22), 117 (49), 116 (26), 105 (19). HRMS for $C_8H_7NO_2SCl_2$ calcd 250.9575, found 250.9582.

According to this procedure the following compounds were obtained.

3.1.2. 3,3-Dichloro-1-ethyl-1,3-dihydro-2,1-benzisothiazole 2,2-dioxide (2b). Colorless crystals. Mp 59–61°C. ^{1}H NMR (400 MHz): δ=1.40 (t, J=7.2 Hz, 3H), 3.81 (q, J=7.2 Hz, 2H), 6.85 (br d, J=7.8 Hz, 1H), 7.18 (ddd, J=7.8, 7.8, 1.0 Hz, 1H), 7.45 (ddd, J=7.8, 7.8, 1.4 Hz, 1H), 7.67 (ddd, J=7.8, 1.4 Hz, 1H). ^{13}C NMR (100 MHz): δ=13.4, 39.1, 88.7, 111.4, 123.7, 125.6, 126.7, 132.8, 136.9. IR (KBr) ν: 2986, 1602, 1475, 1384, 1348, 1328, 1269, 1197, 1177, 1154, 1117, 1062. MS (EI 70 eV, *m*/*z*, %): 265 (12, M^+), 230 (6), 201 (10), 186 (4), 168 (30), 166 (100), 150 (8), 138 (7), 131 (37), 125 (16), 119 (11), 102 (11). HRMS for $C_9H_9NO_2SCl_2$ calcd 264.9731, found 264.9748.

3.1.3. 3,3-Dichloro-1-isopropyl-1,3-dihydro-2,1-benzisothiazole 2,2-dioxide (2c). Colorless crystals. Mp 70–72°C. ^{1}H NMR (200 MHz): δ=1.57 (d, J=7.9 Hz, 6H), 4.40 (sept, J=7.9 Hz, 1H), 6.95 (d, J=8.2 Hz, 1H), 7.18 (ddd, J=8.4, 7.7, 0.7 Hz, 1H), 7.44 (ddd, J=8.2, 7.7, 1.3 Hz, 1H), 7.69 (dd, J=8.4, 1.3 Hz, 1H). ^{13}C NMR (50 MHz): δ=20.6, 49.9, 88.9, 113.0, 123.6, 125.7, 127.1, 132.5, 136.6. MS (EI 70 eV, *m*/*z*, %): 279 (25, M^+), 244 (4), 202 (24), 200 (25), 180 (42), 166 (100), 145 (21), 138 (16), 119 (10). HRMS for $C_{10}H_{11}NO_2SCl_2$ calcd 278.9888, found 278.9895.

3.1.4. 3,3-Dichloro-1,5-dimethyl-1,3-dihydro-2,1-benzisothiazole 2,2-dioxide (2d). Colorless crystals. Mp 94–95°C. ^{1}H NMR (200 MHz): δ=2.39 (s, 3H), 3.25 (s, 3H), 6.74 (d, J=8.2 Hz, 1H), 7.28 (dd, J=8.2, 1.8 Hz, 1H), 7.50 (br s, 1H). ^{13}C NMR (50 MHz): δ=20.9, 29.3, 88.6, 111.2, 125.5, 126.2, 133.5, 134.0, 135.9. IR (KBr) ν: 2935, 1615, 1587, 1490, 1463, 1450, 1431, 1344, 1311, 1278, 1193, 1164, 1143, 1006. MS (EI 70 eV, *m*/*z*, %): 265 (34, M^+), 230 (9), 201 (20), 166 (100), 131 (62), 130 (31), 119 (15), 118 (15), 116 (9). HRMS for $C_9H_9NO_2SCl_2$ calcd 264.9731, found 264.9741. Elemental analysis for $C_9H_9NO_2SCl_2$ calcd C 40.63, H 3.41, N 5.27, found C 40.57, H 3.48, N 5.22.

3.1.5. 3,3-Dichloro-1-methyl-1,3-dihydroisothiazolo[4,3-*b*]pyridine 2,2-dioxide (2e). Colorless crystals. Mp 111–113°C. ^{1}H NMR (200 MHz): δ=3.34 (s, 3H), 7.22 (dd, J=8.2, 1.3 Hz, 1H), 7.48 (dd, J=8.2, 4.8 Hz, 1H), 8.46 (dd, J=4.8, 1.3 Hz, 1H). MS (EI 70 eV, *m*/*z*, %): 252 (36) [M^+], 188 (28), 153 (100), 147 (18). HRMS for $C_7H_6N_2O_2SCl_2$ calcd 251.9527, found 251.9536. Elemental analysis for $C_7H_6Cl_2N_2O_2S$ (253.1): calcd C 33.22, H 2.39, N 11.07; found: C 33.42, H 2.30, N 11.12.

3.1.6. 3,3-Dichloro-1-propyl-1,3-dihydroisothiazolo[4,3-*b*]pyridine 2,2-dioxide (2f). Oil. ^{1}H NMR (400 MHz): δ=1.06 (t, J=7.3 Hz, 3H), 1.80–1.88 (m, 2H), 3.70 (t, J=7.3 Hz, 2H), 7.19 (dd, J=8.2, 1.4 Hz, 1H), 7.40 (dd, J=8.2, 4.9 Hz, 1H), 8.40 (dd, J=4.9, 1.4 Hz, 1H). ^{13}C NMR (100 MHz): δ=11.4, 21.7, 45.8, 88.0, 119.0, 127.3, 134.5, 143.4, 144.8. IR (neat) ν: 2971, 2937, 1581, 1470, 1428, 1357, 1300, 1257, 1186, 1137, 1069, 1043. MS (EI 70 eV, *m*/*z*, %): 280 (25, M^+), 245 (4), 216 (17), 187 (37), 183 (33), 181 (100), 153 (22), 145 (25), 133 (21), 126 (33), 11 (25). HRMS for $C_9H_{10}N_2O_2SCl_2$ calcd 279.9840, found 279.9845.

3.2. Addition of amines to dichloroxylylenes. General procedure

Dichlorosultam **2e–f** (0.5 mmol) and monoamine (360 mg, 4 mmol) or diamine (2 mmol) in 1,2-dichlorobenzene (5 mL) were refluxed for 15 min. The reaction mixture was cooled then poured into saturated aqueous sodium hydrogen carbonate (10 mL) and extracted with dichloromethane (2×25 mL). The combined extracts were dried with magnesium sulfate. The solvent was evaporated and the residue was subjected to column chromatography on silica gel. Dichlorobenzene was eluted with cyclohexane–ethyl acetate 20:1, and then products were separated with hexane–ethyl acetate 2:1 (in the case of pyridine derivatives cyclohexane–ethyl acetate 1:1). The following compounds were obtained.

3.2.1. *N*^{1},*N*^{2}-Diphenyl-2-[3-(methylamino)pyridyl]amidine (3). Yield 45%. Oil. ^{1}H NMR (200 MHz): δ=2.98 (s,

3H), 6.70–7.15 (m, 12H), 7.91 (dd, *J*=4.3, 1.3 Hz, 1H), 9.6 (br s, 2H). MS (EI 70 eV, *m/z*, %): 302 (91) [M^+], 227 (12), 210 (100), 107 (20), 93 (14); HRMS for $C_{19}H_{18}N_4$ calcd 302.1532, found 302.1527.

3.2.2. *N*-Methyl-2-(4,4-dimethyl-4,5-dihydro-1,3-oxazol-2-yl)aniline (7). Yield 16%. Oil. ^{1}H NMR (400 MHz): δ=1.36 (s, 6H), 2.93 (s, 3H), 3.97 (s, 2H), 6.60 (ddd, *J*=7.8, 7.2, 1.1 Hz, 1H), 6.65 (d, *J*=8.4 Hz, 1H), 7.30 (ddd, *J*=8.4, 7.2, 1.8 Hz, 1H), 7.71 (dd, *J*=7.8, 1.8 Hz, 1H), 8.25 (br s, 1H). ^{13}C NMR (100 MHz): δ=28.7, 29.5, 67.8, 77.1, 108.5, 109.7, 114.1, 129.6, 132.3, 149.8, 162.3. IR (film) ν: 3272, 2963, 2929, 1632, 1586, 1527, 1467, 1426, 1357, 1332, 1283, 1211, 1193, 1173, 1120, 1074, 1038, 965. MS (EI 70 eV, *m/z*, %): 204 (100, M^+), 189 (20), 173 (4), 160 (10), 149 (16), 147 (42), 132 (94), 131 (47), 118 (22), 105 (21). HRMS for $C_{14}H_{13}N_4O_2$ calcd 204.1263, found 204.1261.

3.2.3. 2-[2-(Methylamino)phenyl]benzimidazole (11). Light brown crystals. Mp 205–207°C, lit.[19] Mp 208–209°C. ^{1}H NMR (400 MHz): δ=3.03 (s, 3H), 6.71 (ddd, *J*=8.2, 7.2, 1.1 Hz, 1H), 6.79 (d, *J*=8.0 Hz, 1H), 7.18–7.28 (m, 4H), 7.34 (ddd, *J*=8.4, 7.2, 1.5 Hz, 1H), 7.55 (dd, *J*=7.5, 1.5 Hz, 1H), 7.8 (br s, 2H, N–H). IR (KBr) ν: 3385, 2885, 1625, 1607, 1582, 1534, 1514, 1486, 1468, 1452, 1439, 1429, 1394, 1322, 1279, 1225, 1174, 1122, 1062. MS (EI 70 eV, *m/z*, %): 223 (100, M^+), 222 (47), 221 (7), 220 (6), 207 (15), 206 (15), 205 (11), 195 (17), 194 (30), 193 (10), 131 (5), 119 (13), 112 (14). HRMS for $C_{14}H_{13}N_3$ calcd 223.1110, found 223.1109.

3.2.4. 2-[2-(Methylamino)phenyl]benzoxazole (12). Light brown crystals. Mp 80–82°C. ^{1}H NMR (400 MHz): δ=3.06 (s, 3H), 6.75 (ddd, *J*=8.1, 7.2, 1.1 Hz, 1H), 6.79 (d, *J*=8.2 Hz, 1H), 7.29–7.35 (m, 2H), 7.40 (ddd, *J*=8.6, 7.0, 1.6 Hz, 1H), 7.53–7.58 (m, 1H), 7.68–7.73 (m, 1H), 8.11 (ddd, *J*=7.8, 1.6, 0.4 Hz, 1H), 8.25 (br s, 1H). ^{13}C NMR (100 MHz): δ=29.8, 107.9, 110.2, 110.4, 114.9, 119.1, 124.2, 124.6, 128.9, 132.8, 141.7, 149.1, 149.3, 163.3. IR (KBr) ν: 3318, 2818, 1620, 1589, 1542, 1523, 1475, 1465, 1454, 1425, 1324, 1269, 1244, 1177, 1073, 1030. MS (EI 70 eV, *m/z*, %): 224 (75, M^+), 207 (9), 195 (6), 167 (4), 146 (5), 131 (7), 117 (100), 112 (6). HRMS for $C_{14}H_{12}N_2O$ calcd 224.0950, found 224.0950.

3.2.5. 2-[(2-Isopropylamino)phenyl]benzimidazole (13). Yellow crystals. Mp 130–132°C. ^{1}H NMR (400 MHz): δ=1.36 (d, *J*=6.4 Hz, 6H), 3.79 (sept, *J*=6.4 Hz, 1H), 6.67 (ddd, *J*=8.2, 7.1, 1.2 Hz, 1H), 6.70–6.73 (m, 2H), 6.80 (d, *J*=8.4 Hz, 1H), 7.29 (ddd, *J*=8.4, 7.2, 1.6 Hz, 1H), 7.23–7.27 (m, 2H), 7.54 (dd, *J*=7.9, 1.6 Hz, 1H), 7.60 (br s, 1H), 9.0 (br s, 1H). ^{13}C NMR (100 MHz): δ=22.9, 43.8, 110.5, 112.0, 114.4, 116.7, 120.3, 122.6, 126.8, 131.2, 134.7, 147.3, 152.2. IR (KBr) ν: 3385, 2978, 1626, 1607, 1582, 1503, 1475, 1450, 1432, 1401, 1368, 1322, 1272, 1248, 1221, 1176, 961, 744. MS (EI 70 eV, *m/z*, %): 251 (37, M^+), 236 (100), 221 (17), 220 (11), 194 (28), 126 (6), 111 (13). HRMS for $C_{16}H_{17}N_3$ calcd 251.1423, found 251.1421.

3.2.6. 2-[2-(Isopropylamino)phenyl]benzoxazole (14). Yellow crystals. Mp 86–87°C. ^{1}H NMR (400 MHz): δ=1.38 (d, *J*=6.4 Hz, 6H), 3.84 (sept, *J*=6.4 Hz, 1H), 6.69 (ddd, *J*=8.1, 7.1, 1.0 Hz, 1H), 6.81 (d, *J*=8.4 Hz, 1H), 7.28–7.37 (m, 3H), 7.52–7.58 (m, 1H), 7.68–7.73 (m, 1H), 8.10 (dd, *J*=7.9, 1.5 Hz, 1H), 8.30 (br s, 1H). ^{13}C NMR (100 MHz): δ=22.9, 43.7, 107.8, 110.1, 111.4, 114.5, 119.3, 124.1, 124.5, 129.2, 132.7, 141.8, 147.6, 149.1, 163.4. IR (KBr) ν: 3294, 2961, 1623, 1601, 1588, 1542, 1526, 1476, 1457, 1383, 1332, 1323, 1246, 1197, 1183, 1169, 1127, 1052, 1029, 923. MS (EI 70 eV, *m/z*, %): 252 (35, M^+), 237 (100), 222 (4), 219 (3), 210 (3), 195 (4), 145 (12), 144 (22), 130 (5), 126 (5), 111 (10). HRMS for $C_{16}H_{16}N_2O$ calcd 252.1263, found 252.1261.

3.2.7. 2-[2-(Isopropylamino)phenyl]perimidine (15). Yellow crystals. Mp 131–132°C. ^{1}H NMR (400 MHz): δ=1.30 (d, *J*=6.2 Hz, 6H), 3.70 (sept, *J*=6.2 Hz, 1H), 6.54 (br s, 1H), 6.64 (ddd, *J*=8.1, 7.1, 1.2 Hz, 1H), 6.75 (br d, *J*=8.4 Hz, 1H), 7.11–7.20 (m, 4H), 7.25–7.28 (m, 2H), 7.29 (ddd, *J*=8.4, 7.1, 1.5 Hz, 1H), 7.39 (dd, *J*=8.1, 1.5 Hz, 1H), 8.0 (br s, 1H). ^{13}C NMR (100 MHz): δ=22.8, 43.3, 112.5, 113.5, 114.6, 119.5, 119.6, 121.0, 126.1, 128.2, 128.3, 132.2, 135.3, 148.2, 153.1. IR (KBr) ν: 2964, 1634, 1613, 1598, 1574, 1522, 1457, 1406, 1372, 1337, 1273, 1242, 1177, 1163, 1132, 822, 770, 747. MS (EI 70 eV, *m/z*, %): 301 (100, M^+), 287 (22), 286 (98), 270 (11), 260 (11), 259 (59), 258 (14), 244 (77), 166 (17), 143 (18). HRMS for $C_{20}H_{19}N_3$ calcd 301.1579, found 301.1585.

3.2.8. 2-[3-(Methylamino)-2-pyridyl]benzimidazole (16). Pale yellow crystals. Mp 135–137°C. ^{1}H NMR (200 MHz): δ=3.11 (s, 3H), 7.16 (dd, *J*=8.5, 1.2 Hz, 1H), 7.24–7.39 (m, 4H), 7.80–7.85 (m, 1H), 7.99 (dd, *J*=4.4, 1.3 Hz, 1H), 8.89 (br s, 1H), 11.65 (br s, 1H). MS (EI 70 eV, *m/z*, %): 224 (100) [M^+], 223 (49), 208 (6), 195 (25), 119 (15), 69 (8). HRMS for $C_{13}H_{12}N_4$ calcd 224.1062, found 224.1051.

3.2.9. 2-[2-(3-Propylamino)pyridyl]benzoxazole (17). Light brown crystals. Mp 107–108°C. ^{1}H NMR (400 MHz): δ=1.11 (t, *J*=7.5 Hz, 3H), 1.77–1.88 (m, 2H), 3.28–3.34 (m, 2H), 7.15 (dd, *J*=8.6, 1.3 Hz, 1H), 7.27 (dd, *J*=8.6, 4.4 Hz, 1H), 7.35–7.40 (m, 2H), 7.66–7.70 (m, 1H), 7.73–7.79 (m, 1H), 8.11 (dd, *J*=4.4, 1.3 Hz, 1H), 8.41 (br s, 1H). ^{13}C NMR (100 MHz): δ=11.7, 22.4, 44.4, 111.1, 118.2, 119.6, 124.5, 125.4, 126.5, 126.6, 136.8, 141.3, 145.5, 149.6, 162.3. IR (KBr) ν: 3310, 2967, 2934, 1595, 1575, 1537, 1509, 1473, 1452, 1409, 1348, 1316, 1299, 1247, 1225, 1182, 1154, 1127, 1045. MS (EI 70 eV, *m/z*, %): 253 (100, M^+), 238 (24), 236 (40), 225 (14), 224 (86), 207 (7), 196 (35), 169 (9), 146 (21), 145 (36), 118 (4), 105 (9). HRMS for $C_{15}H_{15}N_3O$ calcd 253.1215, found 253.1216.

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