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# SYNTHESIS OF 4*H*-THIENO[3,2-*c*]CHROMENES BY INTRAMOLECULAR ARYLATION OF 4-ARYLOXY-METHYL-5-IODOTHIOPHENE-2-CARBALDEHYDES

**A. S. Fisyuk[1]*, Yu. P. Bogza[1], L. V. Belyaeva[1], and V. B. Belyaev[1]**

*The iodination of 4-chloromethylthiophene-2-carbaldehyde by N-iodosuccinimide under solvent-free conditions gives 4-chloromethyl-5-iodothiophene-2-carbaldehyde, which is used to obtain 4-aryloxy-methyl-5-iodothiophene-2-carbaldehydes. The palladium-catalyzed intramolecular cyclization of 4-aryloxymethyl-5-iodothiophene-2-carbaldehydes yields 4H-thieno[3,2-c]chromene-2-carbaldehydes.*

**Keywords:** 4-aryloxymethyl-5-iodothiophene-2-carbaldehydes, 4-chloromethyl-5-iodothiophene-2-carbaldehyde, 4*H*-thieno[3,2-*c*]chromene-2-carbaldehydes, intramolecular cyclization, palladium catalysis.

Derivatives of 4*H*-thieno[3,2-*c*]chromene are of interest due to their physiological activity. Some of these compounds act as antipyretic, anti-inflammatory, analgesic [1-2], and mucoregulatory drugs [3-5], while others possess diuretic [6] and antiparkinson action [7].

Methods involving the fusion of a thiophene ring to benzopyrans [7-12], the concurrent formation of both rings [13-16], or formation of a pyran ring [17-19] are used to construct condensed systems consisting of benzopyran and thiophene rings. A single example of a pyran ring C–C bond formation by means of the Ullmann reaction [19] is among the methods involving formation of a pyran ring. Despite the good yields of the desired products, the use of butyllithium, toxic reagents, and low temperatures reduce the value of this method for preparative purposes.

The palladium-catalyzed intramolecular arylation of π-electron-rich hetarenes and aryl halides is an efficient alternative synthesis for condensed structures [20-23], which is tolerant to functional groups and proceeds under mild conditions.

In previous work [21], we showed that 4-[(2-iodoaryloxy)methyl]thiophene-2-carbaldehydes under conditions of the Heck reaction are capable of forming a pyran ring to give the 4*H*-thieno[3,2-*c*]chromene system. 2-Formyl-4*H*-thieno[3,2-*c*]chromene derivatives hold special interest since these compounds can be readily transformed into other functional derivatives, including compounds with known biological activity [2, 4, 5]. At the same time, our method for the synthesis of 2-substituted 4*H*-thieno[3,2-*c*]chromenes [21] is limited by the availability of the starting *o*-iodophenols.

*To whom correspondence should be addressed, e-mail: fisyuk@omsu.ru.

[1]F. M. Dostoevskii Omsk State University, 55a Mira Ave., 644077 Omsk, Russia.

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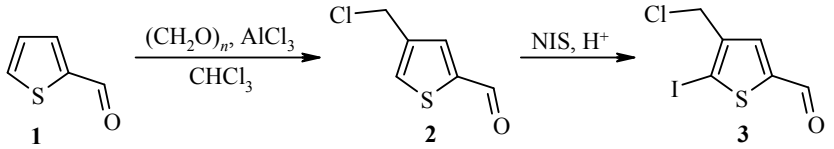
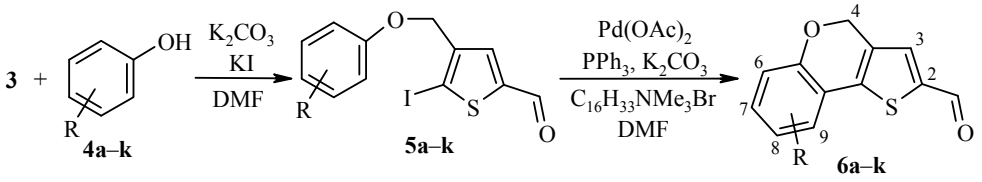
An alternative method for the preparation of 4*H*-thieno[3,2-*c*]chromene-2-carbaldehydes based on the intramolecular arylation of precursors **5**, containing an iodine atom not in the benzene ring, but rather in the thiophene ring, to date has not been carried out yet. 4-Chloromethyl-5-iodothiophene-2-carbaldehyde (**3**) may be a starting compound for the preparation of precursors **5**.

We have developed a convenient synthesis of 4-chloromethyl-5-iodothiophene-2-carbaldehyde (**3**) by the iodination of 4-chloromethylthiophene-2-carbaldehyde (**2**), which is prepared by a reported method involving the action of paraformaldehyde in the presence of excess aluminum chloride on commercially available thiophene-2-carbaldehyde (**1**) [24].




The iodination of carbaldehyde **2** was carried out using *N*-iodosuccinimide (NIS) in the presence of sulfuric, methanesulfonic, polyphosphoric (PPA), or *p*-toluenesulfonic acid under solvent-free conditions. Carbaldehyde **2** and NIS were taken in molar ratios 1.0:1.5, 1.0:1.8, and 1.0:2.0. The yields of iodocarbaldehyde **3** ranged from 20 to 80%. The best yields (70-80%) were achieved using PPA and *p*-toluene-sulfonic acid with carbaldehyde **2** and NIS in 1.0:1.5 molar ratio.




**4–6 a** R = H, **b** R = 2(6)-Me, **c** R = 4(8)-Me, **d** R = 3(7)-Me, **e** R = 2(6)-MeO, **f** R = 4(8)-MeO, **g** R = 3(7)-MeO, **h** R = 4(8)-HexO, **i** R = 2(6)-Cl, **j** R = 3(7)-Cl, **k** R = 4(8)-Cl
(the position of the substituent in product **6** is given in parentheses)

4-Aryloxymethyl-5-iodothiophene-2-carbaldehydes **5a-k** were obtained by the reaction of iodocarbaldehyde **3** with phenols **4a-k** in dry DMF in the presence of potassium carbonate at room temperature over 48 h. The yields of iodocarbaldehydes **5a-k** were 60-87% (Table 1).

The cyclization of iodocarbaldehydes **5a-k** was carried out by the action of palladium diacetate in the presence of triphenylphosphine and potassium carbonate in DMF at 110-120°C for 5-6 h. A quaternary ammonium salt, namely, hexadecyltrimethylammonium bromide was used to increase the rate of this reaction. The reaction course was monitored by thin-layer chromatography. 4*H*-Thieno[3,2-*c*]chromene-2-carbaldehydes **6a-k** were obtained in 44-85% yields (Table 1). The structures of all the products were supported by elemental analysis (Table 1), mass spectrometry, $^{1}$H and $^{13}$C NMR spectroscopy, and IR spectroscopy (Table 2). The spectral parameters for chromenecarbaldehydes **6b**,**d-j** are in accord with the literature data for products **6a**,**c**,**k** previously prepared by a different method [21].

Thus, we have found a synthesis method for previously unreported 4-chloromethyl-5-iodothiophene-2-carbaldehyde by the means of iodination of the available 4-chloromethylthiophene-2-carbaldehyde using *N*-iodosuccinimide under solvent-free conditions. An efficient synthesis method was developed for 2-substituted 4*H*-thieno[3,2-*c*]chromenes using the intramolecular palladium-catalyzed cyclization of 4-aryl-oxymethyl-5-iodothiophene-2-carbaldehydes.

TABLE 1. Physicochemical Characteristics of Compounds **5a-k** and **6a-k**

| Compound | Empirical formula | Found, % / Calculated, % | | Mp, °C (EtOH) | Yield, % |
|---|---|---|---|---|---|
| | | C | H | | |
| **5a** | $C_{12}H_9IO_2S$ | 41.78 / 41.88 | 2.60 / 2.64 | 85-86 | 65 |
| **5b** | $C_{13}H_{11}IO_2S$ | 43.51 / 43.59 | 3.14 / 3.10 | 110-111 | 66 |
| **5c** | $C_{13}H_{11}IO_2S$ | 43.48 / 43.59 | 3.03 / 3.10 | 101-103 | 67 |
| **5d** | $C_{13}H_{11}IO_2S$ | 43.53 / 43.59 | 3.05 / 3.10 | Oil | 70 |
| **5e** | $C_{13}H_{11}IO_3S$ | 41.66 / 41.73 | 2.92 / 2.96 | 68-69 | 78 |
| **5f** | $C_{13}H_{11}IO_3S$ | 41.60 / 41.73 | 2.89 / 2.96 | 78-79 | 64 |
| **5g** | $C_{13}H_{11}IO_3S$ | 41.62 / 41.73 | 3.01 / 2.96 | 51-52 | 60 |
| **5h** | $C_{18}H_{21}IO_3S$ | 48.73 / 48.66 | 4.80 / 4.76 | 65-66 | 73 |
| **5i** | $C_{12}H_8ClIO_2S$ | 37.94 / 38.07 | 2.08 / 2.13 | 114-115 | 76 |
| **5j** | $C_{12}H_8ClIO_2S$ | 37.97 / 38.07 | 2.10 / 2.13 | 55-57 | 87 |
| **5k** | $C_{12}H_8ClIO_2S$ | 38.01 / 38.07 | 2.16 / 2.13 | 98-100 | 72 |
| **6a** | $C_{12}H_8O_2S$ | 66.58 / 66.65 | 3.69 / 3.73 | 114-115 (113 (EtOH) [21]) | 85 |
| **6b** | $C_{13}H_{10}O_2S$ | 67.75 / 67.80 | 4.42 / 4.38 | 132-134 | 61 |
| **6c** | $C_{13}H_{10}O_2S$ | 67.68 / 67.80 | 4.32 / 4.38 | 136-138 (136 (EtOH) [21]) | 62 |
| **6d** | $C_{13}H_{10}O_2S$ | 67.72 / 67.80 | 4.35 / 4.38 | 135-137 | 55 |
| **6e** | $C_{13}H_{10}O_3S$ | 63.22 / 63.40 | 4.02 / 4.09 | 134-136 | 65 |
| **6f** | $C_{13}H_{10}O_3S$ | 63.31 / 63.40 | 4.05 / 4.09 | 104-105 | 82 |
| **6g** | $C_{13}H_{10}O_3S$ | 63.28 / 63.40 | 4.12 / 4.09 | Oil | 54 |
| **6h** | $C_{18}H_{20}O_3S$ | 68.58 / 68.33 | 6.43 / 6.37 | 70-71 | 83 |
| **6i** | $C_{12}H_7ClO_2S$ | 57.38 / 57.49 | 2.75 / 2.81 | 187-189 | 74 |
| **6j** | $C_{12}H_7ClO_2S$ | 57.32 / 57.49 | 2.74 / 2.81 | 191-193 | 44 |
| **6k** | $C_{12}H_7ClO_2S$ | 57.58 / 57.49 | 2.83 / 2.81 | 191-193 (192 (EtOH) [21]) | 75 |

## EXPERIMENTAL

The IR spectra were recorded on an Infralum FT-801 spectrometer in KBr pellets. The $^1H$ and $^{13}C$ NMR spectra were recorded on a Bruker DRX 400 spectrometer (400 and 100 MHz, respectively), in $CDCl_3$ with TMS as internal standard. The mass spectra were recorded on an Agilent 6890N mass spectrometer. The ionizing electron energy was 70 eV, and the injector temperature was 230-250°C. The elemental analysis was carried out on a Carlo Erba 1106 CHN analyzer. The melting points were determined on a Kofler bench. The reaction course and purity of the products were checked by thin-layer chromatography on Sorbfil UV-254 plates with chloroform as the eluent. The plates were visualized with iodine vapor or UV light.

TABLE 2. Spectral Characteristics of Compounds Synthesized **5a–k** and **6a–k**

| Compound | Mass spectrum, *m/z* ($I_{rel.}$, %) | IR spectrum, ν, $cm^{-1}$ (C=O) | $^1$H NMR spectrum ($CDCl_3$), δ, ppm (*J*, Hz) | $^{13}$C NMR spectrum ($CDCl_3$), δ, ppm |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| **5a** | 344 $[M]^+$ (4) | 1667 | 4.97 (2H, s, $CH_2$); 6.94-7.04 (3H, m, H Ph); 7.29-7.36 (2H, m, H Ph); 7.61 (1H, s, H-3); 9.78 (1H, s, CHO) | 67.0 ($CH_2$); 88.5 (C-5); 114.8, 121.6, 129.6 (C Ph); 135.8 (C-3); 143.5 (C-2); 148.6 (C-4); 158.0 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5b** | 358 $[M]^+$ (8) | 1651 | 2.28 (3H, s, $CH_3$); 4.96 (2H, s, $CH_2$); 6.84-6.95 (2H, m, H Ar); 7.14-7.21 (2H, m, H Ar); 7.60 (1H, s, H-3); 9.79 (1H, s, CHO) | 16.4 ($CH_3$); 67.2 ($CH_2$); 88.1 (C-5); 111.4, 121.3, 126.9, 127.1, 131.0 (C Ar); 35.7 (C-3); 144.0 (C-2); 148.6 (C-4); 156.1 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5c** | 358 $[M]^+$ (11) | 1651 | 2.30 (3H, s, $CH_3$); 4.94 (2H, s, $CH_2$); 6.84-6.88 (2H, m, H Ar); 7.09-7.13 (2H, m, H Ar); 7.59 (1H, s, H-3); 9.77 (1H, s, CHO) | 20.5 ($CH_3$); 67.2 ($CH_2$); 88.4 (C-5); 114.7, 130.1, 130.9 (C Ar); 136.0 (C-3); 143.9 (C-2); 148.6 (C-4); 155.9 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5d** | 358 $[M]^+$ (4) | 1668* | 2.35 (3H, s, $CH_3$); 4.94 (2H, s, $CH_2$); 6.74-6.84 (3H, m, H Ar); 7.19 (1H, t, $^3J$ = 7.8, H Ar); 7.60 (1H, s, H-3); 9.77 (1H, s, CHO) | 21.5 ($CH_3$); 66.9 ($CH_2$); 88.5 (C-5); 111.6, 115.7, 122.4, 129.4, 139.8 (C Ar); 135.9 (C-3); 143.8 (C-2); 148.6 (C-4); 158.1 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5e** | 374 $[M]^+$ (13) | 1669 | 3.89 (3H, s, $OCH_3$); 5.03 (2H, s, $CH_2$); 6.86-7.04 (4H, m, H Ar); 7.64 (1H, s, H-3); 9.76 (1H, s, CHO) | 55.9 ($CH_3$); 68.5 ($CH_2$); 88.4 (C-5); 112.1, 115.0, 120.9, 122.5 (C Ar); 136.1 (C-3); 144.0 (C-2); 147.4 (C–$OCH_3$); 148.6 (C-4); 150.0 (C–$OCH_2$ Ar); 181.5 (CHO) |
| **5f** | 374 $[M]^+$ (19) | 1644 | 3.78 (3H, s, $OCH_3$); 4.91 (2H, s, $CH_2$); 6.83-6.96 (4H, m, H Ar); 7.60 (1H, s, H-3); 9.77 (1H, s, CHO) | 55.7 ($CH_3$); 67.8 ($CH_2$); 88.6 (C-5); 114.8, 116.0 (C Ar); 135.9 (C-3); 143.9 (C-2); 148.6 (C-4); 152.1 (C–$OCH_3$); 154.5 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5g** | 374 $[M]^+$ (8) | 1646 | 3.80 (3H, s, $OCH_3$); 4.95 (2H, s, $CH_2$); 6.45-6.60 (3H, m, H Ar); 7.17-7.25 (1H, m, H Ar); 7.60 (1H, s, H-3); 9.78 (1H, s, CHO) | 55.4 ($CH_3$); 67.1 ($CH_2$); 88.6 (C-5); 101.5, 106.9, 107.1, 130.1 (C Ar); 135.8 (C-3); 143.6 (C-2); 148.7 (C-4); 159.3 (C–$OCH_3$); 161.0 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5h** | 444 $[M]^+$ (19) | 1644 | 0.85-0.99 (3H, m, $CH_3$); 1.25-1.54 (6H, m, $3CH_2$); 1.71-1.81 (2H, m, $CH_2$); 3.92 (2H, t, $^3J$ = 6.6, $OC\underline{H}_2CH_2$); 4.92 (2H, s, $CH_2$); 6.83-6.92 (4H, m, H Ar); 7.60 (1H, s, H-3); 9.78 (1H, s, CHO) | 14.3 ($CH_3$); 22.6 ($CH_2$); 25.7 ($CH_2$); 29.3 ($CH_2$); 31.6 ($CH_2$); 67.8 ($CH_2$); 68.6 ($CH_2$); 88.5 (C-5); 115.5, 115.9 (C Ar); 135.9 (C-3); 144.0 (C-2); 148.6 (C-4); 152.0 (C–$OC_6H_{13}$); 154.0 (C–$OCH_2$ Ar); 181.4 (CHO) |
| **5i** | 378 $[M]^+$ (4) | 1656 | 5.03 (2H, s, $CH_2$); 6.94-6.99 (2H, m, H Ar); 7.21-7.26 (1H, m, H Ar); 7.41 (1H, dd, $^3J$ = 8.2, $^4J$ = 1.6, H Ar); 7.68 (1H, s, H-3); 9.80 (1H, s, CHO) | 68.2 ($CH_2$); 88.1 (C-5); 114.2, 122.5, 123.4, 127.8, 130.6 (C Ar); 135.8 (C-3); 143.2 (C-2); 148.7 (C-4); 153.4 (C–$OCH_2$ Ar); 182.1 (CHO) |
| **5j** | 378 $[M]^+$ (2) | 1668 | 4.94 (2H, s, $CH_2$); 6.82-6.88 (1H, m, H Ar); 6.96-7.04 (2H, m, H Ar); 7.20-7.27 (1H, m, H Ar); 7.59 (1H, s, H-3); 9.78 (1H, s, CHO) | 67.2 ($CH_2$); 89.0 (C-5); 113.2, 115.4, 121.8, 130.5, 135.1 (C Ar); 135.7 (C-3); 143.0 (C-2); 148.8 (C-4); 158.8 (C–$OCH_2$ Ar); 181.4 (CHO) |

TABLE 2 (continued)

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| **5k** | 378 $[M]^+$ (6) | 1659 | 4.94 (2H, s, $CH_2$); 6.87-6.92 (2H, m, H Ar); 7.24-7.30 (2H, m, H Ar); 7.58 (1H, s, H-3); 9.78 (1H, s, CHO) | 67.3 ($CH_2$); 88.8 (C-5); 116.1, 126.5, 129.5 (C Ar); 135.6 (C-3); 143.1 (C-2); 148.7 (C-4); 156.6 (C–$OCH_2$ Ar); 181.3 (CHO) |
| **6b** | 229 $[M–H]^+$ (100) | 1650 | 2.24 (3H, s, $CH_3$); 5.28 (2H, s, 4-$CH_2$); 6.89 (1H, t, $^3J$ = 7.6, H-8); 7.09-7.14 (1H, m, H-7); 7.23-7.27 (1H, m, H-9); 7.48 (1H, s, H-3); 9.84 (1H, s, CHO) | 15.9 ($CH_3$); 65.5 (C-4); 118.5 (C-9a); 121.7 (C-9); 121.8 (C-8); 126.7 (C-6); 131.9 (C-9b); 132.7 (C-7); 132.9 (C-3); 141.7 (C-3a); 143.1 (C-2); 151.2 (C-5a); 182.3 (CHO) |
| **6d** | 229 $[M–H]^+$ (100) | 1650 | 2.32 (3H, s, $CH_3$); 5.24 (2H, s, 4-$CH_2$); 6.76-6.78 (1H, m, H-6); 6.79-6.82 (1H, m, H-8); 7.27 (1H, d, $^3J$ = 7.7, H-9); 7.45 (1H, s, H-3); 9.83 (1H, s, CHO) | 21.6 ($CH_3$); 65.6 (C-4); 116.4 (C-9a); 117.5 (C-6); 123.2 (C-8); 123.9 (C-9); 131.3 (C-9b); 133.0 (C-3); 141.2 (C-3a); 142.2 (C-7); 142.9 (C-2); 153.0 (C-5a); 182.2 (CHO) |
| **6e** | 245 $[M–H]^+$ (100) | 1657 | 3.91 (3H, s, $OCH_3$); 5.35 (2H, s, 4-$CH_2$); 6.88-6.92 (1H, m, H-7); 6.96 (1H, t, $^3J$ = 7.9, H-8); 7.02-7.06 (1H, m, H-9); 7.50 (1H, s, H-3); 9.86 (1H, s, CHO) | 56.2 ($CH_3$); 66.0 (C-4); 113.6 (C-7); 116.2 (C-9); 119.8 (C-9a); 122.2 (C-8); 132.0 (C-9b); 132.8 (C-3); 142.1 (C-3a); 142.4 (C-2); 148.8 (C-5a); 154.1 (C-6); 182.3 (CHO) |
| **6f** | 245 $[M–H]^+$ (100) | 1661 | 3.81 (3H, s, $OCH_3$); 5.21 (2H, s, 4-$CH_2$); 6.80-6.92 (3H, m, H-6,7,9); 7.48 (1H, s, H-3); 9.85 (1H, s, CHO) | 55.8 ($CH_3$); 65.6 (C-4); 108.4 (C-9); 117.3 (C-7); 118.0 (C-6); 119.7 (C-9a); 132.7 (C-9b); 132.8 (C-3); 142.0 (C-3a); 142.6 (C-2); 147.2 (C-5a); 154.8 (C-8); 182.3 (CHO) |
| **6g** | 245 $[M–H]^+$ (100) | 1673* | 3.79 (3H, s, $OCH_3$); 5.06 (2H, s, 4-$CH_2$); 6.53-6.58 (2H, m, H-6,8); 7.21 (1H, d, $^3J$ = 8.2, H-9); 7.81 (1H, s, H-3); 9.92 (1H, s, CHO) | — |
| **6h** | 316 $[M]^+$ (47) | 1647 | 0.92 (3H, m, $CH_3$); 1.31-1.38 (4H, m, 2$CH_2$); 1.42-1.52 (2H, m, $CH_2$); 1.73-1.83 (2H, m, $CH_2$); 3.94 (2H, t, $^3J$ = 6.5, O$\underline{C}H_2CH_2$); 5.21 (2H, s, 4-$CH_2$); 6.80-6.84 (1H, m, H-9); 6.87-6.92 (2H, m, H-6,7); 7.49 (1H, s, H-3); 9.85 (1H, s, CHO) | 14.0 ($CH_3$); 22.6 ($CH_2$); 25.7 ($CH_2$); 29.3 ($CH_2$); 31.6 ($CH_2$); 65.6 (C-4); 68.8 ($CH_2$); 109.2 (C-9); 117.8 (C-7); 117.9 (C-6); 119.6 (C-9a); 132.7 (C-9b); 132.8 (C-3); 141.9 (C-3a); 142.7 (C-2); 147.1 (C-5a); 154.4 (C-8); 182.3 (CHO) |
| **6i** | 249 $[M–H]^+$ (100) | 1657 | 5.41 (2H, s, 4-$CH_2$); 6.94 (1H, t, $^3J$ = 7.9, H-8); 7.29-7.34 (2H, m, H-7,9); 7.51 (1H, s, H-3); 9.87 (1H, s, CHO) | 66.3 (C-4); 120.5 (C-9a); 122.5 (C-9); 122.6 (C-8); 131.6 (C-7); 132.2 (C-9b); 132.6 (C-3); 138.8 (C-6); 141.3 (C-3a); 142.8 (C-2); 148.9 (C-5a); 182.3 (CHO) |
| **6j** | 249 $[M–H]^+$ (100) | 1678 | 5.30 (2H, s, 4-$CH_2$); 6.95-7.00 (2H, m, H-6,8); 7.30-7.35 (1H, m, H-9); 7.48 (1H, s, H-3); 9.86 (1H, s, CHO) | 65.9 (C-4); 117.6 (C-6); 117.7 (C-9a); 122.7 (C-8); 124.8 (C-9); 131.8 (C-9b); 132.7 (C-3); 136.4 (C-7); 141.3 (C-3a); 142.2 (C-2); 153.7 (C-5a); 182.2 (CHO) |

* IR spectra of compounds **5d** and **6g** recorded in $CHCl_3$ solution.

**4-Chloromethyl-5-iodothiophene-2-carbaldehyde (3).** 4-Chloromethylthiophene-2-carbaldehyde (0.300 g, 1.87 mmol) was added to finely ground *N*-iodosuccinimide (0.632 g, 2.80 mmol), and the mixture was thoroughly ground. Then, one or two drops of PPA were added. The mixture was again ground and left for 48 h in the dark. Then, water (20 ml) was added, and the mixture was extracted with $CHCl_3$ (3×15 ml). The extract was washed with saturated aqueous sodium sulfite, then water and dried over anhydrous magnesium sulfate. The solvent was distilled off in vacuum, and the residue was recrystallized from hexane. Yield 0.407 g (76%); mp 88-89°C. IR spectrum, ν, $cm^{-1}$: 1650 (C=O). $^1H$ NMR spectrum, δ, ppm (*J*, Hz): 4.54 (2H, s, $CH_2$); 7.60 (1H, s, H-3); 9.79 (1H, s, CHO). $^{13}C$ NMR spectrum, δ, ppm: 41.8 ($CH_2$); 91.0 (C-5); 135.8 (C-3); 143.6 (C-2); 148.7 (C-4); 181.13 (CHO). Mass spectrum, *m/z* ($I_{rel}$, %): 285.9 $[M-H]^+$ (42); 252.9 (5); 251.9 (8); 250.9 (100); 96.0 (12); 95.0 (10); 70.0 (7); 69.0 (11). Found, %: C 25.04; H 1.37. $C_6H_4ClIOS$. Calculated, %: C 25.15; H 1.41.

**4-(Aryloxymethyl-5-iodothiophene-2-carbaldehydes 5a-k (General Method)**. A mixture of 4-chloromethyl-5-iodothiophene-2-carbaldehyde (**3**) (0.287 g, 1.0 mmol), the corresponding phenol (1.1 mmol), $K_2CO_3$ (0.138 g, 1.0 mmol), and potassium iodide (0.017 g, 0.1 mmol) in anhydrous DMF (1 ml) was stirred for 24-48 h until the starting compounds disappeared. The reaction mixture was poured into cold water (25-30 ml). The crystalline products were filtered off, while the oily products were extracted with ether. The extract was washed with water and dried over anhydrous magnesium sulfate. The solvent was distilled off in vacuum, and the reaction product was recrystallized from ethanol.

**4*H*-Thieno[3,2-*c*]chromenes 6a-k (General Method)**. A suspension of $K_2CO_3$ (0.502 g, 3.60 mmol) and hexadecyltrimethylammonium bromide (0.531 g, 1.41 mmol) was prepared in anhydrous DMF (5 ml) and stirred for 20 min under an inert atmosphere. Then, $PPh_3$ (0.038 g, 0.15 mmol), compound **5a-k** (1.40 mmol), and $Pd(OAc)_2$ (0.024 g, 0.10 mmol) were added consecutively. The reaction mixture was heated under an inert atmosphere for 5-6 h at 110-120°C until the starting compound disappeared. After cooling, the mixture was poured into water (30 ml) and extracted with ether (3×15 ml). The extract was filtered to remove solid particles. The organic phase was washed with saturated aqueous sodium chloride (2×10 ml) and dried over anhydrous magnesium sulfate. The solvent was distilled off in vacuum. The crude product was purified by flash chromatography on silica gel (0.035-0.070 mm) with 1:1 chloroform–hexane as the eluent. The product was recrystallized from ethanol. The physicochemical and spectral data for compounds **6a**,**c**,**k** corresponded to the literature values [21].

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