New method for preparation of 2,3- and 3,4-thiophenedicarboxylic acids and their 4,5- and 2,5-dihydro analogues

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A method new for preparation of 2,3-thiophenedicarboxylic acid and modified for preparation of 3,4-thiophenedicarboxylic acid using the same starting compounds, i.e. methyl thioglycolate and ethyl acrylate, and including selective preparation of methyl 3-oxotetrahydrothiophene-2-carboxylate and methyl 4-oxotetrahydrothiophene-3-carboxylate from methyl 3-thiaadipate has been described. The method can be used also for preparation of the respective dihydro analogues of these acids.

2,3-Thiophenedicarboxylic acid was prepared by many-step synthesis from difficultly attainable and expensive 3-methylthiophene [1—9] or 2,3-dibromo-thiophene [9—13] giving usually low yields. In 1977 a procedure starting from attainable methyl thioglycolate and dimethyl fumarate affording total 24 % yield was published [14].

3,4-Thiophenedicarboxylic acid was prepared for the first time in 1954 from 3,4-diiodothiophene [5]. However, this synthesis has not been practicable because of low yields. In 1968 Takaya et al. [15, 16] described a relatively advantageous and practicable synthesis of 3,4-thiophenedicarboxylic acid from ethyl thioglycolate and ethyl acrylate with a total 26 % yield. Recently, this acid has been prepared also in two independent ways from 3,4-dibromothiophene [9, 17].

We have prepared 2,3-thiophenedicarboxylic acid (XIV, Scheme 1) by a similar procedure as described by Takaya et al. [15, 16] for preparation of 3,4-thiophenedicarboxylic acid. The starting compounds in this reaction were methyl...
or ethyl thioglycolate (I) and methyl or ethyl acrylate (II). These, under catalysis of piperidine, afforded dimethyl, diethyl, and methyl ethyl 3-thiaadipate, respectively (alkoxycarbonylmethyl alkoxycarbonylethyl sulfide) (III) in quanti-
tative yield. This may give by Dieckmann cyclization two isomeric products, i.e. methyl (ethyl) 3-oxo-2-tetrahydrothiophenecarboxylate (IV) and methyl (ethyl) 4-oxo-3-tetrahydrothiophenecarboxylate (V). Much attention has been devoted to

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\text{HSCH}_2\text{COOR}^1 + \text{CH}_2=\text{CH-COOR}^2 \\
\overset{I}{\longrightarrow} \\
\text{R}^1\text{OOCC} \equiv \text{S-CH}_2\text{CH}_2\text{COOR}^2 \\
\text{IIIa: } R^1 = R^2 = \text{CH}_3 \\
\text{IIIb: } R^1 = \text{CH}_3 \\
\quad R^2 = \text{C}_2\text{H}_5 \\
\text{IIIc: } R^1 = R^2 = \text{C}_2\text{H}_5 \\
\]

Scheme 1

preferential formation of one of these isomers in dependence on reaction conditions, however, this problem has not been solved satisfactorily so far [18—26]. Hromatka et al. [23] studied the mechanism of this cyclization in detail and explained the relative proportions of the isomers IV and V in the reaction mixture by operation of a kinetically and thermodynamically controlled reaction. On the basis of this recognition they worked out a method for preparation of the 3,4-isomer (V) which, later, has been perfected by simple removal of the accompanying small portion of the 2,3-isomer (IV) [27]. In spite of many attempts, the Dieckmann reaction of III has not led to formation of the isomer IV as the dominant oxo ester. Since successful preparation of 2,3-thiophenedicarboxylic acid from the starting compounds I and II depended on preparation of the kinetically controlled 2,3-isomer (IV), it was necessary to lead the reaction so that preferably the anion of alkoxycarbonylmethyl group reacted with the carbonyl carbon of the second alkoxycarbonyl group. We have found that when in the Dieckmann reaction dimethyl 3-thiaadipate (IIIa, R¹ = R² = CH₃) was used and the reaction was performed at 0 °C under catalysis of sodium methoxide in methanol, the isomer IV dominated in the product obtained in 66 %. Thus, the proportion (%) of IV was higher than in the case when the reaction was catalyzed by sodium, sodium amide, etc. It was even more advantageous to start from methoxycarboxylmethyl ethoxycarbonylmethyl sulfide (IIIb, R¹ = CH₃, R² = C₂H₅), prepared from methyl thioglycolate and ethyl acrylate. In this case we obtained 85 % yield, where the compound V was present in less than 8 %. The spectral data indicated that the distillation product contained only negligible amount of ethyl esters (< 3 %) of the respective isomers. Similarly, when using ethoxycarboxylmethyl ethoxycarbonylmethyl sulfide (IIIc, R¹ = R² = C₂H₅), we achieved 85 % yield, however, the content of ethyl esters of the isomers increased to 15 %. At the same conditions but elevated temperature under reflux in methanol we obtained 50—55 % yield of the product V practically in pure state. It is of interest that on crystallization from methanol a pure enol form was obtained (see Experimental, ¹H NMR spectra of the compound V), though the literature [26, 27] reported a mixture of oxo-enol forms.

By the reaction of methyl 3-oxo-2-tetrahydrothiophenecarboxylate (IV) and methyl 4-oxo-3-tetrahydrothiophenecarboxylate with HCN the respective cyano-hydridines were formed in quantitative yield. These were subjected to direct dehydration with POCl₃ in pyridine. The formed methyl esters of 3-cyano-4,5-dihydrothiophene-2-carboxylic acid (VI) and 4-cyano-2,5-dihydrothiophene-3-carboxylic acid (VII) were subjected to aromatization. Aromatization of VII with sulfuryl chloride in dichloromethane at 0 °C proceeded quantitatively under formation of methyl 4-cyano-3-thiophenecarboxylate (XIII). With the compound VI, under the same conditions, addition of chlorine proceeded and the resulting product was methyl 2,3-dichloro-3-cyanotetrahydrothio-
phene-2-carboxylate (XI). Therefore, aromatization was carried out with N-bromosuccinimide in which case HBr was eliminated from the substitution product immediately to give methyl 3-cyano-2-thiophencarboxylate (XII) in 92 % yield. Similar yield can be obtained by aromatization with bromine. Hydrolysis of methyl 3-cyano-2-thiophencarboxylate (XII) and 4-cyano-3-thiophencarboxylate (XIII) afforded the expected 2,3-thiophenedicarboxylic acid (XIV) and 3,4-thiophenedicarboxylic acid, respectively. Similar hydrolysis of 3-cyano-4,5-dihydrothiophene-2-carboxylic acid (VI) was unsuccessful because it stopped at the formation of 3-carbamoyl-4,5-dihydrothiophene-2-carboxylic acid (X) which precipitated from the solution. Alkali hydrolysis of both X and VI gave 4,5-dihydrothiophene-2,3-dicarboxylic acid. On the other hand, acid hydrolysis of VII and IX proceeded smoothly (Scheme 1).

In the procedure presented above, the total yield of XIV with regard to the starting methyl thioglycolate represented 40 %. This is more than those obtained by the methods described in the literature, except Ref. [9] (46 %) where the disadvantageous 3-methylthiophene was used as the starting compound and the procedure was much more complicated.

**Experimental**

Melting points were measured on a Kofler block. Infrared spectra were measured with a Perkin—Elmer 180 spectrophotometer (calibrated with a polystyrene foil), ¹H NMR spectra with a Tesla 487 apparatus at 80 MHz (chemical shifts expressed in δ values), and ¹³C NMR spectra with a Jeol FX-100 spectrometer at 25 MHz.

Methyl thioglycolate was prepared by esterification of thioglycolic acid according to [28]. Methyl and ethyl acrylates were used as commercial products without purification. Dimethyl 3-thiaadipate (IIIa) was prepared according to [18] with 95 % yield. Diethyl 3-thiaadipate (IIIc) was prepared according to [21]. When ethyl acrylate was used in 5 % excess only with regard to HSCH₂COOEt, the yield obtained was 94 %.

**Methyl 3-thiaadipate (IIIb)**

To the solution of HSCH₂COOCH₃ (159 g; 1.50 mol) and piperidine (1.5 cm³) ethyl acrylate (160 g; 1.60 mol) was added dropwise with stirring at 30—40 °C within a period of 45 min. After 10 min and 20 min further portions of piperidine were added (2 × 1.5 cm³). The reaction mixture was allowed to stand at room temperature for 20 h, washed with water (50 cm³), dried (Na₂SO₄), and distilled at 147—148 °C and 1.73 kPa. Yield of the colourless oil = 303 g (98 %). When the reaction time was shortened to 1 h, the yield was only 80 %.

For C₅H₁₀O₂S (M₁ = 206.0) w₁(calcd): 46.60 % C, 6.80 % H, 15.56 % S; w₁(found): 46.71 % C, 6.77 % H, 15.72 % S. ¹H NMR (CDCl₃, TMS) δ/ppm: 1.25 (t, 3H, CH₃), 2.33—3.10 (m, 4H, SCH₂CH₂—), 3.26 (s, 2H, —CH₂S—), 3.75 (s, 3H, COOCH₃), 4.16 (q, 2H, CH₂).
Methyl 3-oxotetrahydrothiophene-2-carboxylate (IV)

Sodium (17.3 g; 0.75 mol) was dissolved in absolute methanol (200 cm³) at cooling, the solution was cooled to 0 °C and IIIb (103 g; 0.50 mol) was added dropwise with stirring during 1 h. At first a white suspension was formed which after 45 min turned into a transparent and colourless solution. Stirring was continued at 0 °C for 5 h and the solution was set aside in a refrigerator overnight. The reaction mixture was poured into a mixture of ice (500 g) and concentrated HCl (125 cm³). The precipitated light-yellow oil was separated, the water layer was extracted with CH₂Cl₂ or CHCl₃ (3 × 200 cm³), the oil was dissolved in the combined extracts and washed with water (2 × 300 cm³), dried (Na₂SO₄), and distilled at 122—124 °C and 2.40 kPa or 80—82 °C at 0.27 kPa. Yield of the colourless oil = 68.2 g (85 %), n(D, 18 °C) = 1.5008. Prolonged reaction time (three days) has not led to increased yield. In the analogous reaction with IIIc the yield obtained was 85 % and with IIIa only 66 %.

For C₆H₅NO₂S (Mr = 160.0) w(calc.): 44.98 % C, 5.00 % H, 20.03 % S; w(found): 44.76 % C, 5.28 % H, 19.75 % S. ¹H NMR (CCl₄, TMS) δ/ppm: 3.89 (s, 0.9H, —CH), 3.75, 3.73 (both s, totally 3H, —CH₃), 2.50—3.65 (m, 4H). ¹³C NMR (CCl₄, TMS) δ/ppm: oxo form 207.1 (CO), 169.1 (CO, OCH₃), 53.0 (CH₃), 51.9 (—CH), 38.8, 25.5 (CH₂). IR (CCl₄) ν/cm⁻¹: ν(C=O) 1759.5, 1734.

The reaction performed in ethanol instead of methanol has not led to success. At first, it was necessary to use by a half amount more ethanol so that the ethanolate solution was transparent at 0 °C. However, immediately after addition of the sulfide a white-yellow precipitate was formed. The usual isolation procedure afforded only 11 % of the desired ethyl 3-oxotetrahydrothiophene-2-carboxylate.

Methyl 3-cyano-4,5-dihydrothiophene-2-carboxylate (VI)

To liquid HCN (19 cm³) and 50 % KOH (0.10 cm³) cooled in an ice bath the solution of IV (35.5 g; 0.22 mol) in methanol (12 cm³) was added dropwise, keeping the temperature at 10—20 °C. After 15 h standing at 0—5 °C, the mixture was acidified with 85 % H₃PO₄ (0.7 cm³) and evaporated to dryness in vacuo (HCN was captured in a U tube filled with KOH). Crude yellow-red cyanohydrine was obtained in 98—100 % yields. This was dissolved directly in benzene (60 cm³) and dried with Na₂SO₄. Sodium sulfate was washed with benzene (50 cm³), the solution of cyanohydrine was diluted with dry pyridine (110 cm³) and POCl₃ (47 cm³) was added dropwise at occasional cooling with water. The temperature was kept at 40—45 °C till the reaction turned exothermic. The mixture was set aside for 6 h and then poured into a mixture of concentrated HCl (150 cm³) and ice (300 g). The organic layer was washed successively with diluted HCl (250 cm³), 3 % NaOH (250 cm³), and diluted HOAc (250 cm³, volume ratio α = 1 : 15) and distilled at 120—124 °C and 0.13 kPa. Yield of the crude product = 29.6 g (80 %). Recrystallization from the mixture ether—petroleum ether afforded 25.3 g (68 %) of white crystals with m.p. = 53.5—54 °C.

For C₇H₇NOS (Mr = 168.0) w(calc.): 49.69 % C, 4.14 % H, 8.28 % N, 18.96 % S; w(found): 50.07 % C, 4.11 % H, 8.20 % N, 18.83 % S. ¹H NMR (CDCl₃, TMS) δ/ppm: 3.00—3.58 (m, 4H, CH₂—CH₃), 3.90 (s, 3H, CH₃). IR (CHCl₃) ν/cm⁻¹: ν(C=O) 1732, ν(C=C) 1589, ν(C≡N) 2195.
Since it was not necessary to use anhydrous HCN in this reaction, its preparation was simplified considerably: 50 % (by volume) H₂SO₄ was added dropwise to KCN crystals, the vapours evolved were led to a vertical cooled spiral tube and the liquid was collected in an ice-cooled cylinder (yield about 70 %).

**Methyl 3-cyanothiophene-2-carboxylate (XII)**

*a) Using N-bromosuccinimide*

The compound VI (16.90 g; 0.1 mol) was dissolved in absolute CCl₄ (250 cm³) at heating and the solution was allowed to cool down to 30 °C. N-Bromosuccinimide (17.8 g; 0.1 mol) and azo-bis-isobutyronitrile (0.20 g) were added and the mixture was heated to the oil bath temperature 75 °C to start a vigorous reaction. The evolved HBr was led into water and the progress of the reaction was controlled by rate of bubbling. When the reaction was too vigorous, heating was stopped but only for a while so that the reaction continued. After 30 min the mixture was heated to the oil bath temperature 105 °C and the mixture was allowed to react for further 30 min. Then succinimide, being on the surface, was filtered off, and washed with hot CCl₄ (100 cm³). The filtrate was evaporated to 250 cm³, allowed to cool down slowly, and set aside in a refrigerator for 1 h. After filtration a white powdery compound (14.40 g) of m.p. = 101—103 °C was obtained. Crystallization from the mixture benzene—heptane (α = 2 : 1) gave 15.30 g (92 %) of compound of m.p. = 104—105 °C.

For C₇H₅NO₂S (Mᵣ = 167.0) w(calc): 50.28 % C, 2.99 % H, 8.38 % N, 19.19 % S; w(found): 49.75 % C, 2.90 % H, 8.48 % N, 18.55 % S. 'H NMR (CDCl₃, TMS) δ/ppm: 4.00 (s, 3H, CH₃), 7.38 (d, 1H), 7.66 (d, 1H). IR (CHCl₃) v/cm⁻¹: ν(C=O) 1728.5, ν(C≡N) 2215.

*b) Using bromine*

The compound VI (1.69 g; 0.01 mol) was dissolved at heating in absolute CCl₄ (25 cm³) and the solution was cooled with ice water. The solution of bromine (1.60 g) in CCl₄ (5 cm³) was added dropwise over a period of 15 min, the mixture was stirred in ice water for 1 h, heated to the water bath temperature and allowed to reflux for 30 min. The solution was evaporated to 15 cm³ and set aside in a refrigerator overnight. The precipitate was sucked to give the crude product in 1.40 g (83 %) yield. Recrystallization from the mixture benzene—n-heptane (α = 2 : 1) gave 1.19 g (71 %) of product of m.p. = 103—105 °C.

**2,3-Thiophenedicarboxylic acid (XIV)**

The mixture of XII (1.67 g; 0.01 mol), CH₃COOH (8 cm³), and HCl (7 cm³) was refluxed for 15 h, allowed to cool down and the crystals formed were sucked and dried. Yield of the crude product = 1.40 g (81 %). Crystallization from water gave 1.32 g (76 %) of white needles with m.p. = 284—285 °C (decomposition).

For C₈H₆O₂S (Mᵣ = 172.0) w(calc): 41.86 % C, 2.33 % H, 18.64 % S; w(found): 41.75 % C, 2.29 % H, 18.79 % S. 'H NMR (DMSO, D₂MSO) δ/ppm: 7.40 (d, 1H, CH), 7.78 (d, 1H, CH), 11.35 (s, 2H, OH).
Hydrolysis performed under similar conditions in 10% H2SO4 gave 1.35 g (79%) of the brown crude product which on crystallization afforded only low yield. Hydrolysis in 10% NaOH did not lead to higher yield, on the contrary, the isolation was lengthy and the product was less pure.

**4,5-Dihydrothiophene-2,3-dicarboxylic acid (VIII)**

The compound VI (1.69 g; 0.01 mol) was refluxed for 1 h in the solution of NaOH (0.80 g; 0.02 mol) in water (7.2 cm³), cooled in ice water and acidified with diluted HCl (α = 1 : 1) to pH = 1. The mixture was set aside in a refrigerator for 2 h, the precipitate was filtered off, washed with a small amount of cold water, and recrystallized from water. Yield = 0.69 g (40%) of yellow needles with m.p. = 208—209 °C (Ref. [29] gives m.p. = 196—198 °C).

For C₁₀H₆O₃S (Mᵣ = 174.0) \( w_c \) (calc.): 41.38 % C, 3.45 % H, 18.43 % S; \( w_f \) (found): 41.21 % C, 3.52 % H, 18.85 % S. 'H NMR ((CD₃)₂CO, HDMSO) \( \delta \)/ppm: 7.58 (s, 2H, ОН), 2.75—3.63 (m, 4H, СН₂).

**3-Carbamoyl-4,5-dihydrothiophene-2-carboxylic acid (X)**

The mixture of VI (1.0 g; 0.006 mol), CH₃COOH (3 cm³), and concentrated HCl (5 cm³) was refluxed for 1 h, then heated at the oil bath temperature 110 °C for 2 h and allowed to stand at room temperature for three days. The obtained white crystals were sucked, washed with a small amount of cold water, and dried. Yield = 0.73 g (72%); m.p. = 218—219 °C.

For C₁₀H₇N₂O₃S (Mᵣ = 173.0) \( w_c \) (calc.): 41.60 % C, 4.04 % H, 8.09 % N, 18.53 % S; \( w_f \) (found): 41.42 % C, 3.95 % H, 7.85 % N, 18.64 % S. 'H NMR (DMSO, HDMSO) \( \delta \)/ppm: 8.28 (d, 2H, NH₂), 2.83—3.50 (m, 4H, СН₂).

When reflux was prolonged to 20 h, the mixture became dark continuously and the crystalline compound, precipitating within few minutes, afforded on dissolution pasty products.

**Methyl 2,3-dichloro-3-cyanotetrahydrothiophene-2-carboxylate (XI)**

To the solution of VI (1.69 g; 0.01 mol) in CH₂Cl₂ (10 cm³) SO₂Cl₂ (0.90 cm³; 0.011 mol) was added over a period of 10 min at 0 °C and the solution was stirred for 1 h at this temperature. The reaction mixture was washed with 10% Na₂CO₃ (6 cm³) and water (3×10 cm³). The organic layer was dried (Na₂SO₄), CH₂Cl₂ was evaporated in vacuo and the residue was crystallized from ether. Yield = 2.17 g (91%) of colourless crystals with m.p. = 107—108 °C.

For C₇H₇Cl₂N₂O₃S (Mᵣ = 240.0) \( w_c \) (calc.): 35.00 % C, 2.92 % H, 29.54 % Cl, 5.83 % N, 13.36 % S; \( w_f \) (found): 35.34 % C, 2.73 % H, 29.67 % Cl, 5.43 % N, 13.29 % S. 'H NMR (CDCl₃, TMS) \( \delta \)/ppm: 3.96 (s, 3H, CH₃), 2.75—3.55 (m, 4H; CH₂).

**Methyl 4-oxotetrahydrothiophene-3-carboxylate (V)**

This compound was prepared by combined procedures described in [23] and [27].

To the boiling solution of Na (64.7 g; 2.81 mol) in absolute methanol (470 cm³) dimethyl...
3-thiaadipate (IIIa) (180 g; 0.94 mol) was added dropwise over a period of 10 min and it was refluxed for 30 min and cooled to room temperature. The reaction mixture was poured into the mixture of crushed ice (600 g) and water (300 cm³), stirred for 15 min, and acidified with concentrated HCl (235 cm³). The precipitated oil was separated, the water layer was extracted with CH₂Cl₂ (3 × 200 cm³), the combined organic phases were washed with saturated NaHCO₃ solution (2 × 200 cm³), dried (Na₂SO₄), and CH₂Cl₂ was distilled off. The residue was distilled at 84—86 °C and 0.13 kPa or 124—126 °C and 2.27 kPa. Yield = 80 g (53 %) of the yellowish oil which solidified in the trap directly. Crystallization from methanol resulted in a pure product of m.p. = 36—37 °C.

For C₇H₇NOS (M_r = 160.0) w_(calc.): 44.98 % C, 5.00 % H, 20.03 % S; w_(found): 44.67 % C, 5.00 % H, 19.53 % S. ¹H NMR (CDCl₃, TMS) δ/ppm: 3.80 (s, 7H), 10.94 (s, 1H, OH). ¹H NMR (CCl₄, TMS) δ/ppm: 3.75 (s, 3H, COOCH₃), 3.79 (s, 4H), 10.90 (s, 1H, OH). ¹³C NMR (CDCl₃, TMS) δ/ppm: 172.5 (=Č—OH), 169.6 (COO), 99.2 (=C<), 51.7 (CH₃), 36.1 (CH₂), 31.5 (CH₂). IR (CCl₄) ν/cm⁻¹: ν(C=O) 1761, 1742.5, ν(C=C) 1674.5.

When IIIb or IIIc was used instead of IIIa, the yields obtained were similar (50—55 %). The product obtained on distillation contained a negligible amount of ethyl ester, the product crystallized was a pure methyl ester.

In the analogous reaction with IIIc performed in ethanol a white salt was formed during the reaction and the mixture became very dense. The usual way of isolation afforded only 19 % of the product.

**Methyl 4-cyano-2,5-dihydrothiophene-3-carboxylate (VII)**

This reaction step was accomplished according to [21] with a yield similar as given in the literature.

For C₇H₇NOS (M_r = 169.0) w_(calc.): 49.69 % C, 4.14 % H, 8.28 % N, 18.96 % S; w_(found): 50.04 % C, 4.13 % H, 8.33 % N, 18.48 % S. ¹H NMR (CDCl₃, TMS) δ/ppm: 3.88 (s, 3H, COOCH₃), 4.09 (s, 4H). IR (CHCl₃) ν/cm⁻¹: ν(C=O) 1729.5, ν(C=O) 1638, ν(C=N) 2210.

**Methyl 4-cyanothiophene-3-carboxylate (XIII)**

To the stirred, ice-cooled solution (0—5 °C) of VII (16.90 g; 0.1 mol) in CH₂Cl₂ (100 cm³) sulfuryl chloride (9.0 cm³; 0.11 mol) was added over a period of 45 min, then it was stirred at 0 °C for 2 h. The reaction mixture was washed with 10 % Na₂CO₃ (100 cm³) and water (3 × 100 cm³). The organic layer was separated, dried (Na₂SO₄), CH₂Cl₂ was distilled off in vacuo and the crude product was crystallized from ether. Yield = 15.25 g (91 %) of white crystalline compound with m.p. = 97 °C.

For C₇H₅NOS (M_r = 167.0) w_(calc.): 50.28 % C, 2.99 % H, 8.38 % N, 19.19 % S; w_(found): 50.54 % C, 2.88 % H, 8.35 % N, 18.91 % S. ¹H NMR (CDCl₃, TMS) δ/ppm: 3.96 (s, 3H, COOCH₃), 8.01 (d, 1H), 8.20 (d, 1H). IR (CHCl₃) ν/cm⁻¹: ν(C=O) 1732, ν(C≡N) 2215.

**3,4-Thiophenedicarboxylic acid (XV)**

A. The mixture of XIII (9.0 g; 0.053 mol), CH₃COOH (75 cm³), and concentrated HCl (50 cm³) was refluxed for 22 h. Then the solvent was evaporated in vacuo to dryness, the
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The residue was extracted with hot acetone, NH₄Cl was filtered off and the filtrate was evaporated again. Crystallization from water gave 7.0 g (76 %) of colourless needles with m.p. = 230—232 °C.

B. The mixture of XIII (1.0 g; 0.006 mol), CH₃COOH (5 cm³), and concentrated HCl (4 cm³) was refluxed for 15 h, then it was allowed to stand at room temperature for three days and the precipitate was sucked. Crude product 0.93 g (91 %). Recrystallization from water gave 0.82 g (80 %) of colourless needles with m.p. = 231—233 °C.

For C₆H₄O₄S (Mᵣ = 172.0) wᵣ(calc.): 41.86 % C, 2.33 % H, 18.64 % S; wᵣ(found): 41.70 % C, 2.30 % H, 18.52 % S. ¹H NMR ((CD₃)₂CO, HDMSO) δ/ppm: 8.45 (s, 2H, CH), 7.13 (s, 2H, OH).

2,5-Dihydrothiophene-3,4-dicarboxylic acid (IX)

The compound IX was prepared according to [22] with 75 % yield (Ref. [22] gives 77 %). For C₆H₄O₄S (Mᵣ = 174.0) wᵣ(calc.): 41.38 % C, 3.45 % H, 18.43 % S; wᵣ(found): 41.56 % C, 3.41 % H, 18.56 % S. ¹H NMR ((CD₃)₂CO, HDMSO) δ/ppm: 10.23 (s, 2H, OH), 4.03 (s, 4H, CH₂).

This compound was prepared also by the following way which gave lower yield but a product of very high purity:

The compound VII (5 g), CH₃COOH (15 cm³), and concentrated HCl (25 cm³) were refluxed for 16 h, the mixture was diluted with water to 200 cm³, purified with charcoal, saturated with NaCl, and extracted with ethyl acetate (3 × 50 cm³). The extracts were dried with Na₂SO₄, evaporated in vacuo and the residue was crystallized from the mixture acetone—benzene. Yield = 3.20 g (62 %) of white crystals with m.p. = 184—185 °C (Ref. [22] gives m.p. = 183—184 °C).

References


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