SYNTHESIS OF THIENO[3,4-c]- AND SELENOPHENO-[3,4-c]PYRYLIUM SALTS

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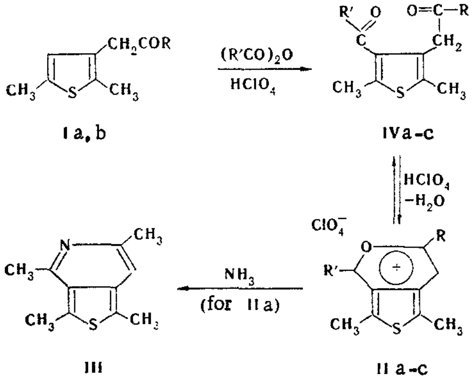
Acylation of 3-acetonyl- and 3-phenacyl-2,5-dimethylthiophenes with aliphatic acid anhydrides in the presence of perchloric acid gives thieno[3,4-c]pyrylium perchlorates. Reaction of the latter with ammonia gives the corresponding thieno[3,4-c]pyridines or diketones of the thiophene series. Selenopheno[3,4-c]pyrylium salts could not be isolated in the acylation of 3-acetonyl- and 3-phenacyl-2,5-dimethylselenophenes.

We have found that perchlorates of a new heteroaromatic system – the thieno[3,4-c]pyrylium cation (II) – are formed in good yields (65-85%) in the acylation of 3-acetonyl- and 3-phenacyl-2,5-dimethylthiophenes (I) with carboxylic acid anhydrides in the presence of perchloric acid.



I;II a $R=CH_3$, b $R=C_6H_5$; II a, b $R'=CH_3$, c $R=CH_3$, $R'=C_2H_5$; IV $R=C_6H_5$, a $R'=CH_3$, b $R'=C_2H_5$

Reaction products II are stable bright-orange compounds. A band of symmetrical stretching vibrations of tetraalkyl-substituted salts is found at 1650-1655 cm^{-1} in their IR spectra, and this, as is well known [1], confirms the presence of the pyrylium cation in the products. When a phenyl substituent is introduced into pyrylium ring (IIb, $R=C_6H_5$) this band is shifted to the low-frequency region (1615-1620 cm^{-1}). The remaining bands correspond to vibrations of the bonds of various fragments of the products.

Perchlorate IIa ($R=R'=CH_3$) reacts with ammonia to give the corresponding thieno[3,4-c]pyridine (III), the very strong absorption band in the IR spectrum of which at 1610 cm^{-1} can apparently be assigned to the stretching vibrations of the C–C bonds of the pyridine ring [2]. The shift in the above-indicated band in the spectrum of the hydrochloride of III to higher frequencies (1668 cm^{-1}), the ease of formation of picrates and hydrochlorides, the absence of carbonyl absorption in the spectrum of the pyridine, and the results of elementary analysis confirm the formation of structure III. When salt IIb is heated to 100° with a saturated alcohol solution of ammonia in a sealed ampul, only the pyrylium ring opens to give 2,5-dimethyl-3-acetyl-4-phenacylthiophene, and the expected thienopyridine is not formed. An identical product was also obtained by heating the above-indicated salt with water; the salt was converted to the starting perchlorate by the action of a mixture of acetic anhydride and perchloric acid.

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A dark-brown solid, which did not dissolve in the strongest polar solvents and in a saturated alcohol solution of ammonia even on heating, was isolated in the acylation of 3-acetonyl- and 3-phenacyl-2,5-dimethylselenophenes. At the same time, the IR spectra show the presence of a pyrylium cation (1655 and 1555 cm^{-1}) and a ClO_4^- anion (1100 and 625 cm^{-1}). The results of elementary analysis, which are close to the values calculated for the expected perchlorates, and the IR spectra of the perchlorates and the products obtained by treatment with ammonia provide a basis for the assumption that polymers are formed during acylation of the ketones. The formation of selenopheno[3,4-c]pyrylium perchlorate apparently leads to considerable deformation (decrease) of the length of the bond between the β β'-carbon atoms, as a result of which the selenophene ring strain increases and the C–Se bond is cleaved to give a polymer.

EXPERIMENTAL METHOD

The IR spectra of KBr pellets of the compounds were recorded with a UR-20 spectrometer. The individuality of the products of conversion of the pyrylium salts was monitored by thin-layer chromatography (TLC) on activity II Al_2O_3 in a benzene–chloroform–hexane–acetone system (30 : 6 : 1 : 4) with development by iodine vapors and in UV light.

Starting thiophenes I were obtained from 2,5-dimethyl-3-formylthiophene (V) [3] as described in [4].

2,5-Dimethyl-3-thienalbutylamine (VI). A mixture of 28.6 g (0.22 mole) of aldehyde V and 19 g (0.26 mole) of butylamine in 60 ml of benzene was refluxed on a water bath for 20 min, after which the benzene, excess butylamine, and water were removed by distillation. The residue was vacuum-distilled to give 40 g (93.5%) of a product with bp 115-117° (5 mm). Found: C 67.5; H 8.6; N 7.3%. $C_{11}H_{17}NS$. Calculated: C 67.7; H 8.7; N 7.2%.

2,5-Dimethyl-3-thienalbenzylamine (VII). This compound, with bp 171-174° (5 mm), was obtained in 90%yield from aldehyde V and benzylamine as in the preceding experiment. Found: C 73.5; H 6.6; N 6.2%. $C_{14}H_{15}NS$. Calculated: C 73.4; H 6.6; N 6.1%.

1-(2,5-Dimethyl-3-thienyl)-2-nitropropylene (VIII). A mixture of 39 g (0.2 mole) of VI and 15.2 g (0.2 mole) of nitroethane in 50 ml of acetic acid was heated on a boiling-water bath for 15 min, after which it was cooled, and the resulting precipitate was removed by filtration, washed with water and alcohol, and dried to give 30 g of product. The addition of 100 ml of water to the filtrate yielded another 6.5 g of product. The total yield of product with mp 67-67.5° (from alcohol) was 36.5 g (92.5%). Found: C 54.9; H 5.7; N 7.2%. $C_9H_{11}NO_2S$. Calculated: C 54.8; H 5.6; N 7.1%.

1-(2,5-Dimethyl-3-thienyl)-2-phenylnitroethylene (IX). This compound, with mp 105-106° (from alcohol), was obtained in 73.6%yield from VI and phenylnitromethane by a method similar to the preceding method. Found: C 64.8; H 5.1; N 5.4%. $C_{14}H_{13}NO_2S$. Calculated: C 64.8; H 5.0; N 5.4%.

2,5-Dimethyl-3-acetonylthiophene (Ia). Concentrated HCl (72 ml) was added in the course of 2 h with vigorous stirring to a refluxing mixture of 36 g (0.18 mole) of VIII, 40 g of powdered iron, 40 ml of toluene, 1 g of ferric chloride, and 80 ml of water, after which the mixture was refluxed and stirred for another 30 min. It was then steam-distilled, the organic layer was separated, and the aqueous layer was extracted with ether. The solvents were removed by distillation, and the residue was vacuum-distilled to give 15.1 g (50%) of a product with bp 86-87° (3 mm) and R_f 0.80. Found: C 64.4; H 7.2; S 19.2%. $C_9H_{12}OS$. Calculated: C 64.3; H 7.1; S 19.0%. IR spectrum: 1707 cm^{-1}. The semicarbazone had mp 164-165° (from alcohol). Found: N 18.6%. $C_{10}H_{15}N_3OS$. Calculated: N 18.7%.

2,5-Dimethyl-3-phenacylthiophene(Ib). As in the preceding experiment, 20 g (0.08 mole) of IX was converted to phenacylthiophene Ib, for the isolation of which the residue obtained after 200 ml of distillate had been obtained by steam distillation was cooled and extracted with ether. The extracts were dried with calcium chloride, the ether was removed by distillation, and the residue solidified to give 5.1 g (27.8) of a product with mp 56-57° (from hexane) and R_f 0.83. Found: C 73.1; H 6.1; S 13.8%. $C_{14}H_{14}OS$. Calculated: C 73.0; H 6.1; S 13.0%. IR spectrum: 1695 cm^{-1}.

1,3,5,7-Tetramethylthieno[3,4-c]pyrylium Perchlorate (IIa). An ice-cooled mixture of 7.5 ml (0.075 mole) of acetic anhydride and 1.2 ml (0.015 mole) of 70%perchloric acid was added with stirring to 2.52 g (0.015 mole) of Ia, after which the mixture was allowed to stand for 1 h. Ether (10 ml) was added, and the resulting precipitate was removed by filtration and washed with ether to give 2.85 g (65%) of a product with mp 101-102°. Found: C 45.4; H 4.6; Cl 12.6; S 11.1%. $C_{11}H_{13}ClO_5S$. Calculated: C 45.2; H 4.4; Cl 12.3; S 10.9%.

1,3,5-Trimethyl-7-ethylthieno[3,4-c]pyrylium Perchlorate (IIc). As in the preceding experiment, this compound, with mp 130-132°, was obtained in 77.7% yield from Ia and propionic anhydride. Found: C 47.3; H 5.2; Cl 11.1; S 10.1%. $C_{12}H_{15}ClO_5S$. Calculated: C 47.0; H 4.9; Cl 11.4; S 10.4%.

1,3,7-Trimethyl-5-phenylthieno[3,4-c]pyrylium Perchlorate (IIb). A) A cooled (with ice water) mixture of 5 ml (0.05 mole) of acetic anhydride and 0.8 ml of 70% perchloric acid was added with stirring to a solution of 2.5 g (0.01 mole) of phenacylthiophene Ib in 5 ml (0.05 mole) of acetic anhydride, and the resulting precipitate was removed by filtration and washed with ether to give 3 g (84.5%) of a product with mp >300°. Found: C 54.3; H 4.4; Cl 10.2; S 8.9%. $C_{16}H_{15}ClO_5S$. Calculated: C 54.1; H 4.2; Cl 10.0; S 9.0%.

B) A mixture of 1.25 ml (12.5 mmole) of acetic anhydride and 0.2 ml (2.5 mmole) of 70% perchloric acid was added with stirring to a solution of 0.7 g (2.5 mmole) of IVa in 1.25 ml (12.5 mmole) of acetic anhydride, and the precipitated bright-orange crystals of a substance with mp >300° were removed by filtration and washed with ether. The yield was quantitative. No melting-point depression was observed for a mixture of the product with perchlorate XII.

2,5-Dimethyl-3-acetyl-4-phenacylthiophene (IVa). A) Ethanol (30 ml) was added to 1.8 g (0.005 mole) of salt IIb, and the mixture was heated to the boiling point. It was then cooled, and the resulting colorless crystals were removed by filtration to give 1 g (73.4%) of a product with mp 179-180° (from aqueous alcohol). Found: C 70.9; H 6.1; S 11.5%. $C_{16}H_{16}O_2S$. Calculated: C 70.6; H 5.9; S 11.8%. IR spectrum: 1680-1620 cm^{-1}.

B) Ammonia was passed for 1 h into a mixture of 3.55 g (0.01 mole) of IIb and 40 ml of alcohol in an ampul, after which the ampul was sealed and heated on a boiling-water bath for 8 h. The alcohol solution was filtered, and 100 ml of water was added to the filtrate. The organic layer was extracted with ether, the ether was removed from the extract by distillation, and the residue began to solidify to give 0.95 g (35%) of a product with mp 179-180° (from aqueous alcohol) and R_f 0.91. Found: C 70.9; H 6.0; S 11.3%. $C_{16}H_{16}O_2S$. Calculated: C 70.6; H 5.9; S 11.7%. No melting-point depression was observed for a mixture of this product with a sample obtained by method A.

1,3-Dimethyl-5-phenyl-7-ethylthieno[3,4-c]pyrylium Perchlorate. This compound, with mp >300°, was obtained in 80% yield from Ib and propionic anhydride by the method described for the synthesis of XII. Found: C 55.5; H 4.8; Cl 9.5; S 8.5%. $C_{17}H_{17}ClO_5S$. Calculated: C 55.4; H 4.6; Cl 9.6; S 8.7%.

1,3,5,7-Tetramethylthieno[3,4-c]pyridine (III). Ammonia was passed for 30 min into a mixture of 5.85 g (0.02 mole) of IIa and 50 ml of alcohol, after which the mixture was refluxed for 30 min and poured into 150 ml of water. The organic layer was extracted with ether, and the extract was washed with water and dried with potassium hydroxide. The solvent was removed by distillation, and the residue began to solidify to give 2.71 g (71%) of a product with mp 57-58° (from hexane) and R_f 0.72. Found: C 69.4; H 7.0; N 7.6; S 16.4%. $C_{11}H_{13}NS$. Calculated: C 69.1; H 6.8; N 7.3; S 16.7%. The picrate had mp 185° (from alcohol). Found: N 13.4%. $C_{11}H_{13}NS \cdot C_6H_3N_3O_7$. Calculated N 13.3%. The hydrochloride had mp 301-302° (from aqueous acetone). Found: N 6.0%. $C_{11}H_{13}NS \cdot HCl$. Calculated: N 6.1%.

2,5-Dimethyl-3-formylselenophene (X). This compound was synthesized via the Sommelet reaction of 2,5-dimethyl-3-chloromethylselenophene [5] with urotropin.

2,5-Dimethyl-3-selenalbutylamine (XI). A mixture of 19.2 g (0.1 mole) of aldehyde X and 9 g (0.12 mole) of butylamine in 20 ml of benzene was refluxed on a water bath for 20 min, after which the benzene, water, and excess butylamine were removed by distillation. The residue was vacuum-distilled to give 22.7 g (93%) of a product with bp 115-117° (2 mm). Found: C 54.7; H 7.2; N 5.7%. $C_{11}H_{17}NSe$. Calculated: C 54.5; H 7.0; N 5.8%.

1-(2,5-Dimethyl-3-selenienyl)-2-nitropropylene (XII). A mixture of 24.2 g (0.1 mole) of XI and 7.5 g (0.1 mole) of nitroethane in 25 ml of acetic acid was heated on a boiling-water bath for 20 min, after which it was cooled, and the resulting precipitate was removed by filtration, washed with water and alcohol, and dried to give 21.2 g of product. The addition of 100 ml of water to the filtrate gave another 1.6 g of product. The total yield of product with mp 60-61° (from alcohol) was 22.8 g (95%). Found: C 44.4; H 4.4; N 5.9%. $C_9H_{11}NO_2Se$. Calculated: C 44.3; H 4.5; N 5.7%.

1-(2,5-Dimethyl-3-selenienyl)-2-phenyl-2-nitroethylene (XIII). This compound, with mp 127° (from alcohol) and R_f 0.86, was obtained in 73% yield from XI and phenylnitromethane by the method described for the synthesis of XVI. Found: C 44.8; H 4.1; N 4.5%. $C_{14}H_{13}NO_2Se$. Calculated: C 44.9; H 4.2; N 4.6%.

2,5-Dimethyl-3-acetonylselenophene (XIV). The method described for the preparation of Ia was used to obtain 18 g (42%) of acetonylselenophene XIV, with bp 83-85° (1 mm) and R_f 0.82, from 42.3 g (0.18 mole) of XII. Found: C 50.1; H 5.7; Se 36.5%. $C_9H_{12}OSe$. Calculated: C 50.2; H 5.6; Se 36.7%. IR spectrum: 1722 cm^{-1}. The thiosemicarbazone had mp 146-147° (from alcohol). Found: N 14.7%. $C_{10}H_{15}N_3OSSe$. Calculated: N 14.6%.

2,5-Dimethyl-3-phenacylselenophene (XV). The method used to obtain phenacylthiophene Ib was used to obtain 6.25 g (30.5%) of phenacylselenophene XV, with mp 97-98° (from hexane) and R_f 0.80, from 22.6 g (0.075 mole) of XIII. Found: C 60.5; H 5.1; Se 28.3%. $C_{14}H_{14}OSe$. Calculated: C 60.6; H 5.0; Se 28.5%. IR spectrum: 1650 cm^{-1}.

Acetylation of XIV. An ice-cooled mixture of 10 ml (0.1 mole) of acetic anhydride and 1.6 ml (0.02 mole) of 70% perchloric acid was added with stirring to 4.3 g (0.02 mole) of XIV, after which the mixture was allowed to stand for 2 h. Ether (100 ml) was added, and the resulting precipitate was removed by filtration and washed with ether to give 5.5 g of product. Found: C 37.2; H 3.4; Cl 8.9; Se 21.2%. The dark-brown product was insoluble in ethanol, acetone, acetic acid, and nitromethane. It decomposed on heating above 200°. It did not dissolve on heating with a saturated alcohol solution of ammonia but took on a light-brown color. The yield was 3.1 g. Found: C 52.6; H 6.5; Se 25.7%. Compound XIV was propionylated by the method described above. With respect to its properties, the product was similar to the product of acetylation of XIV.

Acetylation of XV. As in the preceding experiments, the reaction of 2.8 g (0.01 mole) of XV gave a dark-brown substance that was insoluble in ethanol, acetone, acetic acid, and nitromethane. It decomposed on heating above 200°. Found: C 49.8; H 4.5; Cl 7.9; Se 18.4%. It did not dissolve on heating with a saturated alcohol solution of ammonia but took on a light-brown color. The yield was 1.5 g. Found: C 60.8; H 4.8; Se 21.7%. The propionylation of XV was carried out via the method described above. With respect to its properties, the product was similar to the product of acetylation of XV.

LITERATURE CITED

1. E. Wilson, Phys. Rev., 45, 706 (1934).
2. A. R. Katritzky (editor), Physical Methods in the Chemistry of Heterocyclic Compounds, Academic Press (1963).
3. A. W. Weston and R. I. Michaels, J. Amer. Chem. Soc., 72, 1422 (1950).
4. L. V. Dulenko, G. N. Dorofeenko, S. N. Baranov, I. G. Katts, and V. I. Dulenko, Khim. Geterotsikl. Soedin., 320 (1971).
5. Yu. K. Yur'ev, N. K. Sadovaya, and M. A. Gal'bershtam, Zh. Obshch. Khim., 32, 259 (1962).
6. Yu. K. Yur'ev, M. A. Gal'bershtam, and N. K. Sadovaya, Zh. Obshch. Khim., 32, 13 (1962).