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Dedicated to Academician M.G.Voronkov on occasion of his 80th birthday

2,3,5,6-Tetra(vinylthio)difluorobenzene in Reactions with Difunctional Nucleophiles

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Abstract—Reaction of 2,3,5,6-tetra(vinylthio)difluorobenzene with ethylene glycol affords 1,4-bis[2,3,5,6-tetra(vinylthio)-4-fluorophenoxy-1-ethyloxy-]-2,3,5,6-tetra(vinylthio)benzene, with diethylene glycol arises 2,3,5,6-tetra(vinylthio)-4-(4-hydroxyethoxyethyloxy)-1-fluorobenzene, with 1,5-diaminopentane forms 1,5-bis[2,3,5,6-tetra(vinylthio)-4-fluoroanilino]pentane; in reactions with 2-aminoethanethiol and 2-mercaptoethanol occurs substitution of two fluorine atoms by RS groups.

The nucleophilic substitution in the aromatic ring is one of the principal methods for introduction of functional groups into polyhaloaromatic compounds [1]. The data on (vinylthio)halobenzenes and their functional derivatives were lacking before our publications.

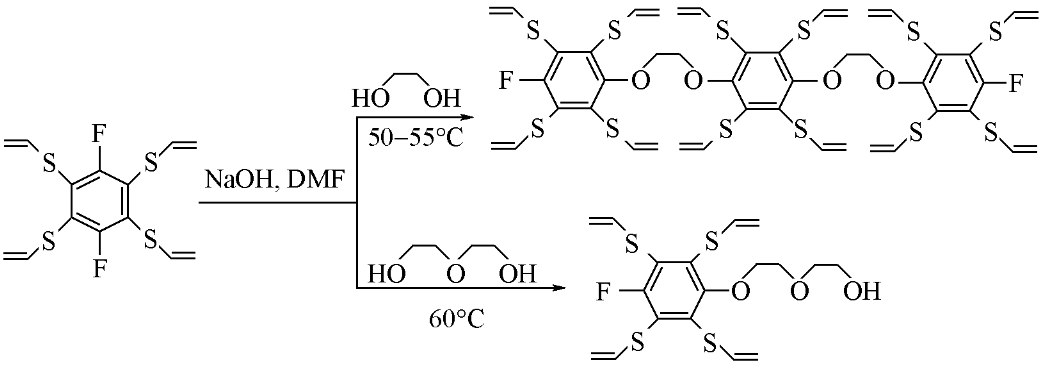
In our previous reports [2–6] we showed that in reactions of di(vinylthio)polyhalobenzenes with binucleophilic reagents occurred regioselective fluorine substitution in the benzene ring affording new (vinylthio)haloaromatic compounds with various functional groups.

This paper reports on the synthesis of highly unsaturated polyfunctional compounds containing four and more vinylthio groups proceeding from 2,3,5,6-tetra(vinylthio)difluorobenzene (**I**) whose preparation in 90% yield we have developed [7].

In [2] we studied the reaction between 2,3,5,6-tetra(vinylthio)difluorobenzene (**I**) and 2-aminoethanol; it was observed that the latter reacts by the hydroxy group providing depending on the reaction temperature either mono- or disubstituted products.

In extension of the investigation on the reactivity of difluoro compound **I** we carried out nucleophilic substitution of fluorine atoms therein by glycols, 1,5-diaminopentane, 2-aminoethanethiol, and 2-mercaptoethanol.

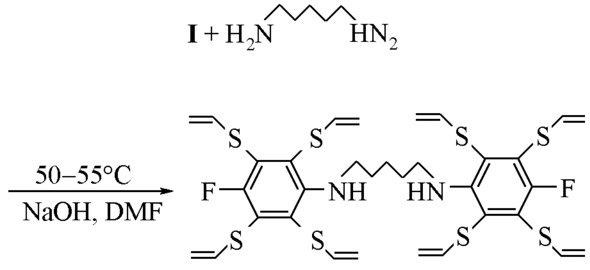
Fluorocompound **I** reacts with ethylene glycol and diethylene glycol in the presence of NaOH at the reagents ratio 1 : 3 : 6 in DMF at 50–60°C; the main product with ethylene glycol is a compound of a bridging structure, 1,4-bis{2-[2,3,5,6-tetra(vinylthio)-4-fluorophenoxy]ethoxy}-2,3,5,6-tetra(vinylthio)benzene (**II**) formed in 10% yield, and with diethylene glycol arises monosubstituted product 2,3,5,6-tetra(vinylthio)-4-(4-hydroxy-3-oxapentoxy)-1-fluorobenzene (**III**) in 20% yield. As show ^{19}F NMR spectra, in reaction mixtures alongside unreacted



compound **I** (giving a singlet at δ_F –96.28 ppm) are present in reaction with ethylene glycol a monosubstituted product (singlet at δ_F –94.89 characteristic of monosubstituted derivatives), and with diethylene glycol traces of the bridging compound (singlet at δ_F –102.71 ppm).

The structure of crystalline compound **II** was proved by IR, ^{1}H, ^{13}C, and ^{19}F spectroscopy. The IR spectrum recorded from mull in mineral oil lacks absorption bands from hydroxy groups. In the ^{1}H NMR spectrum are seen three signals from different vinyloxy groups; one among them is neighboring to the fluorine atom as shows the splitting of its α-proton signal in the region of 6.32 ppm due to spin-spin coupling ($^5J_{HF}$ 0.92 Hz). In the ^{19}F NMR spectrum appears one singlet at δ_F –102.94 ppm.

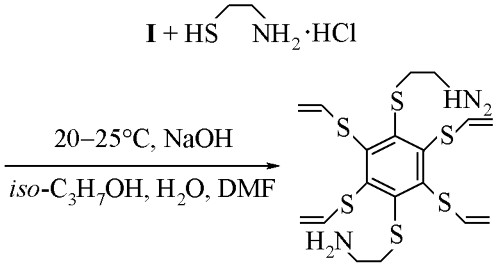
The reaction of fluoroderivative **I** with 1,5-diaminopentane in DMF in the presence of alkali at 110–120°C resulted in substitution of a single fluorine atom in two molecules of compound **I** to furnish 1,5-bis[2,3,5,6-tetra(vinylthio)-4-fluoroanilino]pentane (**IV**) in 12% yield.



IV

The reaction is accompanied by formation of a large amount of polymer as side product for compound **I** with four vinylthio groups is prone to thermal polymerization [8]. The reaction does not go at 50–60°C. We did not detect any monosubstituted products from a single molecule of compound **I**.

In reaction of fluorocompound **I** with 2-aminoethanethiol at 20–25°C in DMF in the presence of alkali same as in reaction with this reagent of 3,6-bis(vinylthio)-1,2,4,5-tetrafluorobenzene and 3-vinylthio-6-chloro-1,2,4,5-tetrafluorobenzene [4] two fluorine atoms are substituted to afford 1,4-bis(2-aminoethylthio)-2,3,5,6-tetra(vinylthio)benzene (**V**) in 20% yield.



IV

The 2-aminoethanethiol was brought into the reaction as hydrochloride (to generate the base was used 50% aqueous 2-propanol and NaOH), and compound **I** was added to the reaction mixture as solution in DMF. The ratio compound **I** : 2-aminoethanethiol hydrochloride : NaOH was equal to 1 : 3 : 6. According to ^{1}H and ^{19}F spectra we failed to free compound **V** from the traces of substrate **I**. We noted that in reaction of compound **I** with 2-aminoethanethiol at 50–55°C in the ^{1}H NMR spectrum appeared additional signals in the region δ, ppm: 4.956 d, 5.245 d, 6.360 q ($SCH{=}CH_2$) evidencing a probable substitution of one (or two) fluorines by attack of the NH_2 group of the 2-aminoethanethiol. We established formerly [4] that 2-aminoethanethiol at 85°C reacted with 3,6-bis(vinylthio)-1,2,4,5-tetrafluorobenzene by both SH and NH_2 groups providing cyclic reaction products.

We failed to isolate individual nucleophilic substitution products of the reaction between difluoroderivative **I** and 2-mercaptoethanol proceeding at 20–50°C in DMF in the presence of NaOH. Apparently the products form as salts, and the major part thereof dissolves in water at workup of the reaction mixture; the acidification of the water solution results in hydrolysis of the vinyloxy groups from the reaction products. The reaction mixture isolated in small amount was studied by ^{1}H and ^{19}F NMR spectroscopy. It was found that in the ^{19}F NMR spectrum appears an only signal at δ_F –96.28 ppm corresponding to initial compound **I**. In the ^{1}H NMR spectrum apart the signals from the vinylthio groups of substrate **I** (δ, ppm: 5.20 d, 5.33 d, 6.41 q) consistent with the published data [7] appear also signals in the following regions, δ, ppm: 4.97 d, 5.28 d, 6.35 q ($SCH{=}CH_2$), 2.82 t (OH), 3.10 t (SCH_2), 3.63 m (OCH_2) that may be assigned to disubstituted product. We formerly proved [5] that reaction of 3,6-bis(vinylthio)-1,2,4,5-tetrafluorobenzene and 3-vinylthio-6-chloro-1,2,4,5-tetrafluorobenzene with 2-mercaptoethanol resulted in nucleophilic substitution of two fluorines in the benzene ring by RS groups.

Thus we demonstrated that despite the tendency of tetra(vinylthio)difluorobenzene (**I**) to polymerize it is possible to prepare therefrom highly unsaturated polyfunctional compounds.

EXPERIMENTAL

IR spectra were recorded on spectrometer Bruker IPS 25 from samples prepared as thin films or KBr pellets. ^{1}H, ^{13}C NMR spectra were registered on spectrometer Bruker DPX-400 in $CDCl_3$ using HMDS as internal reference. ^{19}F NMR spectra were taken on JEOL FX-90Q instrument in $CDCl_3$ with $CF_3C_6F_5$ as internal reference with recalculation of the chemical shifts relative to $CFCl_3$.

1,4-Bis{2-[2,3,5,6-tetra(vinylthio)-4-fluorophenoxy]ethoxy}-2,3,5,6-tetra(vinylthio)benzene (II). To a mixture of 0.65 g of ethylene glycol and 1.2 g of NaOH in 25 ml of DMF was added at 50°C while stirring 1.14 g of compound **I** in 25 ml of DMF. The reaction mixture was heated to 50–55°C for 12 h, then was poured into a large amount of water and extracted with ethyl ether. The extract was washed with water and dried on $MgSO_4$. On removing the ether under reduced pressure remained 0.55 g of amber-colored resinous substance that was washed with hot hexane. We obtained 0.35 g (10%) of light-yellow compound **II** as fine crystals, mp 74–76°C. ^{1}H NMR spectrum, δ, ppm: 4.34 d.d (4H, $2FArOCH_2C\underline{H}_2OAr$), 4.39 d.d (4H, $2FArOC\underline{H}_2CH_2OAr$), 5.18 d, 5.19 d, 5.25 d ($12H^A$), 4.94 d, 5.03 d, 5.13 d ($12H^B$), 6.32 d.d, 6.38 d.d, 6.38 d.d ($12H^X$) ($12SCH^X{=}CH_2^{AB}$, $^3J_{H^BH^X}$ 9.7, 9.8, 9.7, $^3J_{H^AH^X}$ 16.6, 16.6, 16.4, $^5J_{H^XF}$ 0.92 Hz). ^{13}C NMR spectrum, δ_C, ppm: 64.33, 65.07 (OCH_2), 112.34, 112.43, 113.41 (C^β), 130.14, 131.53 (double signal) (C^α) ($SC^\alpha H{=}C^\beta H_2$), 127.03, 132.00, 132.20, ($C_{Ar}S$), 141.66, 145.32 ($C_{Ar}O$), 157.68 ($C_{Ar}F$, $^1J_{CF}$ 340 Hz). ^{19}F NMR spectrum, δ_F, ppm: –102.94 s. Found, %: C 51.22; H 4.02; F 3.87; S 35.13. $C_{46}H_{44}F_2O_4S_{12}$. Calculated, %: C 50.99; H 4.09; F 3.50; S 35.50.

2,3,5,6-Tetra(vinylthio)-4-(4-hydroxy-3-oxapentoxy)-1-fluorobenzene (III) was prepared analogously to compound **II** at 60°C and isolated by chromatography on Al_2O_3 with elution by hexane-ethyl ether mixture, 1:3. Yield 0.2 g (20%), thick colorless substance. IR spectrum, ν, cm^{-1}: 1586 ($SCH{=}CH_2$), 1042 (C–O–C), 3423 (OH). ^{1}H NMR spectrum, δ, ppm: 3.67 t (4H, OCH_2CH_2), 3.84 m (2H, $ArOCH_2C\underline{H}_2O$), 4.14 m (2H, $ArOC\underline{H}_2CH_2O$), 5.08 d, 5.26 d, (4H, $2CH_2{=}$), 6.42 d.d (2H, 2SCH=) (2,6-$SCH{=}CH_2$, $^3J^{cis}_{HH}$ 9.4, $^3J^{trans}_{HH}$ 16.6, $^5J_{HF}$ 2.1 Hz), 5.18 d, 5.28 d (4H, $2CH_2{=}$), 6.44 d.d (2H, 2SCH=), (3,5-$SCH{=}CH_2$ $^3J^{cis}_{HH}$ 9.4, $^3J^{trans}_{HH}$ 16.6 Hz). ^{19}F NMR spectrum, δ_F, ppm: –94.83 s. Found, %: C 49.52; H 4.78; F 4.29; S 29.45. $C_{18}H_{21}FO_3S_4$. Calculated, %: C 49.98; H 4.89; F 4.39; S 29.63.

1,5-Bis[2,3,5,6-tetra(vinylthio)-4-fluoroanilino]-pentane (IV). To a mixture of 0.6 g of 1,5-diaminopentane and 0.4 g of NaOH in 15 ml of DMF was added at 90°C while stirring a solution of 1.04 g of compound **I** in DMF. The reaction mixture was heated to 110–120°C for 6 h and left standing at room temperature for 12 h. Then it was poured into 100 ml of water and extracted with chloroform. The extract was washed with water and dried on $MgSO_4$. On removing the chloroform under reduced pressure the 0.5 g of resinous dark-brown residue was subjected to chromatography on Al_2O_3 (eluent hexane–chloroform, 1 : 4).We isolated 0.10 g of initial compound **I** and 0.2 g (12%) of compound **IV** as viscous light-brown substance contaminated with traces of compound **I**. ^{1}H NMR spectrum, δ, ppm: 1.61 m (6H, $3CH_2$), 2.03 m (4H, $2CH_2NH$), 3.63 br.s (2H, 2NH), 5.02 d, 5.24 d (8H, $4CH_2{=}$), 6.31 d.d (4H, 4SCH=) (2,6-$SCH{=}CH_2$, $^3J^{cis}_{HH}$ 9.4, $^3J^{trans}_{HH}$ 16.6 Hz), 5.22 d, 5.35 d (8H, $4CH_2{=}$), 6.45 d.d (4H, 4SCH=) (3,5-$SCH{=}CH_2$, $^3J^{cis}_{HH}$ 9.4, $^3J^{trans}_{HH}$ 16.6, $^5J_{HF}$ 2 Hz). ^{19}F NMR spectrum, δ_F, ppm: –103.46 s.

1,4-Bis(2-aminoethylthio)-2,3,5,6-tetra(vinylthio)benzene (V). To a solution of 0.7 g of NaOH in 2 ml of H_2O was added at stirring a solution of 1 g of 2-aminoethanethiol in 3 ml of H_2O, 5 ml of 2-propanol, and then a solution of 0.9 g of compound **I** in 35 ml of DMF. The reaction mixture was maintained for 4 days at room temperature, then poured in a large amount of water, extracted with ethyl ether, the extract was washed with water and dried on MgS_4. On removing ethyl ether we obtained 0.6 g of light-yellow substance that was recrystallized from hot hexane to afford 0.4 g (20%) of light-yellow crystalline compound **V** containing according to ^{19}F NMR spectrum impurity of difluorocompound **I**. ^{1}H NMR spectrum, δ, ppm: 1.59 s (4H, $2NH_2$), 2.79 t (4H, $2CH_2S$), 3.02 t (4H, $2CH_2N$), 5.17 d, 5.32 d, (8H, 4CH2=), 6.36 d.d (4H, 4SCH=) ($^3J^{cis}_{HH}$ 9.3, $^3J^{cis}_{HH}$ 16.5 Hz).

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