Russian Journal of General Chemistry, Vol. 72, No. 6, 2002, pp. 957–962. Translated from Zhurnal Obshchei Khimii, Vol. 72, No. 6, 2002, pp. 1024–1029.

Unprecedented and Effective Synthesis of Thiazolines from Perfluoro-3-isothiocyanato-2-methyl-2-pentene and Certain *P*-Nucleofuges

A. V. Rogoza and G. G. Furin

Vorozhtsov Novosibirsk Institute of Organic Chemistry, Siberian Division, Russian Academy of Sciences, Novosibirsk, Russia

Received August 3, 2000

Abstract — The reactions of perfluoro-3-isothiocyanato-2-methyl-2-pentene with PPh_3 and $P(NEt_2)_3$ in the presence of $NaBF_4$, KI, and $NaBPh_4$ form phosphonium salts with the heterocyclic substituent (4*E*)-5,5-bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl, instead of involving desulfurization and formation of P–F-containing products. The reaction with tris(pentafluorophenyl)phosphine fails. The reactions with $P(OEt)_3$ in the presence of $ClSiMe_3$ or $(CH_3O)_2POSiMe_3$ yield diethyl or dimethyl [(4*E*)-5,5-bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl]phosphonates and no intramolecular alkylation products. The ^1H, ^{13}C, ^{19}F, and ^{31}P spectra are presented, and the reaction pathways are discussed. Potential mechanisms of the biological and catalytic activity of the reaction products are considered.

Heterocyclic compounds attract attention in terms of biological activity because of the key role heterocycles play in biochemical processes [1]. Most researcher's efforts in this field are directed toward modeling, synthesis, isolation from natural sources, and identification of compounds that act as agonists or antagonists of *in vivo* ligands [2].

The most important recent tendency is introduction of fluorine and perfluoroalkyl groups into known biologically active compounds, since such modification exerts a profound effect on the physical and biological properties of these molecules [3]. Perfluoroalkylated media and ligands are also interesting objects for extraction and phase-transfer studies [4–8]. Previously we developed syntheses of 4-ethylidene-5,5-dimethyl-2-thiazoline derivatives 2-substituted fragments of O- [9], S- [10], and N-nucleophiles [11–13], some of which proved promising pesticides [14]. The biological activity of such derivatives is probably underlied by a combination of the following factors: (1) the presence of a vinyl fluorine atom which can be substituted by nucleophilic centers of natural substrates on coordination of their electrophilic centers with the heteroatoms of thiazoline and its 2-substituent (the biological activity of vinyl fluoride derivatives, based on the ability to reversibly inhibit enzymatic reactions, have been reported in [15, 16]); (2) the presence of superlipophilic perfluorinated groups which enhance permeability of biologically active substances [17] by two mechanisms simultaneously [18]: (a) by lowering the melting point of the substance by weakening its crystal lattice and thus increasing solubility; (b) by increasing affinity of the substance to both lipophilic and aqueous phases, thus making it amphiphilic and, as a result, more permeable.

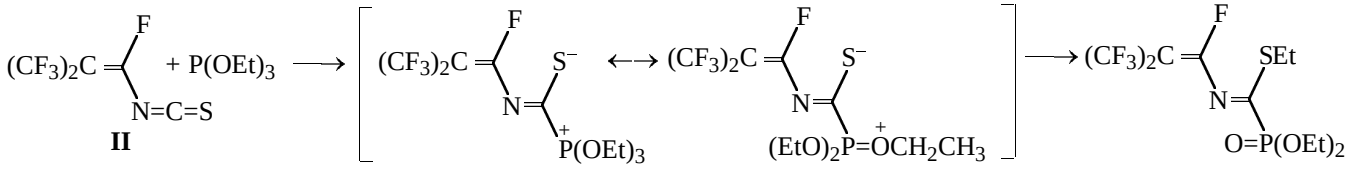
It seems very promising to make use of the superlipophilicity of perfluorinated (perfluoroalkyl, perfluoroalkylsulfuryl, perfluoroalkyloxy, and perfluoroalkylamino) groups for modification of catalytic ligands. The successful use of perfluorinated ligands in catalysis is exemplified by the discovery of fluorous biphase catalysts with superlipophilic phosphine ligands [19], as well as the synthesis of catalysts for olefin hydroborination with a very high turnover [20].

2-Phosphorus-substituted fluorinated thiazolines were prepared by reactions of 3-isothiocyanato-2-methyl-2-pentene (**I**) with nucleophilic P(III) derivatives, similar to earlier studied reactions of compound **I** with O-, S-, and N-nucleophiles. The obtained compounds can exhibit enhanced biological activity, since they contain a $PC{=}N{-}C{=}CFCF_3$ fragment which is bioisosteric [21] to known enzyme inhibitors [22], but, unlike the latter, are capable of multicovalent binding with nucleophilic centers. Moreover, the obtained phosphonium salts and phosphonates with superlipophilic groups are potent extractans and phase-transfer catalysts.

The above synthetic scheme might be expected to involve at least two complications. The first is that

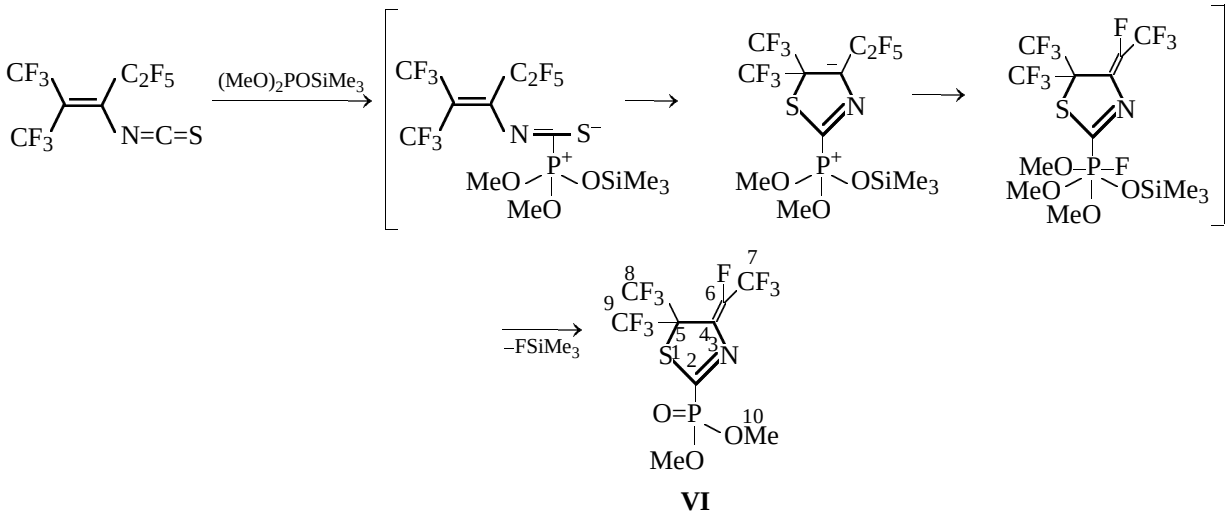
1070-3632/02/7206-0957 $27.00

the most typical reaction of isothiocyanates with P(III) compounds is desulfurization of the isothiocyanate group [23–25]. The second, especially in the case of P–O compounds, is a very high energy of the P–F bond. For this reason, reactions involving liberation of the fluoride ion give complex mixtures of products in which part of oxygen atoms is replaced by fluorine atoms (P–F bonds) [26]. The replacement of oxygen atoms by fluorine can proceed until the PF_6^- anion is formed [27]. At the same time, as showed Sterlin *et al.* [28], the reaction of perfluoro-1-isothiocyanato-2-methyl-1-propene (**II**) with triethyl phosphite may involve no desulfurization. In this case, no heteroring formation was observed, and the formation of compound **IV** was explained by intermolecular alkylation of the sulfur atom in the zwitter ion **III** formed.

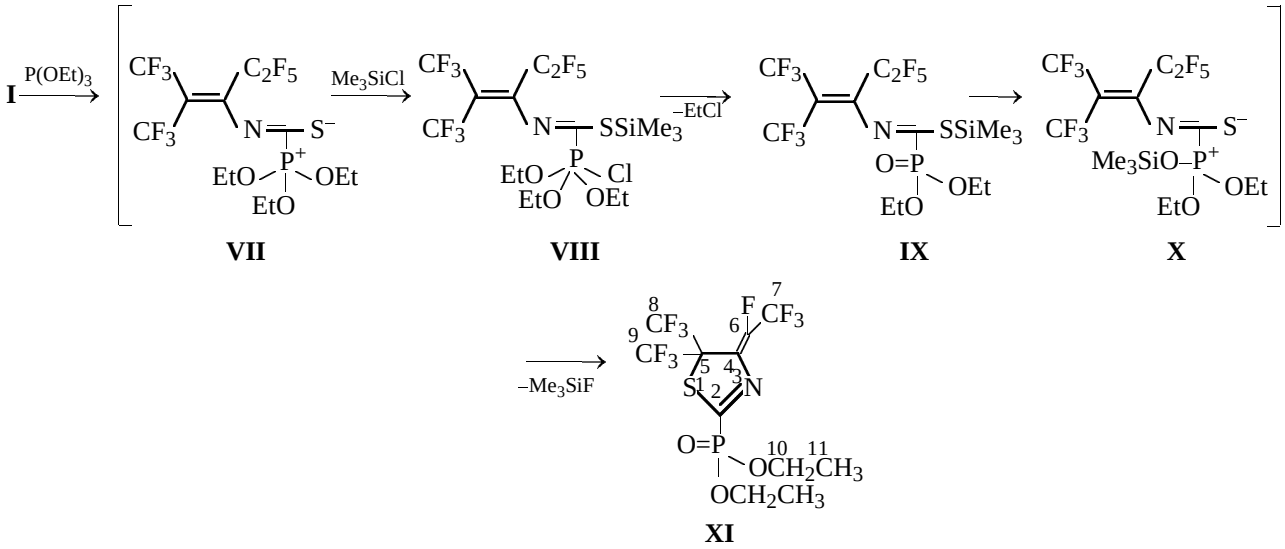


Replacement of the vinyl fluorine atom in perfluoro-1-isothiocyanato-2-methyl-1-propene (**II**) by a perfluoroalkyl group should much reduce the electrophilicity of the olefin double bond [29] in perfluoro-3-isothiocyanato-2-methyl-2-pentene (**I**). Therefore, we expected that attack of the intermediate S-nucleophile by the C=C bond would lead to thiazoline formation. However, on treatment of compound **I** with triethylphosphine or triphenylphosphine we obtained red or violet solutions which, according to ^{19}F NMR data, were complex mixtures of products. Side reactions could be avoided by using the readily available [30, 31] dialkyl trimethylsilyl phosphites which provide high yields of dialkyl phosphonates [32].

The probability of desulfurization in the reaction of dimethyl trimethylsilyl phosphite with compound **I** is reduced, since the trimethylsilyl group better than alkyl stabilizes the positive charge on the oxygen atom in intermediate **V**. Moreover, qualitative conformational analysis of intermediate **V** showed that it provides a biomimetic product control [33]. The =C–N=C–S fragment prefers the *cisoid* conformation and this favors heteroring formation. Because of the repulsion of the $SiMe_3$ and C_2F_5s, the S–C–P–OMe fragment is in the *transoid* conformation, and this prevents desulfurization and intramolecular alkylation. After ring closure, fluorotrimethylsilane is cleaved, which has a strong Si–F bond, and dimethyl phosphonate **VI** is formed in an excellent yield.



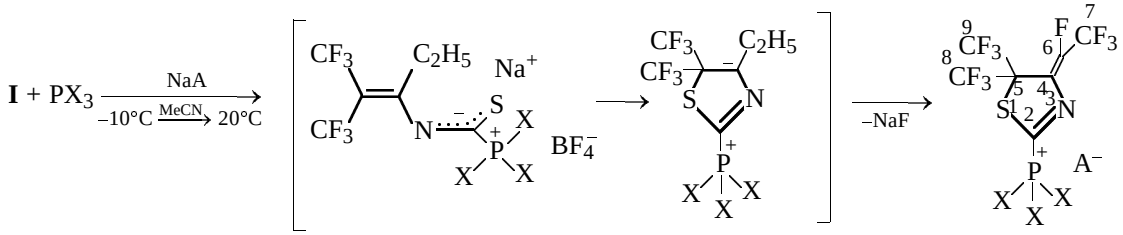
If one reacts compound **I** both with the electrophilic chlorotrimethylsilane and with triethyl phosphite (the latter two compounds do not react with each other under the reaction conditions), then the trimethylsilyl group temporarily blocks the S-nucleophilic center and later acts as fluoride acceptor. The reaction proceeds smoothly by the following scheme to give, according to ^{19}F NMR data, diethyl phosphonate **XI** in a near-quantitative yield (see scheme below).



The initially formed zwitter ion **VII** reacts with chlorotrimethylsilane, providing phosphorane **VIII** which cleaves EtCl to give phosphonate **IX**. The latter, having a strong Si–O bond, isomerizes to compound **X** which is fully identical to intermediate **V**. The *S*-nucleophile attacks the olefin double bond to quantitatively form, after cleavage of fluorotrimethylsilane, phosphonate **XI**.

Posphonium salts were prepared by treatment of compound **I** with triphenylphosphine and tris(dimethylamino)phosphine. Compound **I** fails to form the corresponding salt with tris(pentafluorophenyl)-phosphine. The liberated fluoride ion, in view of the high solubility of phosphonium salts in acetonitrile, makes the reaction reversible. To stabilize the zwitter ion and bind the fluoride ion, we applied the relatively lipophilic salts KI and $NaBF_4$, whose cations form insoluble fluorides. Therewith, compound **I** smoothly reacts with triphenylphosphine and tris(dimethylamino)phosphine to form phosphonium salts **XIIa, XIIb, XIIIa**, and **XIIIb** in quantitative yields. These salts withstand heating in acetonitrile solutions at least to 50°C.

In our opinion, the reaction occurs by the following scheme.



X =  , A = BF_4^- (**XIIa**); X = Ph, A = BPh_4^- (**XIIb**); X = $N(CH_2CH_3)_2$, A = BF_4^- (**XIIIa**); X = NEt_2, A = I^- (**XIIIb**).

The P-nucleophile attacks the carbon atom of the N=C=S group to form zwitter ion **XIV**. The latter is stabilized by the corresponding counterion from $NaBF_4$, KI, or $NaBPh_4$, which prevents desulfurization and intramolecular alkylation. After ring closure, the fluoride ion is taken out of the reaction as NaF or KF.

The compositions and structures of the synthesized compounds were proved by the elemental analyses, ^1H, ^{13}C, ^{19}F, and ^{31}P NMR spectra, IR spectra, and mass spectra. The NMR spectra exhibit the same regularities in nuclear shielding and the same coupling constants which were earlier observed for similar objects [9, 10]. The positions of the F and CF_3 substituents at the C=C bonds in compounds **VI, XI, XII**, and **XIII** are evidently determined by steric factors. When two CF_3 groups are present on C^5, less strained is likely to be the *E* isomer in which the fluorine atom is directed to these substituents. Evidence for this assumption comes from the X-ray diffraction data for certain 2-substituted derivatives of 4,5-dihydro-1,3-thiazole [34]. Moreover, the ^{19}F NMR signal of this fluorine atom is a quartered septet formed by coupling with fluorine atoms of the 5-CF_3 substituent in the dihydrothiazole ring (J_{FF} 22–23 Hz) and fluorine atoms of the CF_3 group at the multiple bond (J_{FF} 6–7 Hz). The IR spectra of the synthesized 4,5-dihydro-1,3-thiazole derivatives all show absorption bands at 1620–1680 ($\nu_{C=C}$) and 1520–1550 cm^{-1} ($\nu_{C=N}$). The signal at 167–170 ppm in the ^{13}C NMR spectra relates to C^2 (d.d, coupling with phosphorus and fluorine on C^6). The signals (δ, ppm) at 148–159 q.d (C^6) and 137–140 d (C^4) belong to the C=C carbons. The carbon atom of the C^9F_3 group attached to the multiple bond appears at 117–119 ppm (d.d). The signals at 75–80 ppm (septet) are assignable to the C^5 atoms of the dihydrothiazole ring.

The signals of phosphonium salts **XIIa, XIIb, XIIIa**, and **XIIIb** in the ^{31}P NMR spectra are at –20 to –36 ppm, which is also characteristic of other known arylphosphonium ions [35, 36]. Substitutients on phosphorus affect the position of this signal: δ_P –19.0 (**XIIa**) and –34.4 ppm (**XIIIa**). The C^2, C^4, and C^6 signals of salt **XIIIa** in the ^{13}C NMR spectrum are doubled by coupling with phosphorus and, in addition, is split by coupling with fluorine atoms. Doublet splitting is observed if 2-substituents are attached to O, N, or S [9–12]. In the ^{13}C NMR spectrum of salt **XIIa**, the C^2 and benzene carbon signals are doublets, and $^1J_{CP}$ decreases from 184.7 Hz for salt **XIIIa** to 105.8 Hz for salt **XIIa**.

Thus, in the present work we found biomimetic approaches to suppression of desulfurization of the isothiocyanate group, intramolecular alkylation, and P–F bond cleavage in the reactions of compound **I** with such P-nucleophiles as $(MeO)_2POSiMe_3$, $P(OEt)_3$, $P(NEt_2)_3$, and PPh_3, which give rise to fluorinated thiazolines. These approaches are quite universal and can be used to success in reactions of various P-nucleophiles with other electrophiles of the hydrocarbon and fluorocarbon series.

EXPERIMENTAL

The ^1H, ^{13}C, ^{19}F, and ^{31}P NMR spectra were obtained on a Bruker WP-400SY spectrometer (400, 100, 188, 162 MHz, respectively), references HMDS, C_6F_6, and H_3PO_4 (J_{CH} were not measured). The IR spectra were obtained on a Specord M-80 spectrometer (CCl_4), and the mass spectra were run on a VG-70-7OE GC–MS system, ionizing energy 70 eV.

Compound **I** was prepared as described in [37].

Dimethyl [(4*E*)-5,5-bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl]phosphonate (VI). To a solution of 3.39 g of compound **I** in 10 ml of acetonitrile at room temperature we added with stirring 2 g of $(CH_3O)_2POSiMe_3$. The mixture was left to stand for 24 h and then heated for 18 h at 50°C. The solvent was removed in a a water-jet-pump vacuum, and the residue was distilled to obtain 3.46 g (80%) of compound **VI**, bp 122–123°C (13 mm). IR spectrum (5% CCl_4 solution), ν, cm^{-1}: 2980, 2880 (C–H), 1680 (C=C), 1555 (C=N), 1350 (C–O), 1250–1160 (C–F). ^1H NMR spectrum (CD_2Cl_2), δ, ppm: 3.77 d (H^{10}, $^3J_{HP}$ 10.1 Hz). ^{13}C NMR spectrum [$(CD_3)_2C=O$], δ_C, ppm (*J*, Hz): 167.0 (C^2, $^1J_{CP}$ 224.4, $^4J_{CF}$ 12.8), 148.7 (C^6, $^1J_{CF}$ 281.3, $^2J_{CF}$ 40.7), 136.9 (C^4, $^2J_{CF}$ 29.9), 120.9 ($C^{8,9}$, $^1J_{CF}$ 283.8), 116.9 (C^7, $^1J_{CF}$ 275.3, $^2J_{CF}$ 37), 75.9 (C^5, $^2J_{CF}$ 32.3), 53.5 (C^{10}). ^{19}F NMR spectrum, δ_F, ppm (*J*, Hz): 97.7 d (6F, $F^{8,9}$, 23), 97.6 d (3F, F^7, 7), 41.5 q. septet (1F, F^6, 23, 7). ^{31}P NMR spectrum: δ_P 0.73 ppm. Mass spectrum, *m/z* (I_{rel}, %): 430 (23.89) $[M]^+$, 410 (12.03) $[M - F]^+$, 399 (10.36) $[M - CH_2O]^+$, 360 (52.67) $[M - CF_3]^+$, 335 (15.24), 294 (14.83), 119 (0.66) $[C_2F_5]^+$, 109 (100) $[O=P(OCH_3)_2]^+$, 100 (0.63) $[CF_2=CF_2]^+$, 69 (15.62) $[CF_3]^+$. Found *m/z* 428.9646 $[M]^+$. Calculated *M* 428.9646. Found, %: C 25.58; 25.61; H 1.46; 1.61; P 6.90; 7.00; S 7.40; 7.26. $C_9H_6F_{10}NO_3PS$. Calculated, %: C 25.17; H 1.40; P 7.23; S 7.46.

Diethyl [(4*E*)-5,5-bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl]phosphonate (XI). To a solution of 3.39 g of compound **I** and 1.09 g of Me_3SiCl in 10 ml of acetonitrile at 0°C we slowly (1 h) added with stirring 1.66 g of $(C_2H_5O)_3P$. The mixture was left to stand

for 24 h at room temperature and then heated for 0.5 h at 50°C. The solvent was removed in a water-jet-pump vacuum, and the residue was distilled to obtain 3.51 g (77%) of compound **XI**, bp 129.5–130.5°C (11 mm). IR spectrum (5% CCl_4) solution, ν, cm^{-1}: 2950, 2920, 2850 (C–H), 1690 (C=C), 1550 (C=N), 1350 (C–O), 1270–1160 (C–F). ^1H NMR spectrum (CD_2Cl_2), δ, ppm (*J*, Hz): 4.30 q. d (H^{10}, J_{HH} 7, $^3J_{HP}$ 8), 1.35 t (H^{11}, J_{HH} 7 Hz). ^{13}C NMR spectrum [$(CD_3)_2C=O$], δ_C, ppm (*J*, Hz): 169.8 (C^2, $^1J_{CP}$ 219.5, $^4J_{CF}$ 12.4), 158.5 (C^6, $^1J_{CF}$ 279.8, $^2J_{CF}$ 40.7), 137.9 (C^4, $^2J_{CF}$ 29.9), 120.9 ($C^{8,9}$, $^1J_{CF}$ 281.8), 116.8 (C^7, $^1J_{CF}$ 276.3, $^2J_{CF}$ 36.9), 80.4 (C^5, $^2J_{CF}$ 35.3), 64.3 (C^{10}), 14.7 (C^{11}). ^{19}F NMR spectrum, δ_F, ppm (*J*, Hz): 97.4 d (6F, $F^{8,9}$, 22.6), 97.2 d (3F, F^7, 6.5), 41.5 q. septet (1F, F^6, 22.6, 6.5). ^{31}P NMR spectrum: δ_P –2.5 ppm. Mass spectrum, *m/z* (I_{rel}, %): 457 (28.51) $[M]^+$, 438 (21.17) $[M - F]^+$, 413 (30.70) $[M - C_2H_4O]^+$, 397 (13.53) $[M - CF_3]^+$, 388 (28.30), 284 (69.67), 119 (0.66) $[C_2F_5]^+$, 100 (0.63) $[CF_2{=}CF_2]^+$, 93 (98.23) $[OPH(OC_2H_5)]^+$, 69 (35.87) $[CF_3]^+$, 45 (20.54) $[OC_2H_5]^+$. Found *m/z* 456.9956 $[M]^+$. Calculated *M* 456.9959. Found, %: C 29.10; 29.09; H 2.15; 2.25; P 7.40; 7.30; S 7.80; 7.10. $C_{11}H_{10}F_{10}NO_3PS$. Calculated, %: C 28.88; H 2.19; P 6.78; S 7.00.

[(4*E*)-5,5-Bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl]triphenylphosphonium tetrafluoroborate (XIIa) and tetraphenylborate (XIIb). To a mixture of compound **I** (1.02 g) and $NaBF_4$ (0.33 g) (or $NaBPh_4$, 1.03 g) in 10 ml of acetonitrile, cooled to –10°C, we added slowly (0.5 h) 3 mmol of triphenylphosphine in 10 ml of THF. The mixture was stirred at that temperature for 1 h and then for 3–4 h at room temperature. The ^{19}F and ^{31}P NMR spectra lacked fluorine signals of compound **I** and the phosphorus signal of triphenylphosphine (δ_P +5.9 ppm). Phosphonium salt **XIIa**. ^{19}F NMR spectrum (THF), δ_F, ppm (*J*, Hz): 98.1 (6F, $F^{8,9}$, 23), 98.0 (3F, F^7, 7), 47.2 (1F, F^6, 23, 7), ratio 6 : 3 : 1, respectively. ^1H NMR spectrum, δ, ppm: 7.74, 7.57, and 7.48 [$(C_6H_5)_3P$]. ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm (*J*, Hz): 163.7 (C^2, $^1J_{CP}$ 105.8, $^4J_{CF}$ 13.6), 151.4 (C^6, $^1J_{CF}$ 286.6, $^2J_{CF}$ 40.8), 161.7 (C^4, $^2J_{CF}$ 14.1), 136.6 (C^{13}, $^4J_{CP}$ 3), 122.9 (C^{11}, $^2J_{CP}$ 11.4), 129.9 (C^{12}, $^3J_{CP}$ 10.3), 120.7 ($C^{8,9}$, $^1J_{CF}$ 284.1), 116.6 (C^7, $^1J_{CF}$ 276.2, $^2J_{CF}$ 36.8), 112.2 (C^{10}, $^1J_{CP}$ 90.7), 73.3 (C^5, $^2J_{CF}$ 29.7). ^{31}P NMR spectrum, δ_P, ppm: –19 s.

Phosphonium salt **XIIb** (counterion BPh_4^-). The ^{19}F NMR spectrum was the same as that of compound **XIIb**, except that it lacked signal at 12.3 ppm (BF_4^-). ^1H NMR spectrum, δ, ppm: 7.74, 7.57 and 7.48 [$(C_6H_5)_3P$], 6.89 and 6.73 [$(C_6H_5)_4B$]. ^{31}P NMR spectrum: δ_P –20.4 ppm.

[(4*E*)-5,5-Bis(trifluoromethyl)-4-(tetrafluoroethylidene)-4,5-dihydro-1,3-thiazol-2-yl]tris(diethylamino)phosphonium tetrafluoroborate (XIIIa) and iodide (XIIIb). *a*. To a solution of 3.39 g of compound **I** and 1.1 g of $NaBF_4$ in 10 ml of MeCN, cooled to –10°C, we added with stirring 2.47 g of $P(NEt_2)_3$ over the course of 0.5 h. The mixture was kept for 1 h at that temperature and then for 3 h at room temperature. The ^{19}F and ^{31}P NMR spectra of the resulting solution lacked fluorine signals of compound **I** and the phosphorus signal of $P(NEt_2)_3$ (δ_P –118.2 ppm). Phosphonium salt **XIIIa**. ^1H NMR spectrum, δ, ppm: 3.25 (H^{10}) and 1.19 (H^{11}). ^{13}C NMR spectrum ($CDCl_3$), δ_C, ppm (*J*, Hz): 167.0 (C^2, $^1J_{CP}$ 184.7, $^4J_{CF}$ 13.5), 150.6 (C^6, $^1J_{CF}$ 285.3, $^2J_{CF}$ 40.8, $^4J_{CP}$ 13.5), 135.8 (C^4, $^2J_{CF}$ 30.1, $^3J_{CP}$ 30.0), 120.8 ($C^{8,9}$, $^1J_{CF}$ 285.0), 116.9 (C^7, $^1J_{CF}$ 242.5, $^2J_{CF}$ 36.8), 76.9 (C^5, $^2J_{CF}$ 29.7), 38.9 (C^{10}, $^3J_{CP}$ 10), 11.3 (C^{11}). ^{19}F NMR spectrum, δ_F, ppm (*J*, Hz): 98.2 (6F, $F^{8,9}$, 23), 98.0 (3F, F^7, 7), 46.4 (1F, F^6, 23, 7), ratio 6 : 3 : 1, respectively. ^{31}P NMR spectrum: δ_P –34.4 ppm.

b. To a mixture of 0.68 g of compound **I** and 0.34 g of KI in 3 ml of MeCN, cooled to –10°C, we added with stirring 0.5 g of $P(NEt_2)_3$ over the course of 15 min. The mixture was stirred for 1 h at that temperature and then for 3 h at room temperature. Phosphonium salt **XIIIb**. ^1H NMR spectrum, δ, ppm: 3.25 (H^{10}) and 1.19 (H^{11}). ^{19}F NMR spectrum, δ_F, ppm (*J*, Hz): 98.1 (6F, $F^{7,8}$, 22), 97.9 (3F, F^9, 7), 45.9 (1F, F^6, 22, 7), ratio 6 : 3 : 1, respectively; 6.8 (Me_3SiF). ^{31}P NMR spectrum: δ_P –36.1 ppm.

REFERENCES

1. Gilchrist, T.L., *Heterocyclic Chemistry*, London: Longman, 1992, 2nd ed.
2. Heinrich, M., *Int. Lab.*, 2000, vol. 30, no. 2, pp. 26–32.
3. *Organofluorine Compounds in Medicinal Chemistry and Biomedical Applications*, Filler, R., Kobayashi, Y., and Yagupolskii, L.M., Amsterdam: Elsevier, 1993.
4. Curran, D.P., *Angew. Chem., Int. Ed. Engl.*, 1998, vol. 37, no. 9, pp. 1174–1196.
5. Bhattachakyya, P., Gudmunsen, D., Hope, E.G., Kemmit, R.D., Paige, D.R., and Stuart, A.M., *J. Chem. Soc., Perkin Trans. 1*, 1997, no. 24, pp. 3609–3612.

6. Juliette, J.J.J., Rutherford, D., Horvath, I.T., and Gladysz, J.A., *J. Am. Chem. Soc.*, 1999, vol. 121, no. 8, pp. 2696–2704.
7. Chambers, R.D. and Edwards, A.R., *J. Chem. Soc., Perkin Trans. 1*, 1997, no. 24, pp. 3623–3627.
8. Vershilov, S.V., Popova, L.M., Mungalov, V.E., and Ryabinin, N.A., Abstracts of Papers, *1 Mezhdunarodnaya konferentsiya "Khimiya, tekhnologiya i primenenie ftorsoedinenii v tekhnike"* (1st Int. Conf. "Chemistry, Technology, and Application of Organofluorine Compounds in Technique"), St. Petersburg, 1994, pp. 3–16.
9. Furin, G.G., Pressman, L.S., Salmanov, I.A., and Zhuzhgov, E.L., *Zh. Obshch. Khim.*, 1999, vol. 69, no. 9, pp. 1499–1503.
10. Rogoza, A.V. and Furin, G.G., *Zh. Obshch. Khim.*, 1999, vol. 69, no. 9, pp. 1491–1498.
11. Furin, G.G., Gatilov, Yu.V., Kiriyanko, V.G., Rybalova, T.V., and Zhuzhgov, E.L., *Zh. Org. Khim.*, 1999, vol. 35, no. 10, pp. 1481–1488.
12. Rogoza, A.V. and Furin, G.G., *Zh. Org. Khim.*, 1997, vol. 33, no. 5, pp. 777–781.
13. Rogoza, A.V. and Furin, G.G., *Izv. Ross. Akad. Nauk, Ser. Khim.*, 1997, no. 4, pp. 831–834.
14 Jpn. Patent 05-04979, 1993, *Chem. Abstr.*, 1993, vol. 118, 207578.
15. Bey, P., Fozard, J., Lacoste, J., McDonald, I.A., Zreika, M., and Palfreyman, M.G., *J. Med. Chem.*, 1984, vol. 27, no. 1, pp. 9–10.
16. McDonald, I.A., Lacoste, J.M., Bey, P., Wagner, J., Zreika, M., and Palfreyman, M.G., *J. Am. Chem. Soc.*, 1984, vol. 106, no. 11, pp. 3354–3356.
17. Rogoza, A.V., Abstracts of Papers, *Int. Conf. on Natural Products and Physiologically Active Substances (ICNPAS-98)*, Novosibirsk, 1998, p. 149.
18. *Organofluorine Chemistry. Principles and Commercial Applications*, Banks, R.E., Smart, B.E., and Tatow, J.C., Eds., New York: Plenum, 1994, pp. 532–533.
19. Horvath, I.T., *Acc. Chem. Res.*, 1998, vol. 31, no. 10, pp. 641–650.
20. Juliette, J.J.J., Horvath, I.T., and Gladysz, J.A., *Angew. Chem., Int. Ed. Engl.*, 1997, vol. 36, no. 15, pp. 1610–1612.
21. Thornber, C.W., *Chem. Soc. Rev.*, 1979, vol. 8, no. 4, pp. 563–579.
22. Tammelin, L.E., *Svensk. Kem. Tidskr.*, 1958, vol. 70, no. 4, pp. 157–181.
23. Mukaiyama, T., Nambu, H., and Okamoto, M., *J. Org. Chem.*, 1962, vol. 27, no. 10, pp. 3651–3554.
24. *Comprehensive Organic Chemistry*, Barton, D. and Ollis, W.D., Oxford: Pergamon, 1979, vol. 2, p. 538.
25. Houben-Weyl, *Methoden der organischen Chemie*, Stuttgart: Thieme, 1963, vol. 12/1, p. 110.
26. Rogoza, A.V. and Furin, G.G., *Zh. Obshch. Khim.*, 1998, vol. 68, no. 5, pp. 798–806.
27. Lermontov, S.A., Rakov, I.M., and Martynov, I.V., Abstracts of Papers, *VI Vsesoyuznaya konferentsiya po khimii ftororganicheskikh soedinenii* (VI All-Union Conf. on Chemistry of Organofluorine Compounds), Novosibirsk, 1990, p. 193.
28. Sterlin, S.R., Dyatkin, B.A., Zhuravkova, L.G., and Knunyants, I.L., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1969, no. 5, pp. 1176–1178.
29. Rozhkov, I.N. and Borisov, Yu.A., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1992, no. 6, pp. 1334–1339.
30. *Fluka–Riedel-de Haen Laboratory Chemicals and Analytical Reagents: Catalog.* 1999/2000.
31. Chernyshev, E.A., Bucherenko, E.F., Akat'eva, A.S., and Naumov, A.D., *Zh. Obshch. Khim.*, 1975, vol. 45, no. 1, pp. 242–243.
32. Woznjak, L. and Choinowski, J., *Tetrahedron*, 1989, vol. 45, no. 9, pp. 2465–2524.
33. Breslow, R., *Acc. Chem. Res.*, 1980, vol. 13, no. 6, pp. 170–177.
34. Furin, G.G., Rogoza, A.V., Bagryanskaya, I.Yu., and Gatilov, Yu.V., *Zh. Org. Khim.*, 1997, vol. 33, no. 5, pp. 787–795.
35. Furin, G.G., Terent'eva, T.V., Rezvukhin, A.I., and Yakobson, G.G., *Zh. Obshch. Khim.*, 1975, vol. 45, no. 7, pp. 1473–1479.
36. Polezhaeva, N.A., Loginova, I.V., Ovechkina, E.V., Galkin, V.I., Sakhibullina, V.G., Cherkasov, R.A., Gubaidullin, A.T., Litvinov, I.A., and Naumov, V.A., *Zh. Obshch. Khim.*, 2000, vol. 70, no. 5, pp. 755–758.
37. Popkova, V.Ya., Mysov, E.I., Galakhov, M.V., Osmanov, V.K., and German, L.S., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1990, no. 12, pp. 2862–2865.