2-(Methylthio)pentafluoropropene

V. G. Andreev, A. Yu. Sizov, and A. F. Kolomiets*

A. N. Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences,
28 ul. Vavilova, 117813 Moscow, Russian Federation.
Fax: +7 (095) 135 5085

2-(Methylthio)pentafluoropropene was obtained by dehydrofluorination of methyl 2*H*-hexafluoroisopropyl sulfide by the $BF_3 \cdot NEt_3$ complex. Its reactivity with respect to allyl alcohol and hexamethyldisilazane was studied. The electrophilicity of 2-(methylthio)pentafluoropropene was compared with the properties of terminal polyfluoroalkenes whose behavior in these reactions has been studied previously.

Key words: 2-(methylthio)pentafluoropropene; terminal polyfluoroalkenes; [3,3]-sigmatropic rearrangement; deprotonation; 2-trifluoromethyl-2-methylthiopent-4-enoic acid and its derivatives; 2-methylthio-2*H*-trifluoropropionic acid nitrile.

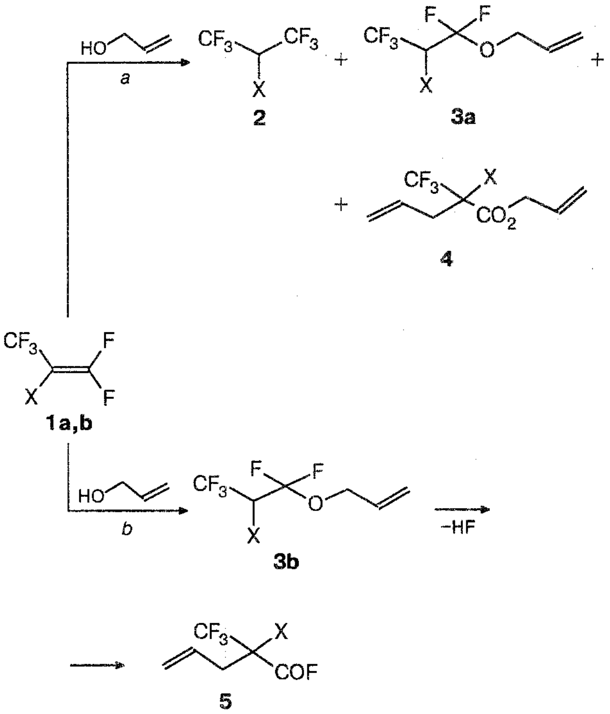
Reactions of terminal perfluoroalkenes (PFA) with 2,3-unsaturated alcohols under ambient conditions afford mixtures of adducts of the starting reactants and the products of a [3,3]-sigmatropic rearrangement (derivatives of fluorine-containing alkenoic acids). The ratio between the products depends on the structure of the PFA and the conditions of its reaction with an alcohol.[1,2] Perfluoroalkenes (**1a**), perfluoropropylene ($X = F$) and perfluoroisobutylene ($X = CF_3$), react with allyl alcohol in protophilic media* to give a mixture of products of the addition of HF (**2**) and allyl alcohol (**3a**) to the starting alkene as well as rearrangement products (**4**) (Scheme 1). On the other hand, highly electrophilic PFA functionally substituted at position 2 (**1b**) react with allyl alcohol in the absence of bases even at low temperatures to give only adducts (**3b**), whose deprotonation allows the rearrangement products (**5**) to be prepared in high yields.[1,2]

Thus, the behavior of terminal PFA in reactions with 2,3-unsaturated alcohols, including their trend to form the products of [3,3]-sigmatropic rearrangement, is one of the qualitative characteristics of the state of the C=C bond in these compounds, which makes it possible to differentiate them according to their electrophilic properties.

Therefore, we were interested in using the reactions with 2,3-unsaturated alcohols, specifically, with allyl alcohol, to estimate the relative electrophilicities of both known and newly synthesized, unsubstituted or functionally 2-substituted terminal PFA. Below are presented the results of this study carried out using 2-(methylthio)pentafluoropropene as an example.

Up to the present work, of the terminal 2-alkylthio substituted PFA, only 2-(ethylthio)pentafluoropropene

Scheme 1



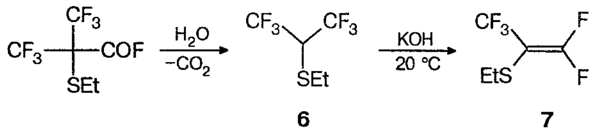
a: X = F, CF_3
b: X = CO_2Me, COF, SO_2F

---

* Perfluoroisobutylene also reacts with allyl alcohol in the absence of protophilic agents.[3,4]

Translated from *Izvestiya Akademii Nauk. Seriya Khimicheskaya,* No. 1, pp. 80—84, January, 1994.

(**7**) was known. Compound **7** was prepared in 58 % yield by dehydrofluorination of ethyl 2*H*-hexafluoroisopropyl sulfide (**6**) with powdered KOH in ether.[5]



Of the properties of compound **7**, its transformation in the presence of the fluoride ion has been studied.[5] Other properties of propene **7** have not been investigated.

We prepared another compound of this type: 2-(methylthio)pentafluoropropene (**11**) and studied its behavior in reactions with allyl alcohol and hexamethyldisilazane.

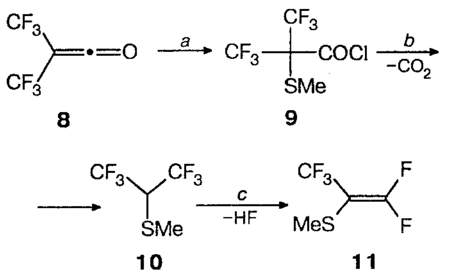
The synthesis of propene **11** was carried out as presented in Scheme 2.

Methylsulfenyl chloride smoothly adds to bis(trifluoromethyl)ketene (**8**) without a catalyst* to give 2-(methylthio)hexaflouroisobutyroyl chloride (**9**), which is readily hydrolyzed by water with simultaneous decarboxylation, similarly to 2-ethylthio- and 2-(phenylthio)hexafluoroisobutyroyl chlorides,[5] to give methyl 2*H*-hexafluoroisopropyl sulfide (**10**) in 72 % yield. The $BF_3 \cdot NEt_3$ complex proved to be a convenient dehydrofluorinating agent for preparing compound **11**. The reaction of sulfide **10** with this base in a sealed tube at 150 °C affords propene **11** in a high yield (73 %).

The ability of propene **11** to undergo [3,3]-sigmatropic rearrangement was studied by looking at its reaction with allyl alcohol with or without a base.

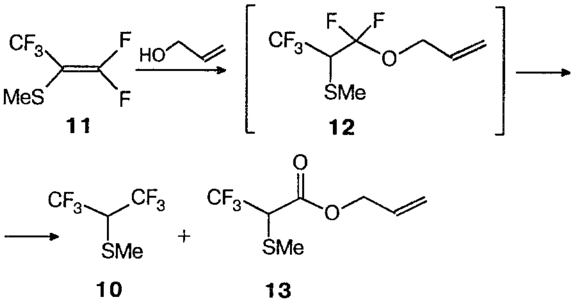
In the absence of a base, propene **11**, like perfluoropropylene, does not react with allyl alcohol even at 80 °C. Under more rigorous conditions (145 °C, a sealed tube) this reaction affords a mixture of products, from which sulfide **10** and allyl 2-methylthio-2*H*-trifluoropropionate (**13**) (in a low yield, 24 %) were isolated (Scheme 3).

Scheme 2



Reagents and conditions: *a*. MeSCl; *b*. H_2O, diglyme; *c*. $BF_3 \cdot NEt_3$, 150 °C.

Scheme 3



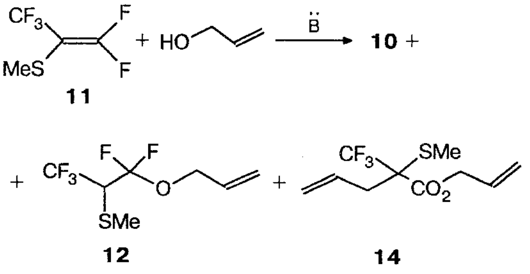
The formation of ester **13** may be due to the hydrolytic cleavage under the reaction conditions of the primary adduct, allyl 2-methylthio-2*H*-pentafluoropropionate (**12**), formed from the starting compounds.

Introduction of bases into the area of the reaction under study dramatically changes its route and conditions. In the presence of a catalytic amount of KOH, propene **11** undergoes an exothermic reaction with allyl alcohol to give a mixture of three products: sulfide **10**, ester **12**, and the product of the [3,3]-sigmatropic rearrangement, allyl 2-methylthio-2-trifluoromethylpent-4-enoate (**14**), whose yield is as high as 25 % (Scheme 4).

In a KF/DMF system propene **11** reacts with allyl alcohol in a similar way, and the yield of ester **14** increases to 32 %. It should be noted that in both cases substantial amounts (up to 30 %) of sulfide **10** are formed. This attests that the fluorinated propene **11**, similarly to its homolog **7** (see Ref. 5), is a relatively efficient acceptor of fluoride ions.

The conditions in which this reaction takes place and the composition of its products make it possible to conclude that propene **11**, though it ranks below other functionally 2-substituted PFA **1b** and perfluoroisobutylene in electrophilicity, exceeds perfluoropropylene in its reactivity towards allyl alcohol and in its tendency to

Scheme 4

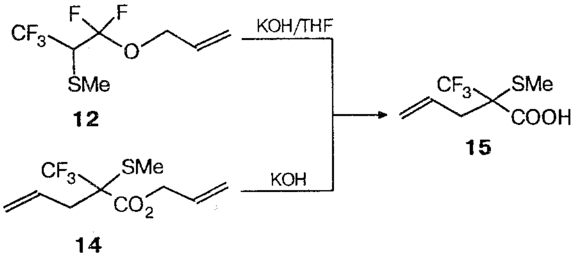


$\ddot{B}$ = KOH, KF/DMF

---

* Addition of phenylsulfenyl chloride to ketene **8** occurs with catalysis by pyridine.[6]

Scheme 5

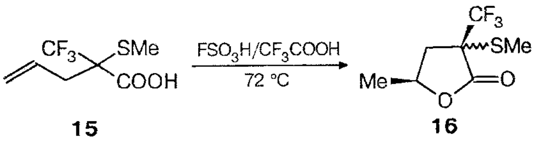


give the rearrangement products in this reaction (the yield of the rearrangement product in the reaction of perfluoropropylene with allyl alcohol in the presence of bases[2] is no more than 15 %).

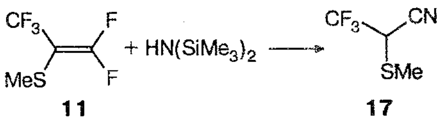
The products of [3,3]-sigmatropic rearrangement are also formed during deprotonation of allyl 2*H*-polyfluoroalkyl ethers **3a**,**b**. The particular deprotonating agent is determined by the CH-acidic properties of the starting adducts **3a**,**b**. In the case of **3a**, KOH is the appropriate agent, while for stronger CH-acids, **3b**, a weaker base, the $BF_3 \cdot NEt_3$ complex, is used.[1,2]

The CH-acidic properties of adduct **12** turned out to be close to those of ether **3a** (X = F), which reacts[7] with KOH only in protophilic solvents (DMSO and DMF) at 60 °C. A high yield (67 %) of the rearrangement product was obtained when compound **12** reacted with KOH in THF (Scheme 5). Acid **15** was also synthesized in 84 % yield by alkaline hydrolysis of ester **14** in an aqueous methanolic solution at 70—73 °C.

Alk-4-enoic acids are convenient precursors for practically valuable compounds such as 4-butanolides, however known methods for the synthesis of the latter[8] are not necessarily applicable to fluorine-containing unsaturated acids with a deactivated double bond. The recently developed method of lactonization[9,10] allows 4-butanolids to be prepared from 2-trifluoromethyl substituted alk-4-enoic acids and their methyl esters under mild conditions. In fact, acid **15** smoothly and stereoselectively cyclizes in trifluoroacetic acid in the presence of a catalytic amount of fluorosulfonic acid to give 2-trifluoromethyl-2-methylthio-4-methyl-4-butanolide (**16**) as a mixture of *cis*- and *trans*-stereoisomers in 8:1 ratio in 74 % total yield.



Another characteristic reaction which qualitatively determines the state of the C=C bond in terminal PFA is their interaction with hexamethyldisilazane (HMDS) (see Refs. 11,12). PFA **1b** (X = CO_2Me, SO_2F) vigorously react with HMDS at moderate cooling and dilution, perfluoroisobutylene reacts at ambient temperature over 24 h, while the least electrophilic perfluoropropylene does not undergo[11] reaction with HMDS even when heated (above 100 °C) in a sealed tube for a long period. We managed to accomplish the reaction of the fluorinated propene **11** with HMDS over 8 h at 120 °C. The yield of the reaction product, 2-methylthio-2*H*-trifluoropropionitrile (**17**), was 60 %.



The results obtained indicate that the electrophilicity of propene **11** is markedly higher than that of perfluoropropylene. However, the other functionally 2-substituted PFA **1b** and even perfluoroisobutylene are far more active in reactions with nucleophilic agents than compound **11**. Thus, the electrophilic properties of the terminal 2-substituted PFA of general formula $CF_3C(X)=CF_2$ increase in the following order of X: $F < MeS < CF_3 < COOMe < COF < SO_2F$, which apparently corresponds to the electron-withdrawing ability of these substituents.

Yields, physicochemical properties, and the elemental analysis data for the compounds synthesized are given in Table 1. The structures of the compounds were confirmed by ^1H and ^{19}F NMR and IR absorption spectroscopy (Table 2).

Experimental

^1H and ^{19}F NMR spectra were recorded on a Bruker WP 200SY spectrometer operating at 200.1 and 188.3 MHz, respectively. Chemical shifts are given in ppm and referred to TMS (^1H, internal standard) or CF_3COOH (^{19}F, external standard). IR spectra were obtained on an UR-20 instrument.

2-(Methylthio)hexafluoroisobutyryl chloride (9). A sealed glass ampule containing a mixture of ketene **8** (9.0 g, 50 mmol) and methylsulfenyl chloride (4.1 g, 50 mmol) obtained at −60 °C was slowly heated to ~20 °C and fractionated.

Methyl 2*H*-hexafluoroisopropyl sulfide (10). 20 mL of water was added dropwise to a cooled (−10÷0 °C) and stirred solution of chloride **9** (13.0 g, 50 mmol) in 30 mL of diglyme. When the intense evolution of carbon dioxide was completed, the reaction mixture was heated to 70 °C, cooled, and diluted with water (60 mL). The organic layer was thoroughly washed with water (3×30 mL), dried with Na_2SO_4, and fractionated *in vacuo* (140 Torr) over concentrated H_2SO_4 and then at atmospheric pressure over P_2O_5.

2-(Methylthio)pentafluoropropene (11). A mixture of sulfide **10** (10.0 g, 50 mmol) and complex $BF_3 \cdot NEt_3$ (16.9 g, 100 mmol) was heated in a sealed glass ampule for 5 h at 150 °C. After cooling the reaction mixture in a vacuum (1 Torr), the volatile compounds were recondensed into a cooled (−78 °C) trap. The contents of the trap were fractionated.

Allyl 2-methylthio-2*H*-trifluoropropionate (13). A mixture of propene **11** (3.6 g, 20 mmol) and allyl alcohol (2.0 g, 34.5 mmol) was heated in a sealed glass ampule for 3.5 h at

Table 1. Yields, physicochemical properties, and the data of elemental analysis for compounds **9—17**

Compound	Yield* (%)	B.p./°C (p/Torr)	d_4^{22} (M.p./°C)	n_D^{22}	$\frac{\underline{\text{Found}}}{\text{Calculated}}$ (%) C	H	F	S	Molecular formula
9	82	45 (30)	—	1.3850	$\underline{22.87}$ 23.04	$\underline{1.01}$ 1.16	$\underline{43.52}$ 43.75	$\underline{12.04}$ 12.30	$C_5H_3ClF_6OS$
10	72	79—80	—	1.3542	$\underline{24.11}$ 24.25	$\underline{2.01}$ 2.04	$\underline{57.23}$ 57.54	$\underline{16.04}$ 16.18	$C_4H_4F_6S$
11	73	66—67	—	1.3550	$\underline{26.68}$ 26.97	$\underline{1.67}$ 1.70	$\underline{53.27}$ 53.33	$\underline{18.13}$ 18.00	$C_4H_3F_5S$
12	36 (30)	75 (27)	1.317	1.3966	$\underline{35.57}$ 35.59	$\underline{3.93}$ 3.81	$\underline{39.83}$ 40.25	$\underline{13.49}$ 13.56	$C_7H_9F_5OS$
13	24	68 (8)	—	1.4193	$\underline{39.54}$ 39.25	$\underline{4.38}$ 4.21	$\underline{26.45}$ 26.64	$\underline{14.78}$ 14.95	$C_7H_9F_3O_2S$
14	25 (32)	114 (22)	1.224	1.4438	$\underline{47.05}$ 47.24	$\underline{5.14}$ 5.12	$\underline{22.51}$ 22.44	$\underline{12.76}$ 12.60	$C_{10}H_{13}F_3O_2S$
15	67 (84)	87 (0.8)	(39.5)	—	$\underline{39.51}$ 39.25	$\underline{4.30}$ 4.21	$\underline{26.62}$ 26.64	$\underline{15.16}$ 14.95	$C_7H_9F_3O_2S$
16	74	55 (1)	1.355	1.4340	$\underline{39.18}$ 39.25	$\underline{4.22}$ 4.21	$\underline{26.67}$ 26.64	$\underline{14.88}$ 14.95	$C_7H_9F_3O_2S$
17	60	71 (75)	—	1.3985	$\underline{30.77}$ 30.97	$\underline{2.52}$ 2.58	$\underline{36.64}$ 36.77	$\underline{20.49}$ 20.65	$C_4H_4F_3NS$

*For compounds **12**, **14**, and **15**, the yields in reactions carried out according to procedure **b** are given in parentheses.

Table 2. Parameters of ^1H, ^{19}F NMR and IR spectra for compounds **9—17**

Compound	^1H NMR (δ)*	^{19}F NMR (δ)	IR (ν/cm^{-1})
9	2.41 s	−14.6 s	—
10	2.46 (s, 3 H, SMe); 4.71 (sept, 1 H, CH, J = 7.5 Hz)	−10.9 (d, J = 7.5 Hz)	—
11	2.40 s	−15.8 (d.d, 3 F, CF_3, J = 21.4, 10.5 Hz); −12.4 and −8.7 (d.q, 2 F, CF_2, J = 4.2, 10.5, 21.4 Hz)	1700 (C=C)
12	1.78 (s, 3 H, SMe); 3.00—3.19 (m, 1 H, CH); 4.11 and 4.15 (both d.d, 2 H, OCH_2, J = 1.2, 1.2, 5.5 Hz); 4.94 and 5.09 (both d.d, 2 H, $=CH_2$, J = 1.8, 10.5, 17.0 Hz); 5.48—5.70 (m, 1 H, CH=)	−12.0 (d.t, 3 F, CF_3, J = 7.5, 10.0 Hz); −6.7 and −5.5 (both m, 2 F, CF_2)	1655 (C=C)
13	1.81 (s, 3 H, SMe); 3.50 (q, 1 H, CH, J = 8.0 Hz); 4.28 and 4.32 (both d.d, 2 H, OCH_2, J = 1.2, 1.2, 5.5 Hz); 4.95 and 5.09 (both d.d, 2 H, $=CH_2$, J = 1.8, 10.5, 17.0 Hz); 5.47—5.67 (m, 1 H, CH=)	−10.4 (d, J = 8.0 Hz)	1750 (C=O); 1655 (C=C)
14	1.88 (s, 3 H, SMe); 2.70 and 2.80 (both d.d, 2 H, C—CH_2, J = 7.5, 7.5, 15.2 Hz); 4.33 (d.d, 2 H, OCH_2, J = 1.2, 5.5 Hz); 4.89—5.12 (m, 4 H, $=CH_2$); 5.48—5.70 (m, 1 H, CH=); 5.71—5.93 (m, 1 H, CH=)	−10.4 s	1745 (C=O); 1660 (C=C)
15	1.86 (s, 3 H, SMe); 2.63 and 2.75 (both d.d, 2 H, C—CH_2, J = 7.5, 7.5, 15.2 Hz); 4.97 and 5.05 (both d.d, 2 H, $=CH_2$, J = 1.8, 10.5, 17.0 Hz); 5.64—5.86 (m, 1 H, CH=), 11.30 (s, 1 H, OH)	−10.7 s	3100 (OH); 1725 (C=O); 1645 (C=C)
16	0.85 (*cis*) and 1.07 (*trans*) (both d, 3 H, Me, J = 6.0 Hz); 1.60 and 1.82 (both d.d, 2 H, CH_2, J = 5.5, 10.0, 15.0 Hz); 2.00 (*cis*) and 2.07 (*trans*) (both s, 3 H, SMe); 4.18—4.37 (m, 1 H, CH)	−5.8 (s, *cis*) −6.3 (s, *trans*)	1780 (C=O)
17	2.43 (s, 3 H, SMe); 4.10 (q, 1 H, CH, J = 7.6 Hz)	−9.5 (d, J = 7.6 Hz)	2270 (C≡N)

* $CDCl_3$ was used as the solvent for compounds **9** and **17**; acetone-d_6 was used for **10** and **11**, and C_6D_6 was used for **12—16**.

145—150 °C. After cooling, the reaction mixture was diluted with ether (30 mL) and thoroughly washed with water. The ethereal layer was dried with $CaCl_2$ and fractionated.

Allyl 2-methylthio-2*H*-pentafluoropropyl ether (12) and allyl 2-trifluoromethyl-2-(methylthio)pent-4-enoate (14).

a. Powdered KOH (0.5 g, 9 mmol) was added to a cooled (10—15 °C) and stirred solution of propene **11** (7.8 g, 44 mmol) in 20 mL of allyl alcohol. The reaction mixture was stirred for 2 h at 30 °C, diluted with water (60 mL), and extracted with ether. The extract was washed with water (2×50 mL), dried with $CaCl_2$, and fractionated.

b. At 15—20 °C propene **11** (6.4 g, 36 mmol) was slowly added dropwise to a stirred suspension containing 10 mL of allyl alcohol and freshly calcined powdered KF (3.0 g, 53 mmol) in 25 mL of abs. DMF. The reaction mixture was stirred for 1.5—2 h at 25—30 °C and thoroughly washed with water (3×60 mL). The organic layer was dried and fractionated.

2-Trifluoromethyl-2-(methylthio)pent-4-enoic acid (15).

a. Powdered KOH (1.7 g, 30 mmol) was added at ~20 °C to a stirred solution of ether **12** (2.4 g, 10 mmol) in 20 mL of abs. THF. The reaction mixture was stirred for 2.5 h at 65 °C and cooled and the solvent was evaporated *in vacuo*. The solid residue was dissolved in water (40 mL), the aqueous solution was treated with 20 % H_2SO_4, until pH was ~1, and extracted with ether. The extract was thoroughly washed with water, dried with $CaCl_2$, and fractionated.

b. At ~20 °C a solution of KOH (1.35 g, 24 mmol) in 15 mL of aqueous methanol (1:2) was added dropwise to a stirred solution of ester **14** (3.0 g, 12 mmol) in 15 mL of aqueous methanol (1:5). The reaction mixture was stirred for 2 h at 70—73 °C and cooled. The solvent was evaporated *in vacuo*. The reaction product was isolated as described in procedure **a**.

2-Trifluoromethyl-2-methylthio-4-methyl-4-butanolide (16). A solution of acid **15** (3.1 g, 14.5 mmol) and fluorosulfonic acid (0.5 g, 0.5 mmol) in 8 mL of trifluoroacetic acid was boiled for 2 h, cooled, diluted with water (35 mL), and extracted with ether. The extract was thoroughly washed with water, dried with $CaCl_2$, and fractionated.

2-Methylthio-2*H*-trifluoropropionitrile (17). A mixture of propene **11** (3.6 g, 20 mmol) and hexamethyldisilazane (3.2 g, 20 mmol) was heated in a sealed glass ampule for 8 h at 120 °C. After cooling, the reaction mixture was fractionated.

References

1. V. G. Andreev, A. F. Kolomiets, and A. V. Fokin, *J. Fluorine Chem.*, 1992, **56**, 259.
2. V. G. Andreev and A. F. Kolomiets, *Usp. Khim.*, 1993, **62**, 594 [*Russ. Chem. Revs.*, 1993, **62** (Engl. Transl.)].
3. R. J. Kosharm, T. C. Simmons, and F. W. Hoffmann, *J. Am. Chem. Soc.*, 1957, **79**, 1741.
4. C. G. Krespan, *Tetrahedron*, 1967, **23**, 4243.
5. Yu. V. Zeifman and L. T. Lantseva, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1980, 1102 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1980, **29**, 809 (Engl. Transl.)].
6. Yu. V. Zeifman, L. T. Lantseva, and I. L. Knunyants, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1978, 2640 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1978, **27**, 2362 (Engl. Transl.)].
7. V. G. Andreev, A. F. Kolomiets, and G. A. Sokol'skii, *Zh. Vsesoyuzn. Khim. Obshch.*, 1980, **25**, 106·[*Mendeleev Chem. J.*, 1980, **25** (Engl. Transl.)].
8. S. Kano, S. Shibuya, and T. Ebata, *Heterocycles*, 1980, **14**, 661.
9. V. G. Andreev, A. F. Kolomiets, and G. A. Sokol'skii, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1991, 516 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1991, **40**, 449 (Engl. Transl.)].
10. V. G. Andreev, A. F. Kolomiets, and A. V. Fokin, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1991, 2805 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1991, **40**, 2447 (Engl. Transl.)].
11. A. Yu. Sizov, A. F. Kolomiets, and A. V. Fokin, *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1987, 2262 [*Bull. Acad. Sci. USSR, Div. Chem. Sci.*, 1987, **36**, 2095 (Engl. Transl.)].
12. Yu. L. Yagupol'skii, V. A. Soloshonok, and I. I. Gerus, *Zh. Org. Khim.*, 1986, **22**, 1828 [*J. Ogr. Chem. USSR*, 1986, **22** (Engl. Transl.)].

Received June 24, 1993