Russian Journal of Organic Chemistry, Vol. 38, No. 2, 2002, pp. 176–181. Translated from Zhurnal Organicheskoi Khimii, Vol. 38, No. 2, 2002, pp. 196–201.

Reactions of Polyfluorinated 3-Substituted 2,4-Cyclohexadienones with Alkynes

V. N. Kovtonyuk and L. S. Kobrina

Novosibirsk Institute of Organic Chemistry, Siberian Division, Russian Academy of Sciences, Novosibirsk, 630090 Russia

Received Spril 18, 2001

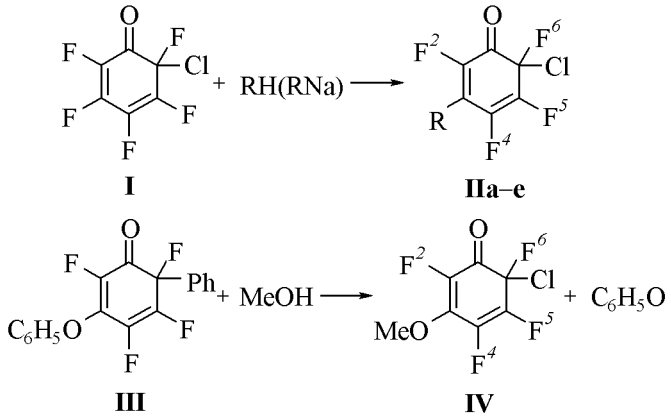
Abstract—Reactions of 2,3,4,5,6-pentafluoro-6-chloro-2,4-cyclohexadienone with anthranylic acid, 2,6-dichloro- and 2,6-dimethylaniline, diethylamine, sodium azide, and also the reaction of 6-phenyl-3-pentafluorophenoxy-2,4,5,6-tetrafluoro-2,4-cyclohexadienone with methanol afford 3-substituted 2,4,5,6-tetrafluoro-2,4-cyclohexadienones. The 3-methoxy-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone and 3-methoxy-6-phenyl-2,4,5,6-tetrafluoro-2,4-cyclohexadienone form cycloadducts with 1-hexyne and propargyl alcohol that under treatment with propyl alcohol in the presence of potassium carbonate undergo ring cleavage to furnish propyl arylfluorochloroacetates and diarylacetates. The reaction between 3-azido-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone and phenylacetylene gives rise to 4-oxo-2-phenyl-3,5,6,7-tetrafluoro-5-chlorobicyclo[4.1.0]hept-2-ene-7-carbonitrile.

Derivatives of arylacetic acids are physiologically active compounds and are contained in quite a number of drugs [1]. Fluorine atoms introduced into these compounds often increase the activity simultaneously reducing their toxicity and enhancing stability [2–4]. We showed formerly that the polyfluorinated 2,4-cyclohexadienones reacted with substituted acetylenes under relatively mild conditions affording in a high yield cycloadducts that under treatment with alcohols or amines underwent ring opening to furnish fluoro-containing derivatives of arylacetic acids [5]. The possibility of introduction by nucleophilic reactions of various substituents into *3* position of 2,4-cyclohexadienones, the use of diverse alkynes, and alcohols or amines for cleavage of bicyclic adducts provide extensive opportunities for preparation of fluoro-containing derivatives of arylacetic acids. Formerly to cycloaddition were applied as a rule 2,4-cyclohexadienes containing in *3* position a fluorine atom or C_6F_5O group [5]. It is known that the polyfluorinated 2,4-cyclohexadienes with the other substituent, e.g., MeO group, undergo cycloaddition with dehydrobenzene [6] but not with fluorostyrenes [7].

We report here on the synthesis of polyfluorinated 2,4-cyclohexadienones containing in *3* position methoxy, carboxy-, 2,6-dimethylanilino- and 2,6-dichloroanilino, diethylamino, and azido groups, and on their reactions with alkynes (1-hexyne, propargyl alcohol, and phenylacetylene).

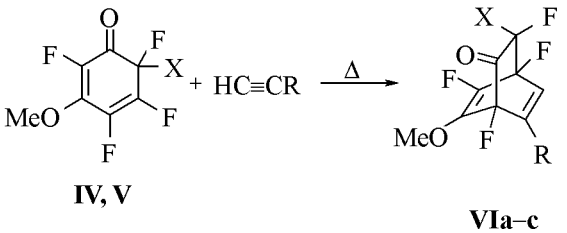
In reactions of 2,3,4,5,6-pentafluoro-6-chloro-2,4-cyclohexadienone (**I**) with anthranylic acid, 2,6-dichloro- and 2,6-dimethylaniline, diethylamine, and sodium azide, were obtained 3-substituted 2,4,5,6-tetrafluoro-2,4-cyclohexadienones (**IIa–e**); and the reaction of 6-phenyl-3-pentafluorophenoxy-2,4,5,6-tetrafluoro-2,4-cyclohexadienone (**III**) with methanol afforded 3-methoxy-6-phenyl-2,4,5,6-tetrafluoro-2,4-cyclohexadienone (**IV**).

The composition and structure of 3-substituted tetrafluoro-2,4-cyclohexadienones **IIa–e** and **IV** were derived from the data of elemental analyses and from comparison of the ^{19}F NMR spectra (see table) with the published spectra of polyfluorinated 2,4-cyclo-



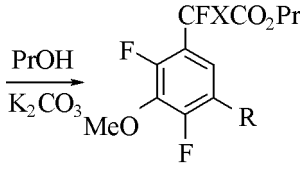
II, R = $NHC_6H_4CO_2H$-2 (a), $NHC_6H_3Cl_2$-2,6 (**b**), $NHC_6H_3Me_2$-2,6 (**c**), NEt_2 (**d**), N_3 (**e**).

1070-4280/01/3802-176$27.00



IV, V

VIa–c



VIIa–c

IV, V = Ph; **V** = Cl; **VI, VII**, X = Cl, R = Bu (**a**); X = Cl, R = CH_2OH (**b**); X = Ph, R = Bu (**c**).

hexadienones [8]. Azidodienone **IIe** that we also prepared by reaction of dienone **I** with trimethylsilyl azide was stable only in solution and decomposed on removing the solvent.

We showed previously that dienone **IV** did not react with fluorostyrenes and instead underwent isomerization into 3-methoxy-6-phenyl-2,4,4,5-tetrafluoro-2,5-cyclohexadienone [7]. The cycloaddition of 3-methoxy-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (**V**) with dehydrobenzene occurred with low yield (37%) [6]. In order to overcome this difficulty we used excess acetylenes in reactions with methoxy-2,4-cyclohexadienones.

The reaction of 3-methoxy-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (**V**) with excess 1-hexyne was carried out at 70°C, with excess propargyl alcohol at 110°C. From the reaction mixtures were isolated the corresponding fluorocontaining bicyclo[2.2.2]octadienones **VIa, b**.

The heating in 1-hexyne to 70°C of a mixture containing dienone **IV** and pentafluorophenol that was obtained by treating dienone **III** with methanol gave rise to a products mixture that was subjected to chromatography on silica gel to isolate cycloadduct **VIc**.

The cleavage of cycloadducts **VIa–c** by 1-propanol in the presence of freshly calcined potassium carbonate afforded fluorocontaining propyl esters of aryl- and diarylacetic acids **VIIa–c**.

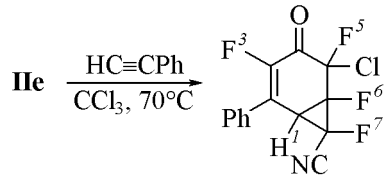
The composition and structure of cycloadducts **VIa–c** and esters **VIIa–c** were established from elemental analyses and from comparison of their ^1H and ^{19}F NMR spectra with the published spectra of model compounds [5].

^{19}F NMR spectra of 3-substituted tetrafluoro-2,4-cyclohexadienones **IIa–e, IV**

Compd. no. (solvent)	Chemical shifts, δ_F, ppm (from C_6F_6)			
	F^2	F^4	F^5	F^6
IIa ($CDCl_3$)	11.1	12.4	14.3	40.9
IIb ($CDCl_3$)	–8.6	0	12.4	31.1
IIc (CH_3CN)	–12.5	10.7	16.5	40.8
IId (CCl_4)	–2.3	15.8	16.5	39.3
IIe (CH_3CN)	11.9	11.8	15.1	37.5
IV (CCl_4)	–5.7	7.0	19.9	2.5

The reaction of dienone **IId** with 1-hexyne and propargyl alcohol yields complex mixtures where are lacking in the spectra the fluorine signals characteristic of cycloaddition products (from fluorine atoms F^1 and F^4 in the region –39… –45 ppm). The reaction of dienone **IIc** with 1-hexyne also did not yield cycloaddition products.

The lack of cycloaddition products in reactions of dienones **IId, c** with alkynes may be caused either by instability of these products under reaction conditions or by generally decreasing reactivity toward cycloaddition at introducing electron-donor substituents into *3* position of polyfluorinated 2,4-cyclohexadienone. We hoped that with less electron-donor substituent, namely, with azido group, we would succeed in obtaining cycloaddition products of reaction between dienone **IIe** and phenylacetylene. However the heating of dienone **IIe** with phenylacetylene in CCl_4 to 70°C gave rise to a reaction mixture, from which we isolated as a prevailing product 4-oxo-2-phenyl-3,5,6,7-tetrafluoro-5-chlorobicyclo[4.1.0]-hept-2-ene-7-carbonitrile (**VIII**).



VIII

The composition and structure of compound **VIII** are confirmed by elemental analysis, IR, ^1H, ^{19}F, and ^{13}C NMR spectra.

In its IR spectrum appears a weak absorption band of CN group vibrations at 2240 cm^{-1}. In the ^1H NMR spectrum (recorded in CCl_4) are present signals in the

region 7.2–7.4 ppm (Ar–H), and a signal at 3.4 ppm, d.d.d (H^1, J_{HF} 19.7, 17.0, 4.0 Hz).

The ^{19}F NMR spectrum (in CCl_4) of compound **VIII** contains 4 signals of equal intensity. The signals at –28.0 ppm, d.d.d.d (J_{HF} 17.0, J_{FF} 7.2, ~3.0, ~2.0 Hz) and –42.3 ppm, d.d.d (J_{HF} 19.7, J_{FF} 13.0, ~2.0 Hz) we assigned to atoms F^6 and F^7. The resonances at 34.8 ppm, d.d (J_{HF} 4.0, J_{FF} ~3.0 Hz) and 52.8 ppm, d.d (J_{FF} 13.0, 7.2 Hz) were assigned to F^3 and F^5 respectively. Two large vicinal coupling constants J_{HF} 19.7 and 17.0 Hz in the ^1H and ^{19}F spectra suggest reciprocal *cis*-position of atoms H^1, F^6 and F^7 in the cyclopropane ring for the *trans*-vicinal coupling constant of atoms H and F in the fluorinated cyclopropanes is commonly small (J_{HF} ~1–2 Hz) [9].

In the ^{13}C NMR spectrum (in acetone-d_6) of compound **VIII** recorded with wide-band decoupling from protons appear 12 signals at 34.12, 73.52, 79.77, 100.27, 109.77, 129.96, 130.15, 130.89, 132.01, 133.10, 148.44, 173.74 ppm. The signal at 34.21 ppm, d.d.d ($^2J_{CF}$ 14.4, $^2J_{CF}$ 11.9, $^3J_{CF}$ 4.1 Hz) is coupled with two neighboring fluorine atoms (F^6, F^7), and we assigned the signal to the nodal carbon C^1. In the spectrum recorded in monoresonance mode to this signal corresponds also a coupling constant J_{CH} 174.5 Hz. The signals at 73.52 ppm, d.d.d.d ($^1J_{CF}$ 254.2, $^2J_{CF}$ 12.3, J_{CF} 6.0, J_{CF} 3.7 Hz) and 79.77 ppm, d.d.d.d ($^1J_{CF}$ 265.4, $^2J_{CF}$ 24.9, $^2J_{CF}$ 10.4, $^4J_{CF}$ 1.5 Hz), coupled both with the directly bonded fluorine atoms and with those attached to the neighboring carbons we ascribed to carbon atoms C^7 and C^1 respectively. The signal at 100.27 ppm, d.d.d.d ($^1J_{CF}$ 249.4, $^2J_{CF}$ 16.4, $^3J_{CF}$ 6.0, $^3J_{CF}$ 2.6 Hz) was assigned to C^5 atom from the CFCl group (cf. with chemical shifts of carbon in the CFCl group of acetylene cycloaddition products to 2,4-cyclohexadienones, ~93–95 ppm [10]). The resonance at 109.77 ppm, d.d.d ($^2J_{CF}$ 32.8, J_{CF} 2.8, J_{CF} ~1 Hz) coupled with a single neighboring fluorine atom was assigned to the carbon of cyano group in agreement with the chemical shifts of ^{13}C in nitriles [11].The signals at 129.96 d (J_{CF} 6.0 Hz), 130.16 s, 130.89 d (J_{CF} ~3 Hz) and 133.10 s, ppm we ascribed to the carbon atoms of the phenyl ring. The signals at 132.01 ppm, d ($^2J_{CF}$ 13.0 Hz) and 148.44 ppm, d.d.d ($^1J_{CF}$ 270.2, J_{CF} 3.4, J_{CF} 1.5 Hz) were regarded as belonging to the carbon atoms of the bond $C^2=C^3$ respectively. The signal at 173.74 ppm, t.d ($^1J_{CF}$ 22.7, J_{CF} 3.3 Hz) was considered to be C^4 of the carbonyl group.

We believe that formation of cyclopropane derivative **VIII** may be described by the following scheme.

At the first stage of the reaction arose the product of normal [4+2]-cycloaddition **IX** of phenylacetylene to the diene system of dienone **IIe**. We tried to detect the formation of cycloadduct **IX** changing the reaction conditions. For instance, after keeping an equimolar mixture of dienone **IIe** and phenylacetylene in acetonitrile at room temperature for 3 days we observed in the ^{19}F NMR spectrum of the reaction mixture ~67% of dienone **IIe**, ~20% of cycloadduct **IX**, and traces of compound **VIII**. In three weeks the amounts of dienone **IIe** and compounds **IX** and **VIII** became about equal; after eight week standing the reaction mixture contained ~70% of compound **VIII**.

In the ^{19}F NMR spectrum (in MeCN) of cycloadduct **IX** we observed 4 signals of equal intensity at –34.3 d.d (F^4, $J_{FH(FF)}$ 7.2, $J_{F^4F^1}$ 2.7 Hz), –33.8 d.d.d.d (F^1, $J_{F^1F^7}$ 14.4, $J_{FH(FF)}$ 11.7, $J_{FH(FF)}$ 4.5, $J_{F^1F^4}$ 2.7 Hz), 16.8 m (F^6), 53.1 d (F^7, $J_{F^7F^4}$ 14.4 Hz) ppm. Both by the chemical shifts and signal patterns the ^{19}F spectrum of cycloadduct **IX** is similar to those for the cycloadduct described earlier and obtained in reaction of 2,4-cyclohexadienones with acetylenes [5].

The further skeleton transformation of cycloadduct **IX** may be represented as cycloaddition of the azido group to the double bond of the "acetylene" moiety of the molecule providing an intermediate compound **X** that decomposes with nitrogen liberation affording cyclopropane derivative **VIII**. It is also presumable that compound **VIII** forms from cycloadduct **IX** by concerted mechanism and through intermediately arising nitrene.

The cyclopropane intermediates formation was formerly suggested to rationalize the pathway of "nitrene" insertion into a C–C bond in the reaction of norbornadiene with $PhSO_2N_3$ [12] and $ArOSO_2N_3$ [13].

EXPERIMENTAL

^1H and ^{19}F NMR spectra were registered on spectrometer Bruker WP-200 (for ^1H operating frequency 200.00 MHz, internal reference HMDS, δ 0.04 ppm; for ^{19}F operating frequency 188.28 MHz, internal reference C_6F_6). ^{13}C NMR spectrum of compound **VIII** was recorded on spectrometer Bruker AC-400 (operating frequency 100.61 MHz, internal reference acetone-d_6, δ_C 29.80 ppm). IR spectrum of compound **VIII** was measured on Specord M-80 instrument from solution in CCl_4. Molecular weights

were determined with high resolution GC/MS instrument Finnigan MAT 8200 and by vapor-phase osmometry.

3-(2-Carboxyanilino)-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IIa). To a boiling solution of 1.4 g of 2-aminobenzoic acid in 10 ml of acetone was added dropwise within 15 min a solution of 2.2 g of dienone **I** in 10 ml of CH_2Cl_2. The mixture was boiled for 15 min more, then the solvent was evaporated, and the residue was recrystallized from benzene. We obtained 3.2 g (94%) of yellow compound **IIa**, mp 158–160°C. Found, %: C 46.48; H 1.83; Cl 10.80; F 22.43; N 4.05. *M* 334. $C_{13}H_6ClF_4NO_3$. Calculated, %: C 46.50; H 1.79; Cl 10.58; F 22.65; N 4.17. *M* 335.5.

3-(2,6-Dichloroanilino)-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IIb). To a solution of 0.66 g of dienone **I** in 10 ml of CCl_4 was added dropwise a solution of 0.9 g of 2,6-dichloroaniline in 3 ml of CCl_4. On completion of addition (in 10 min) the mixture was subjected to column chromatography on silica gel (eluent CCl_4). We obtained 0.64 g (77%) of orange compound **IIb**, mp 150–152.5°C. Found, %: C 39.87; H 1.25; Cl 29.49; F 21.56; N 3.64. *M* 359. $C_{12}H_4Cl_3F_4NO$. Calculated, %: H 39.94, H 1.11; Cl 29.54; F 21.08; N 3.88. *M* 360.5.

3-(2,6-Dimethylanilino)-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IIc). To a solution of 0.66 g of dienone **I** in 5 ml of CCl_4 was added dropwise a solution of 0.36 g of 2,6-dimethylaniline in 5 ml of $CCl4. On completion of addition (in 10 min) the separated precipitate (0.75 g) was filtered off. After purification by chromatography on silica gel (eluent CCl_4) and recrystallization from CCl_4 we obtained 0.44 g (45%) of orange compound **IIc** that quickly got dark in the air, mp 166°C (decomp.). Found $[M]^+$ 319.03891. $C_{14}H_{10}ClF_4NO$. Calculated *M* 319.03870.

3-Diethylamino-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IId). To a solution of 0.55 g of dienone I in 10 ml of CH_2Cl_2 was added 0.36 g of diethylamine. On completion of addition the mixture was subjected to column chromatography on silica gel (eluent CCl_4). We obtained 0.48 g (70%) of compound **IId** as a red-orange viscous fluid. Found $[M]^+$ 271.03869. $C_{10}H_{10}ClF_4NO$. Calculated *M* 271.03868.

3-Azido-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IIe). To a solution of 0.44 g of dienone **I** in 10 ml of CCl_4 was added at stirring 0.13 g of sodium azide in 2 ml of water. The emulsion obtained was stirred for 1 h and then it was applied to a column packed with silica gel. Elution in succession with CCl_4 and $CHCl_3$ afforded 0.42 g (86%) of compound **IIe** as brown viscous fluid decomposing on keeping at 20–25°C.

3-Methoxy-6-phenyl-2,4,5,6-tetrafluoro-6-chloro-2,4-cyclohexadienone (IV). A solution of 2 g of dienone **III** in 20 ml of methanol was heated to 60°C for 4 h. On distilling off the solvent we obtained 2.2 g of mixture containing according to ^{19}F NMR data equimolar amounts of dienone **IV** and pentafluorophenol. By chromatography on a column packed with silica gel (eluent CCl_4) we isolated 1.1 g (86%) of compound **IV** as a viscous yellow fluid that partially crystallized on standing at 20–25°C. Found $[M]^+$ 272.04632. $C_{13}H_8F_4O_2$. Calculated *M* 272.04603.

7-Butyl-6-methoxy-1,3,4,5-tetrafluoro-3-chlorobicyclo[2.2.]octa-5,7-dien-2-one (VIa). A mixture of 0.46 g of dienone **V** and 3 g of 1-hexyne was heated at reflux (70°C) for 20 h. On distilling off the excess 1-hexyne we obtained 0.64 g (97%) of reaction product containing according to ^{19}F NMR data 90% of compound **VIa**. After purification by chromatography on silica gel (eluent CCl_4) compound **VI** was light-yellow viscous fluid. ^{19}F NMR spectrum (CCl_4), δ_F, ppm: –40.8 (F^1), –39.1 (F^4), 2.6 (F^5), 49.3 (F^3). Found $[M]^+$ 312.05405. $C_{13}H_{13}ClF_4O_2$. Calculated *M* 312.05401.

7-Hydroxymethyl-6-methoxy-1,3,4,5-tetrafluoro-3-chlorobicyclo[2.2.]octa-5,7-dien-2-one (VIb). To a solution of 0.85 g of dienone **V** in 5 ml of toluene was added 0.45 g of propargyl alcohol, and the mixture was refluxed for 12 h. On distilling off the solvent and excess propargyl alcohol we obtained 1.13 g of reaction mixture containing according to ^{19}F NMR data 80% of compound **VIb** that was subsequently purified by chromatography on silica gel (eluent CH_2Cl_2). We isolated 0.95 g (835%) of viscous orange compound **VIb**. ^{19}F NMR spectrum (CCl_4), δ_F, ppm: –44.4 (F^1), –38.9 (F^4), 2.7 (F^5), 49.9 (F^3). Found, %: C 41.32; H 2.35; Cl 12.10; F 26.54. $[M]^+$ 286. $C_{10}H_7ClF_4O_3$. Calculated, %: C 41.91; H 2.46; Cl 12.37; F 26.51. *M* 286.

7-Butyl-6-methoxy-3-phenyl-1,3,4,5-tetrafluorobicyclo[2.2.]octa-5,7-dien-2-one (VIc). A solution of 0.84 g of dienone **III** in 10 ml of methanol was heated to 60°C for 4 h. The residue after methanol distillation was dissolved in 6 ml of 1-hexyne and heated at reflux (70°C) for 70 h. After evaporation of

excess hexyne the reaction mixture was subjected to column chromatography on silica gel. Elution with CCl_4 afforded 0.35 g (49%) of compound **Vc** as viscous yellow fluid. ^{19}F NMR spectrum (CCl_4), δ_F, ppm: –42.1 (F^1), –38.1 (F^4), 2.1 (F^5), 23.6 (F^3). Found, %: C 64.58; H 5.08; F 20.98. *M* 362. $C_{19}H_{18}F_4O_2$. Calculated, %: C 64.41; H 5.08; F 21.47. *M* 354.

Propyl (5-butyl-3-methoxy-2,4-difluorophenyl)-fluorochloroacetate (VIIa). To compound **VIa** prepared by heating 0.46 g of dienone **V** with 3 ml 1-hexyne to 70°C for 20 h on removing excess 1-hexyne was added 6 ml of 1-propanol and 1 g of freshly calcined K_2CO_3. The mixture was stirred for 3 h at room temperature, 50 ml of diluted hydrochloric acid was added, and the product was extracted into dichloromethane (3 × 50 ml). The extract was dried with calcium chloride, the solvent was evaporated, and the residue was subjected to chromatography on silica gel. Elution with CCl_4 afforded 0.35 g of ester **VIIa** (50% with respect to dienone **V**) as viscous light fluid. ^1H NMR spectrum (CCl_4), δ, ppm: 6.9 (1H, Ar–H), 3.8 (OCH_2), 3.5 (OCH_3), 2.2, 1.5–0.7 ($4CH_2$), 0.5 ($2CH_3$). ^{19}F NMR spectrum (CCl_4), δ_F, ppm: 32.2 and 33.9 (F^2 and F^4), 58.8 (α-F). Found $[M]^+$ 352.10529. $C_{16}H_{20}ClF_3O_3$. Calculated *M* 352.10500.

Propyl (5-hydroxymethyl-3-methoxy-2,4-difluorophenyl)fluorochloroacetate (VIIb). To compound **VIb** prepared by heating 0.46 g of dienone **V** with 0.23 g of propargyl alcohol in 5 ml of toluene to 115°C for 10 h on evaporating in a vacuum was added 5 ml of 1-propanol and 2 g of freshly calcined K_2CO_3. The mixture was stirred for 2 h at room temperature, then 50 ml of diluted HCl was added, and the product was extracted into dichloromethane (3 × 50 ml). The extract was dried with calcium chloride, the solvent was evaporated, and the residue was subjected to chromatography on silica gel. Elution with $CHCl_3$ afforded 0.25 g of ester **VIIb** (78% with respect to dienone **V**). ^1H NMR spectrum (CCl_4), δ, ppm: 7.5 (1H, Ar–H), 4.6 ($C\underline{H}_2OH$), 4.2 (OCH_2), 3.9 (OCH_3), 3.5 (OH), 1.7 (CH_2), 0.9 (CH_3). ^{19}F NMR spectrum (CCl_4), δ_F, ppm: 32.2 and 34.0 (F^2 and F^4), 57.3 (α-F). Found $[M]^+$ 326.05326. $C_{13}H_{14}ClF_3O_4$. Calculated *M* 326.05326.

Propyl (5-butyl-3-methoxy-2,4-difluorophenyl)-phenylfluoroacetate (VIIc). To a solution of 0.35 g of compound **VIc** in 3 ml of 1-propanol was added 1.4 g of freshly calcined K_2CO_3. The reaction mixture was stirred for 50 h at room temperature, then filtered, and 1-propanol was evaporated in a vacuum. The residue was subjected to chromatography on silica gel. Elution with $CHCl_3$ afforded 0.33 g (85%) of ester **VIIc** as viscous light-yellow fluid. ^1H NMR spectrum (CCl_4), δ, ppm: 7.3–7.5 (C_6H_5), 6.3 (1H, Ar–H), 4.2 (OCH_2), 3.9 (OCH_3), 2.4, 1.7–1.2 ($4CH_2$), 0.8 ($2CH_3$). ^{19}F NMR spectrum (CCl_4), δ_F, ppm: 18.7 (α-F), 31.6 and 33.2 (F^2 and F^4). Found $[M]^+$ 394.17562. $C_{22}H_{25}F_3O_3$. Calculated *M* 394.17556.

4-Oxo-2-phenyl-3,5,6,7-tetrafluoro-5-chlorobicyclo[4.1.0]hept-2-ene-7-carbonitrile (VIII). (a) To a solution of 0.42 g of azidodienone **IIe** in 10 ml of CCl_4 was added 0.4 g of phenylacetylene, and the mixture was heated to 70°C for 8 h. The solution was applied to a column packed with silica gel and on successive elution with CCl_4 and $CHCl_3$ we separated 0.24 g (44%) of nitrile **VIII**. After two recrystallizations from hexane we obtained 0.14 g of compound **VIII**, (VIII), mp 67–69°C. IR spectrum, ν, cm^{-1}: 3042 w (C–H), 2240 w (C≡N), 1722 s (C=O), 1625 m, 1447 m, 1418 m, 1331 m, 1309 m, 1249 m, 1190 m, 1162 m, 1080 m, 1023 m, 993 m, 914 m, 878 s, 835 s. Found, %: C 53.19; H 2.07; N 4.54. $[M]^+$ 315.00733. $C_{14}H_6ClF_4NO$. Calculated, %: C 53.25; H 1.90; N 4.44. *M* 315.00740.

(b) To a solution of 0.5 g of dienone **I** in 10 ml of acetonitrile was added 0.3 g of trimethylsilyl azide, and the mixture was maintained at room temperature for 30 min. According to ^{19}F NMR data the resulting mixture contained equal amounts of azidodienone **IIe** and trimethylfluorosilane. To this mixture was added 0.23 g of phenylacetylene, and the resulting solution was kept for 8 weeks with intermittent registering of ^{19}F NMR spectra. The spectra showed that after 3 days the reaction mixture contained ~67% of dienone **IIe**, ~20% of cycloadduct **IX**, and trace amounts of nitrile **VIII**. In 3 weeks these compounds were contained in equal amounts, and in 8 weeks in the reaction mixture was 80% of compound **VIII**.

REFERENCES

1. Mashkovskii, M.D., *Lekarstvennye sredstva* (Drugs), Kharkov: Torsing, 1998, vol. 1, 560 p; vol. 2, 592 p.
2. *Fluorine-Containing Molecules. Structure, Reactivity, Synthesis and Applications*, Liebman, J.F., Greenberg, A., and Dolbier, W.R., Eds., New York: VCH Publish. Inc., 1988.
3. *Organofluorine Compounds in Medicinal Chemistry and Biomedical Applications*, Filler, R., Kobaya-

shi, Y., and Yagupolskii, L.M., Eds., Amsterdam: Elsevier, 1983.
4. *Biomedical Frontiers of Fluorine Chemistry*, Ojima, I., McCarthy, J.R., and Welch, J.T., ACS Symposium Series 639, Washington: DC, 1996.
5. Kobrina, L.S. and Bogachev, A.A., *J. Fluor. Chem.*, 1993, vol. 62, nos. 2–3, pp. 243–258.
6. Bogachev, A.A., Kobrina, L.S. and Shteingarts, V.D., *Izv. Akad. Nauk, Ser. Khim.*, 1994, no. 9, pp. 1634–1637.
7. Bogachev, A.A., Kobrina, L.S., Meyer, O.G.J., and Haufe, G., *J. Fluor. Chem.*, 1999, vol. 97, nos. 1–2, pp. 135–143.
8. Akhmetova, N.E., Kostina, N.G., Mamatyuk, V.I., Shtark, A.A., and Shteingarts, V.D., *Izv. SO Akad. Nauk SSSR, Ser. Khim. Nauk*, 1973, vol. 14, no. 6, pp. 86–100.
9. Battiste, M.A. and Posey, R.G., *J. Fluor. Chem.*, 2000, vol. 102, no. 1–2, pp. 285–292.
10. Bogachev, A.A., Bagryanskaya, I.Yu., Rybalova, T.V., Gatilov, Yu.V., and Kobrina, L.S., *Zh. Org. Khim.*, 1996, vol. 66, no. 8, pp. 1324–1333.
11. Kalinowski, H.-O., Berger, S., and Braun, S., *^{13}C NMR Spektroskopie*, Stuttgart–New York: Georg Thieme Verlag, 1984, p. 227.
12. Oehlschlager, A.C. and Zalkow, L.H., *Chem. Commun.*, 1965, no. 4, pp. 70–71.
13. Hedayatullah, M., Guy, A., and Hugneny, J.C., *J. Heterocyclic Chem.*, 1984, vol. 21, no. 5, pp. 1385–1387.