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Reaction of Fluoro-containing 3-Oxoesters with Benzaldehyde*

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Abstract—Depending on conditions, fluorinated 3-oxoesters in reactions with benzaldehyde afford either 2-benzylidene-3-fluoroalkyl-3-oxoesters or 3,5-dialkoxycarbonyl-2,6-dihydroxy-2,6-difluoroalkyl-4-phenyltetrahydropyrans. The latter were also obtained by treating 3-oxoesters with 2-benzylidene-3-oxoesters. Pentafluorobenzoylacetate with benzaldehyde furnishes 3,5-diethoxycarbonyl-2-pentafluorophenyl-4-phenyl-7,8,9,10-tetrafluoro-4,5-dihydrobenzo[b]oxacin-6-one.

Reaction of 1,3-dicarbonyl compounds with aldehydes (Knoevenagel reaction) is extensively used in organic synthesis for preparation of various compounds [1]. Depending on conditions and structures of the initial reagents unfluorinated 3-oxoesters in reaction with aromatic aldehydes furnish either 2-arylmethylene-3-oxoesters, 2-arylmethylenedi(3-oxoesters), or cyclohexanones [1–3]. The data on this type reactions with fluorinated 3-oxoesters is limited to transformations of trifluoroacetoacetic acid ester resulting either in 2-arylmethylene-substituted trifluoroacetoacetic acid esters [4] or in 4-aryl-2,6-dihydroxy-3,5-diethoxycarbonyl-2,6-di(trifluoromethyl)tetrahydropyrans [5].

In this study, we investigated reaction of fluoro-containing 3-oxoesters **Ia–i** with benzaldehyde under various conditions.

It was shown that boiling for 6–8 h of equimolar amounts of 3-oxoesters **Ia–g** and benzaldehyde in aprotic solvents (toluene, benzene) in the presence of piperidine as catalyst with simultaneous azeotropic distillation of the forming water afforded fluoroalkyl-containing 2-benzylidene-3-oxoesters **IIa–g** in a limited yield (Scheme 1). The yields of reaction products decrease with the growing length of the chain in fluoroalkyl substituent.

Compounds **IIa–g** were light-yellow oily substances that were purified by column chromatography on silica gel (eluent hexane, benzene). Note that elution with benzene considerably enhanced the yield of products.

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In the IR spectra of compounds **IIa–g** was observed a shift to lower frequencies by ~30 cm^{-1} of absorption bands corresponding to the ester and keto carbonyl groups as compared with the values characteristic of the keto form of the initial 3-oxoesters [6]; this fact was caused by their participation in a long conjugation chain (Table 2).

In compounds **IIa–g** *Z*,*E*-isomers exist due to variation in substituents position at a C=C bond. In their ^1H and ^{19}F spectra appear two sets of signals indicating that the compounds are present in solutions as a mixture of *E*- and *Z*-isomers. In the IR spectra of compounds **IIa–g** all the carbonyl absorption bands are broadened or sometimes are doubled confirming the presence of two isomers.

The ratio of *E*- and *Z*-isomers was derived from the analysis of signals belonging to methine protons in the ^1H NMR spectra. In each case one of methine protons signals looks like a broadened singlet apparently due to interaction with fluorine atoms of the fluoroalkyl substituent; this is possible only in the *Z*-isomer. The existence of such interaction is suggested by the ^{19}F NMR spectrum of 2-benzylidene-substituted trifluoroacetoacetate **IIb** registered in $CDCl_3$ with digital resolution 0.122 Hz per point. In the spectrum appears a singlet from trifluoromethyl group of the *E*-isomer at 85.99 ppm, and a doublet from this group belonging to the *Z*-isomer at 90.42 ppm (J_{F-H} 1 Hz).

Besides in [7] was demonstrated that signals from methine protons of *E*-isomers 2-arylmethylene-substituted acetoacetates appeared downfield with respect to the corresponding signals of *Z*-isomers. This relation is conserved with the fluoroalkyl-substituted analogs **IIa–g**.

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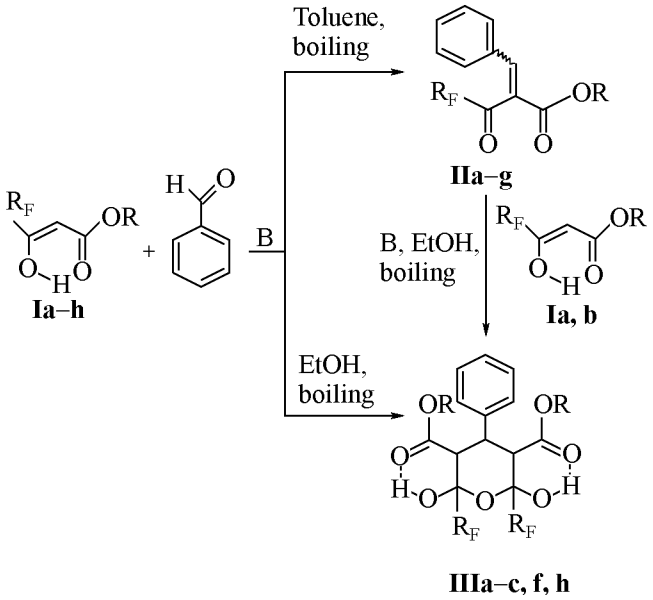
Scheme 1.



R = Et: R_F = HCF_2 (**a**), CF_3 (**b**), $H(CF_2)_2$ (**c**), $H(CF_2)_4$ (**d**), C_6F_{13} (**e**); **R = Me: R_F = $H(CF_2)_2$ (f**).

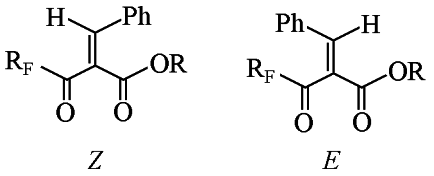
C_4F_9 (**g**); R = Et, R_F = C_4F_9 (**h**); B = KF, HN⟨⟩.

The ratio of *E*- and *Z*-isomers is individual for each case. It should be noted however that with difluoromethyl and trifluoromethyl substituents in compounds **IIa, b** the content of *Z*- and *E*-isomers is approximately equal, and with growing length of the fluoroalkyl substituent (compounds **IIc–g**) the *E*-isomer becomes prevailing (Table 1).

Under the other conditions, namely, on heating in ethanol at reflux in the presence of bases, from the reaction mixtures of 3-oxoesters **Ia–c, f, h** with benzaldehyde were isolated compounds **IIIa–c, f, h**. As catalysts were applied KF and piperidine, and the yield with KF were higher.

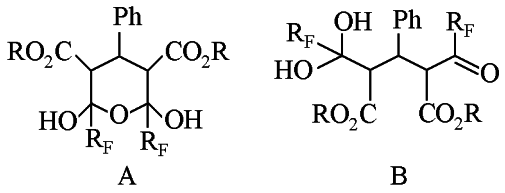
According to elemental analyses two structures can be ascribed to compounds **III** with equal probability: cyclic tetrahydropyran A and open-chain substituted dialkyl glutarate B. In reaction of trifluoroacetoacetate with benzaldehyde [5] was separated a substance with a similar value of melting point as we found for compound **IIIb**. To this product in [5] was ascribed pyran structure basing only on the IR spectrum. We applied to structure determination of compounds **IIIa–c, f, h** ^1H and ^{19}F NMR spectroscopy that provide a possibility of deciding between the presumed structures. In the ^1H NMR spectra a single set of proton signals from two ester groups is

Table 1. Ratio of *Z*- and *E*-isomers in 2-benzylidene-3-oxoesters **IIa–g** according to NMR spectra recorded in $CDCl_3$



Compd. no.	R_F	R	*Z*-isomer, %	*E*-isomer, %
IIa	HCF_2	Et	46	54
IIb	CF_3	Et	48	52
IIc	$H(CF_2)_2$	Et	39	61
IIf	$H(CF_2)_2$	Me	34	66
IId	$H(CF_2)_4$	Et	25	75
IIg	C_4F_9	Me	36	64
IIe	C_6F_{13}	Et	29	71

observed as is possible only for pyran structure, whereas for structure B two sets of signals should appear. Besides the signals from protons H^3, H^4, H^5 appear as AB_2-system that can exist only in pyran structure when two magnetically-equivalent protons are coupled with the third nonequivalent one. In the ^{19}F NMR spectra two equivalent fluoroalkyl groups give rise to a single set of signals, and therewith the signal from fluorine atoms attached to α-carbon appears as *AB*-system. The latter fact is characteristic of fluoroalkyl group bonded to an asymmetrical center.



In the structure of tetrahydropyrans **IIIa–c, f, h** are present 4 chiral and 1 pseudochiral centers. Therefore they can exist as 16 stereoisomers. However, the analysis of NMR spectra shows that in every case only one diastereomer is present, apparently racemate. The experimental value of coupling constant (12.3–12.5 Hz) corresponding to axial-axial interaction of protons at carbon atoms C^3, C^4 and C^5 [8] indicates equatorial position of phenyl and alkoxycarbonyl groups. The position of the fluoroalkyl substituent can be deduced taking into account the known fact that the electron-withdrawing fluorinated

Table 2. Spectral characteristics of compounds **IIa–g, IIIa–c,f,h, IV**

Compd. no.	IR spectrum, ν, cm^{-1}	NMR spectrum in $CDCl_3$, δ, ppm (*J*, Hz)	
		^1H	^{19}F
IIa[a]	3040 (C–H stretch), 1720 (C=O), 1690 (CO_2Et), 1600–1595 (C=C conjug.), 1010–1250 (C–F)	*Z*: 1.26 t (3H, $OCH_2\underline{CH}_3$, *J* 7.2), 4.35 q (2H, $O\underline{CH}_2CH_3$, *J* 7.2), 6.24 t (1H, HCF_2, *J* 53.4), 7.42 m (5H, C_6H_5), 7.96 br.s (1H, CH) *E*: 1.29 t (3H, $OCH_2\underline{CH}_3$, *J* 7.2), 4.35 q (2H, $O\underline{CH}_2CH_3$, *J* 7.2), 6.08 t (1H, HCF_2, *J* 53.4), 7.45 m (5H, C_6H_5), 7.96 s (1H, CH)	*Z*: 37.04 d (2F, HCF_2, *J* 53.2) *E*: 34.23 d (2F, HCF_2, *J* 53.2)
IIb[a]	3050 (C–H stretch), 1730 (C=O), 1700 (CO_2Et), 1615–1570 (C=C conjug.), 1070–1300 (CF)	*Z*: 1.29 t (3H, $OCH_2\underline{CH}_3$, *J* 7.2), 4.35 q (2H, $O\underline{CH}_2CH_3$, *J* 7.2), 7.47 m (5H, C_6H_5), 7.81 br.s (1H, CH), *E*: 1.32 t (3H, $OCH_2\underline{CH}_3$, *J* 7.2), 4.33 q (2H, $O\underline{CH}_2CH_3$, *J* 7.2), 7.38 m (5H, C_6H_5), 7.99 s (1H, CH)	*Z*: 85.97 s (3F) *E*: 90.38 s (3F)
IIc[a]	3045 (C–H stretch), 1720 (C=O), 1690 (CO_2Et), 1600–1570 (C=C conjug.), 1070–1300 (CF)	*Z*: 1.28 t (3H, $O\underline{CH}_2CH_3$, *J* 7.2), 4.35 q (2H, $OCH_2\underline{CH}_3$, *J* 7.2), 6.23 t.t [1H, $H(CF_2)_2$, ^2J 52.0, ^3J 5.5], 7.39 m (5H, C_6H_5), 7.92 br.s (1H, CH), *E*: 1.35 t (3H, $O\underline{CH}_2CH_3$, *J* 7.2), 4.33 q (2H, $OCH_2\underline{CH}_3$, *J* 7.2), 6.11 t.t [1H, $H(CF_2)_2$, ^2J 52.0, ^3J 5.5], 7.39 m (5H, C_6H_5), 8.01 s (1H, CH)	*Z*: 23.04 m (2F, $H\underline{CF}_2CF_2$, ^2J 52, ^3J 5.5), 41.99 m (^2F, $HCF_2\underline{CF}_2$), *E*: 23.8 m (2F, $H\underline{CF}_2CF_2$, ^2J 52.0, ^3J 5.5), 39.40 m (2F, $HCF_2\underline{CF}_2$)
IId[a]	3050 (C–H stretch), 1730 (C=O), 1700 (CO_2Et), 1615–1570 (C=C conjug), 1090–1280 (CF)	*Z*: 1.29 t (3H, $O\underline{CH}_2CH_3$, *J* 7.06), 4.33 q (2H, $OCH_2\underline{CH}_3$, *J* 7.06), 6.28 t.t [1H, $H(CF_2)_4$, 2*J* 52.0, ^3J 5.5], 7.47 m (5H, C_6H_5), 7.99 br.s (1H, CH), *E*: 1.32 t (3H, $O\underline{CH}_2CH_3$, *J* 7.06), 4.35 q (2H, $OCH_2\underline{CH}_3$, *J* 7.06), 5.99 t.t [1H, $H(CF_2)_4$, ^2J 52.0, ^3J 5.5], 7.38 m (5H, C_6H_5), 7.81 s (1H, CH)	*Z*: 48.21 m (2F, CF_2), 40.74 m (2F, CF_2), 33.11 m (2F, CF_2), 24.66 d.m (2F, HCF_2, J_{H-F} 52) *E*: 45.80 m (2F, CF_2), 38.73 m (2F, CF_2), 32.51 m (2F, CF_2), 24.66 d.m (2F, HCF_2, J_{H-F} 52)
IIe[a]	3030 (C–H stretch), 1730 (C=O), 1700 (CO_2Et), 1610–1560 (C=C conjug.), 1090–1210 (C–F)	*Z*: 1.29 t (3H, $\underline{CH}_3CH_2$, *J* 7.2), 4.35 q (2H, $CH_3\underline{CH}_2$, *J* 7.2), 7.54 m (5H, C_6H_5), 7.88 br.s (1H, CH), *E*: 1.31 t (3H, $\underline{CH}_3CH_2$, *J* 7.2), 4.33 q (2H, $CH_3\underline{CH}_2$, *J* 7.2), 7.4 m (5H, C_6H_5),	*Z*: 35.05 m (2F, CF_2), 39.05 m (2F, CF_2), 40.64 m (2F, CF_2), 40.94 m (2F, CF_2), 48.52 m (2F, CF_2), 81.03 m (3F, CF_3) *E*: 35.68 m (2F, CF_2),

Table 2. (Contd.).

Compd. no.	IR spectrum, ν, cm^{-1}	NMR spectrum in $CDCl_3$, δ, ppm (*J*, Hz)	
		^1H	^{19}F
IIe[a]		8.6 s (1H, CH)	39.05 m (2F, CF_2), 40.23 m (2F, CF_2), 40.63 m (2F, CF_2), 45.76 m (2F, CF_2), 81.03 m (3F, CF_3)
IIf[a]	3075 (C–H stretch), 1720 (C=O), 1690 (CO_2Me), 1535–1600 (C=C conjug.), 1100–1230 (CF)	*Z*: 3.85 s (3H, CH_3), 7.46 m (5H, C_6H_5), 65.28 t.t [1H, $H(CF_2)_2$, ^2J 52.65, ^3J 5.5], 7.9 br.s (1H, CH) *E*: 3.85 s (3H, CH_3), 7.39 m (5H, C_6H_5), 6.09 t.t [1H, $H(CF_2)_2$, ^2J 52.65, ^3J 5.5]; 8.0 s (1H, CH)	*Z*: 23.08 m (2F, $H\underline{CF}_2CF_2$, ^2J 52.65, ^3J 5.5), 41.83 m (2F, $HCF_2\underline{CF}_2$) *E*: 23.77 m (2F, $H\underline{CF}_2CF_2$, ^2J 52.65, ^3J 5.5), 39.35 m (2F, $HCF_2\underline{CF}_2$)
IIg[a]	3050 (C–H stretch), 1740 (C=O), 1710 (CO_2Me), 1615–1565 (C=C conjug.), 1130–1290 (CF)	*Z*: 3.87 s (3H, CH_3), 7.48 m (5H, C_6H_5), 7.84 s (1H, CH) *E*: 3.87 s (3H, CH_3), 7.41 m (5H, C_6H_5), 8.08 s (1H, CH)	*Z*: 36.56 m (2F, CF_2), 39.96 m (2F, CF_2), 48.25 m (2F, CF_2), 80.88 m (2F, CF_3) *E*: 36.05 m (2F, CF_2), 39.49 m (2F, CF_2), 45.69 m (2F, CF_2), 80.88 m (2F, CF_3)
IIIa[b]	3380 (OH), 1750 (CO_2Et), 1090–1240 (CF)	0.85 t (3H, $OCH_2\underline{CH}_3$, *J* 7.1), 3.07 m (3H, H^3, H^4, H^5), 3.77 q (2H, $O\underline{CH}_2CH_3$, *J* 7.1), 5.7 t (1H, HCF_2, *J* 54.7), 7.23 s (5H, C_6H_5)	28.57 (*AB*-system, 2F, HCF_2, $^2J_{F-F}$ 278, $^2J_{H-F}$ 54.7)
IIIb[b]	3340 (OH), 1710 (CO_2Et), 1020–1220 (CF)	0.75 t (3H, $O\underline{CH}_3$, *J* 7.1), 3.29–4.37 m (3H, H^3, H^4, H^5), 3.74 q (2H, $O\underline{CH}_2CH_3$, *J* 7.1), 7.29 m (5H, C_6H_5)	79.54 s (3H, CF_3)
IIIc[b]	3400 (OH), 1710 (CO_2Et), 1105–1200 (CF)	0.72 t (3H, $OCH_2\underline{CH}_3$, *J* 7.1), 3.36 d (2H, H^3, H^5, *J* 12.3), 4.08 t (1H, H^4, *J* 12.3), 3.71 q (2H, $O\underline{CH}_2CH_3$, *J* 7.1), 6.52 t.t [2H, 2 $H(CF_2)_2$, ^2J 51.8, ^3J 6.6], 7.28 c (5H, C_6H_5), 7.47 br.s (2H, 2OH)	25.09 d.t (2F, $H\underline{CF}_2CF_2$, ^2J 51.8, ^3J 6.6), 33.41 (*AB*-system, 2F, $HCF_2\underline{CF}_2$, ^2J 265.6, ^3J 6.6)
IIIf	3490, 3320 (OH), 1715, 1700 (CO_2Me), 1115–1270 (CF)	3.36 c (3H, OCH_3), 3.50 (AB_2-system, 3H, H^3, H^4, H^5, ν_{AB} 37.9, J_{AB} 12.5), 5.93 s (2H, 2OH), 6.13 t.t [$H(CF_2)_2$, ^2J 52, ^3J 6.6], 7.30 br.s (5H, C_6H_5)	27.02 d.t (2F, $H\underline{CF}_2CF_2$, ^2J 52, ^3J 6.6), 33.44 (*AB*–system, 2F, $HCF_2\underline{CF}_2$, ^2J 265.1, ^3J 6.6)

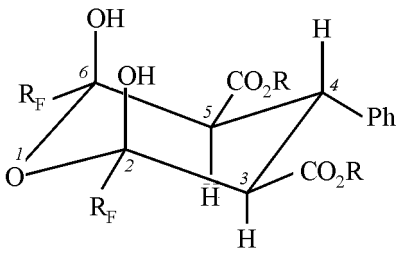
Table 2. (Contd.).

Compd. no.	IR spectrum, ν, cm^{-1}	NMR spectrum in $CDCl_3$, δ, ppm (*J*, Hz)	
		^1H	^{19}F
IIIh	3360 (OH), 1710 (CO_2Et), 1100–1270 (CF)	0.76 t (3H, $OCH_2C\underline{H}_3$, *J* 7.2), 3.84 q (2H, $OC\underline{H}_2CH_3$, *J* 7.2), 3.22–4.03 m (3H, H^3, H^4, H^5), 6.17 s (2H, 2OH), 7.30 s (5H, C_6H_5)	35.50 m (2F, CF_2), 41.29 m (4F, $2CF_2$), 81.03 m (3F, CF_3)
IV[b]	1745 (CO_2Et), 1710 (CO_2Et, C=O), 1625 (C=C), 970 (CF)	1.09, 0.96 2 t (6H, $2OCH_2C\underline{H}_3$, *J* 7.2), 4.14–3.88 2 q (4H, $2OC\underline{H}_2CH_3$, *J* 7.2), 5.05 (*AB*–system, 2H, H^3, H^4, Δν 29.56, *J* 11.33), 7.6–7.28 m (5H, C_6H_5)	23.98–20.64 m (2F), 19.83–19.31 m (1F), 16.48–15.83 m (1F), 12.78–12.13 m (1F), 8.04–7.50 m (1F), 5.75–5.16 m (1F), –0.34–1.78 m (2F)

[a] Compounds exist as a mixture of *Z*- and *E*-isomers, the ratio see Table 1.

[b] ^1H and ^{19}F NMR spectra of compounds were recorded in DMSO-d_6.

substituent at axial position suffers strong repulsion from the electron cloud of the axial hydrogen attached to C^3 or C^5 [8]. Consequently the fluoroalkyl substituent possesses higher conformational energy and therefore it with greater probability would occupy the equatorial position, and the hydroxy group should obviously take the axial position. Besides Potapov in [8, p. 211] gives the conformational energies for CF_3 (8.8 kJ mol^{-1}) and OH (2.2 kJ mol^{-1}) groups in substituted cyclohexanes that evidence the prevailing equatorial orientation of the CF_3 substituent (see figure).



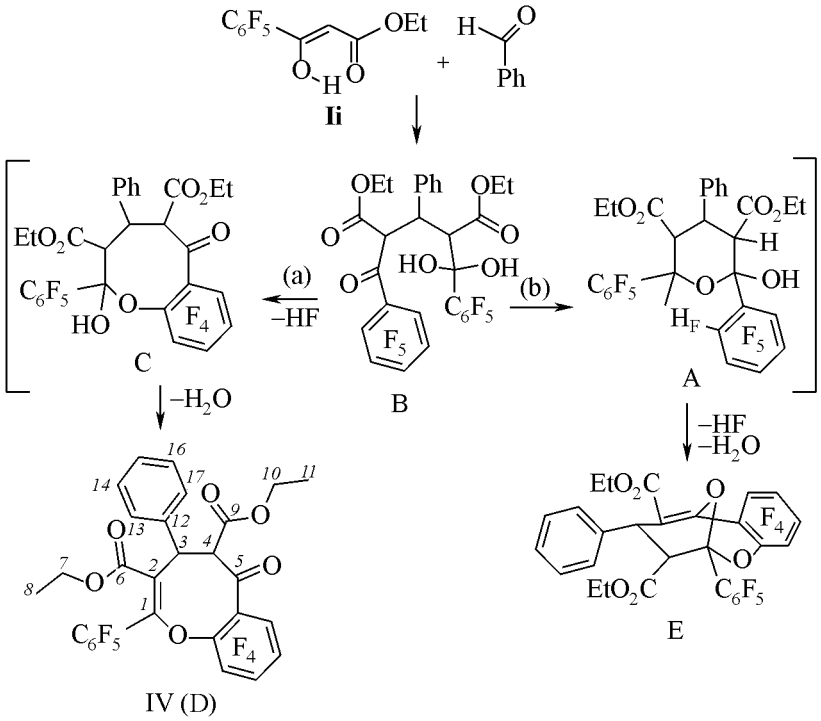
Heterocyclic compounds **III** can be prepared also from 2-benzylidene-3-oxoesters **II**. For instance, boiling in ethanol of 2-benzylidene-3-oxoesters **IIa, b** with the corresponding 3-oxoesters **Ia, b** in the presence of KF furnished tetrahydropyrans **IIIa, b** in a little higher yields that along the above described procedure. However our attempts to prepare unsymmetrical pyrans by reaction between 3-oxoesters and 2-benzylidene-3-oxoesters with unlike fluoroalkyl substituents failed for in all cases we obtained intractable mixtures of compounds.

Somewhat lower values of the stretching vibrations frequencies of the ester groups in the IR spectra of compounds **IIIa–c, f, h** as compared with the values published in [6] are due to the participation of the groups in the intramolecular hydrogen bonds with the hydroxy groups (Table 2).

We failed to carry out dehydration of pyrans **III** by boiling in toluene in the presence of *p*-toluenesulfonic acid with azeotropic distillation of water. Apparently the presence of electron-withdrawing fluoroalkyl substituents and the participation of the hydroxy groups in the intramolecular hydrogen bonds stabilize the tetrahydropyran structure of the said heterocycles and prevent the dehydration.

Pentafluorobenzoylacetate **Ii** on boiling in ethanol with benzaldehyde in the presence of KF affords compound **IV**. In the IR spectrum of the compound unlike the spectra of pyrans **III** the absorption band corresponding to vibration of hydroxy groups is lacking, but instead appears an absorption band at 1625 cm^{-1} characteristic of C=C vibrations. In the ^{19}F NMR spectrum are present the signals from fluorine atoms of pentafluoro- and tetrafluorobenzene fragments in 1:1 ratio. In the ^1H NMR spectrum appears a double set of protons from nonequivalent ester groups and of two methine protons as *AB*-system (*J* 11.3 Hz).

Scheme 2.



Compound **IV** according to elemental analysis, IR, ^{1}H and ^{19}F NMR spectra may be assigned two structures: 3,5-diethoxycarbonyl-2-pentafluorophenyl-4-phenyl-7,8,9,10-tetrafluoro-4,5-dihydrobenzo[b]-oxacin-6-one (D) or 4,2-(1,3-diethoxycarbonyl-2-phenyl-1,3-propylenediyl)-2-pentaflyorophenyl-5,6,7,8-tetrafluoro-1,3-benzo[d]dioxane (E). The presumable formation mechanism of compounds D, E is shown on Scheme 2. Therewith in both cases as intermediate serves glytarate B that under the reaction conditions undergoes intramolecular cyclization yielding either heterocycle D (route a) or compound E (route b via tetrahydropyran A). The cyclization occurs by intramolecular nucleophilic substitution of the *ortho*-fluorine in the pentafluorophenyl substituent by hydroxy group, and it is accompanied by HF liberation.

Deciding between structures D and E was performed using ^{13}C NMR spectroscopy: in the spectrum of reaction product **IV** appeared a signal of carbonyl group carbon at 190 ppm, and that was possible only for D structure.

Apparently in the reaction in question as with fluoroalkyl-substituted 3-oxoesters the primary product is glutarate B, but the finally isolated substance is heterocycle **IV** that arises as a result of intramolecular nucleophilic substitution of the *ortho*-fluorine in the pentafluorophenyl substituent by hydroxy group (Scheme 2, route a).

Reactions of 3-oxoesters with benzaldehyde in anhydrous aprotic solvents (benzene, toluene) result in 2-benzylidene-3-oxoesters whereas in proton-donor solvents (alcohols) is favored formation of substituted pyrans. At boiling in toluene the arising water is eliminated by azeotropic distillation, and the reaction stops at the stage of 2-benzylidene-3-oxoester as in transformations of unfluorinated 3-oxoesters [2]. In alcoholic medium 2-benzylidene-3-oxoester apparently adds the second molecule of 3-oxoester affording as an intermediate 2-benzylidenedi(3-oxoester). The latter undergoes cyclization into tetrahydropyran at carbonyl groups attached to the fluorinated substituents, and one of the carbonyls preliminary takes up a molecule of water. Note that formation of pyran series heterocycles in reactions of fluoroalkyl-containing 3-oxoesters with benzaldehyde is a specific feature of these compound compared to unfluorinated analogs. With the latter depending on the structure of the acyl substituent the reaction either stopped at formation of benzylidenedi(3-oxoester)s, or with acetoacetate occurred aldol condensation at the methyl group to afford a substituted cyclohexanone [3]. The pyrans synthesis from the fluoroalkyl-containing oxoesters and benzaldehyde is realized due to the capability of carbonyl groups at fluorinated substitu-

Table 3. Elemental analyses of compounds **IIa**–**g**, **IIIa**–**c**, **f**, **h**, **IV**

Compd. no.	Found, %			Formula	Calculated, %		
	C	H	F		C	H	F
IIa	61.27	4.71	15.22	$C_{13}H_{12}F_2O_3$	61.42	4.76	14.94
IIb	57.11	4.00	20.83	$C_{13}H_{11}F_3O_3$	57.36	4.07	20.94
IIc	55.29	4.19	24.88	$C_{14}H_{12}F_4O_3$	55.27	3.98	24.98
IId	47.32	3.31	38.00	$C_{16}H_{12}F_8O_3$	47.53	2.99	37.60
IIe	41.73	2.05	47.00	$C_{18}H_{11}F_{13}O_3$	41.71	2.11	47.02
IIf	54.13	3.17	26.59	$C_{13}H_{10}O_3F_4$	53.80	3.47	26.19
IIg	44.44	2.37	41.90	$C_{15}H_9F_9O_3$	44.13	2.22	41.89
IIIa	52.03	5.29	17.69	$C_{19}H_{22}F_4O_7$	52.05	5.06	17.34
IIIb	48.13	4.27	24.25	$C_{19}H_{20}F_6O_7$	48.11	4.25	24.03
IIIc	46.82	4.05	28.30	$C_{21}H_{22}F_8O_7$	46.85	4.12	28.23
IIIf	44.98	3.60	30.00	$C_{19}H_{18}F_8O_7$	44.72	3.56	29.78
IIIh	38.83	2.62	44.33	$C_{25}H_{20}F_{18}O_7$	38.77	2.60	44.16
IV	55.16	2.81	27.35	$C_{29}H_{17}F_9O_6$	55.07	2.71	27.04

ent to take up water [9]. The presence in the 3-oxoesters of a pentafluorophenyl substituent provides additional opportunities for transformations, as shows the example of formation of 3,5-diethoxycarbonyl-2-pentafluorophenyl-4-phenyl-7,8,9,10-tetrafluoro-4,5-dihydrobenzo[b]oxacin-6-one.

Thus fluorinated 3-oxoesters in the Knoevenagel condensation depending on conditions can afford either acyclic unsaturated ketones or heterocyclic reaction products.

EXPERIMENTAL

IR spectra were recorded on spectrometer Specord 75IR in the range 400–4000 cm^{-1} from mulls in mineral oil. ^1H NMR spectrometers were registered on spectrometers Tesla BS-567 A and Bruker DRX-400 relative to TMS at operating frequencies 80 and 400 MHz respectively. ^{19}F NMR spectra were recorded on spectrometer Tesla BS-567 A at operating frequency 75 MHz relative to C_6F_6, ^{13}C NMR spectra were measured on spectrometer Bruker DRX-400 (100 MHz, relative to TMS). Elemental analysis was performed on analyzer Carlo Erba CHNS-O EA 1108. The IR and NMR spectra are given in Table 2, the elemental analyses in Table 3.

Ethyl 2-benzylidene-3-oxo-4,4-difluorobutanoate (IIa). A mixture of 3-oxoester **Ia** (3.3 g, 0.02 mol) and of benzaldehyde (2.12 g, 0.02 mol) was boiled in toluene with azeotropic distillation of water for 6 h. Then toluene was distilled off in a vacuum. On subjecting the residue to column chromatography on silica gel (eluent benzene) we obtained 2.64 g (52%) of compound **IIa** as an oily fluid.

Ethyl 2-benzylidene-3-oxo-4,4,4-trifluorobutanoate (IIb). In a similar way from 3-oxoester **Ib** (3.68 g, 0.02 mol) and benzaldehyde (2.12 g, 0.02 mol) we obtained 2.94 g (54%) of compound **IIb** as oily fluid.

Ethyl 2-benzylidene-3-oxo-4,4,5,5-tetrafluoropentanoate (IIc). In a similar way from 3-oxoester **Ic** (4.32 g, 0.02 mol) and benzaldehyde (2.12 g, 0.02 mol) we obtained 3.22 g (53%) of compound **IIc** as oily fluid.

Ethyl 2-benzylidene-3-oxo-4,4,5,5,6,6,7,7-octafluoroheptanoate (IId). In a similar way from 3-oxoester **Id** (6.32 g, 0.02 mol) and benzaldehyde (2.12 g, 0.02 mol) we obtained 3.23 g (40%) of compound **IId** as oily fluid.

Ethyl 2-benzylidene-3-oxo-4,4,5,5,6,6,7,7,8,8,9,9,9-tridecafluorononoate (IIe). In a similar way from 3-oxoester **Ie** (8.66 g, 0.02 mol) and benzaldehyde (2.12 g, 0.02 mol) we obtained 4.73 g (45%) of compound **IIe** as oily fluid.

Methyl 2-benzylidene-3-oxo-4,4,5,5-tetrafluoropentanoate (IIf). In a similar way from 3-oxoester **Ib** (4.04 g, 0.02 mol) and benzaldehyde (2.12 g, 0.02 mol) we obtained 2.67 g (46%) of compound **IIf** as oily fluid.

Methyl 2-benzylidene-3-oxo-4,4,5,5,6,6,7,7,7-nonafluoroheptanoate (IIg). In a similar way from 3-oxoester **Id** (6.4 g, 0.02 mol) and benzaldehyde

(2.12 g, 0.02 mol) we obtained 2.86 g (40%) of compound **IIg** as oily fluid.

2,6-Dihydroxy-2,6-di(difluoromethyl)-3,5-diethoxycarbonyl-4-phenyltetrahydropyran (IIIa). (a) A mixture of 3-oxoester Ia(16.61 g, 0.1 mol), benzaldehyde (5.31 g, 0.05 mol), and calcined KF (1.57 g, 0.027 mol) in ethanol (50 ml) was boiled for 6–8 h. Then the reaction mixture was poured into 100 ml of cold water. The reaction products were extracted into ethyl ether (2×30 ml). The combined extracts were washed with 40% solution of $NaHCO_3$ and water. The ether was evaporated under reduced pressure, and the oily residue solidified. It was growned into a powder and recrystallized from 50% aqueous ethanol. We obtained 8.77 g (40%) of compound **IIIa**, mp 128–130°C.

(b) Similarly from a mixture of 3-oxoester **Ia** (16.61 g, 0.1 mol) and of compound **IIa** (25.42 g, 0.1 mol) was obtained 22.79 g (52%) of compounds **IIIa**, mp 128–130°C. **2,6-Dihydroxy-2,6-di(trifluoromethyl)-3,5-diethoxycarbonyl-4-phenyltetrahydropyran (IIIb).** (a) In the same way from 3-oxoester **Ib** (18.41 g, 0.1 mol), and benzaldehyde (5.31 g, 0.05 mol) was obtained 10.19 g (43%) of compound **IIIb**, mp 115–117°C [5]. (b) Similarly from a mixture of 3-oxoester **Ib** (18.41 g, 0.1 mol) and of compound **IIb** (27.22 g, 0.1 mol) was obtained 26.09 g (55%) of compounds **IIIb**, mp 115–117°C.

2,6-Dihydroxy-2,6-di(1,1,2,2-tetrafluoroethyl)-3,5-diethoxycarbonyl-4-phenyltetrahydropyran (IIIc). In the same way from 3-oxoester **Ic** (21.61 g, 0.1 mol), and benzaldehyde (5.31 g, 0.05 mol) was obtained 9.42 g (35%) of compound **IIIc**, mp 125–127°C.

2,6-Dihydroxy-2,6-di(1,1,2,2-tetrafluoroethyl)-3,5-dimethoxycarbonyl-4-phenyltetrahydropyran (IIIf). In the same way from 3-oxoester **If** (20.21 g, 0.1 mol), and benzaldehyde (5.31 g, 0.05 mol) was obtained 10.21 g (40%) of compound **IIIf**, mp 143–144°C.

2,6-Dihydroxy-2,6-di(nonafluorobutyl)-3,5-diethoxycarbonyl-4-phenyltetrahydropyran (IIIh). In the same way from 3-oxoester **Ih** (33.41 g, 0.1 mol), and benzaldehyde (5.31 g, 0.05 mol) was obtained 13.16 g (34%) of compound **IIIh**, mp 125–127°C.

3,5-Diethoxycarbonyl-2-pentafluorophenyl-4-phenyl-7,8,9,10-tetrafluoro-4,5-dihydrobenzo[b]-oxacin-6-one (IV). By a similar procedure from 3-oxoester **Ii** (28.22 g, 0.1 mol) and benzaldehyde (5.31 g, 0.05 mol) was obtained and isolated by column chromatography on silica gel (eluent chloroform) compound **IV** in 12.01 g (38%) yield, mp 105–106°C. ^{13}C NMR spectrum (DMSO-d_6) δ, ppm: 13.11 (C^8), 13.63 (C^{11}), 45.54 (C^4), 60.83 (C^3), 61.49 (C^7), 62.11 (C^{10}), 128.53 (C^{14}, C^{16}), 128.99 (C^{13}, C^{17}), 131.83 (C^2), 138.17 (C^{12}), 146.22 (C^1), 163.72 (C6), 166.75 (C^9), 190.0 (C^5).

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