TABLE 2. Data of Experiments on the Telomerization of 3,3,3-Trifluoropropene by Methyl Isobutanoate (120°C, 2 mole % TBP, 20-40 min*)

Run No.	S_H	M_H	K_M, %	[M]/[S] av.	Content of telomer homologs with n monomer units, mole %			
	mmoles				T_1	T_2	T_3	$\sum_{n \geq 4} T_n$
1	57.6	5.4	24.8	0.08	59.0	34.6	4.6	1.8
2	57.6	6.9	27.9	0.10	56.5	34.9	6.0	2.6
3	58.5	9.6	24.7	0.14	49.7	38.7	7.9	3.7
4	58.9	18.2	28.3	0.26	42.5	38.6	11.6	7.3
5	57.6	24.3	25.8	0.37	39.1	37.8	13.6	9.5
6	58.1	32.3	21.9	0.50	33.2	36.4	16.7	13.7
7	57.5	37.8	18.1	0.60	35.0	35.0	16.5	13.5
8	57.5	48.9	27.8	0.74	30.8	31.9	18.4	18.9
9	58.2	55.6	22.0	0.85	27.7	30.6	18.5	23.2
10	57.6	64.1	23.8	0.98	27.8	27.7	18.3	26.2

*Telogen conversion in the experiments <3%.

2. The comparatively small change of the chain-transfer constants C_n with increasing length of the radical chain indicates a weak polar effect in the chain-transfer stage.

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REACTION OF POLYFLUOROCARBONYL COMPOUNDS WITH INDOLINES*

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According to [2], indoline reacts with hexafluoroacetone (I) with formation of the C^5-alkylation product. Such a course of the reaction is in line with the generally accepted concept of the orientation of an electrophilic substituent on indoline [3], but the reaction conditions (120°C) are in conflict with known data on the reactivity of ketone (I) in regard to arylamines [4, 5]. In this article we present the results of the investigation of the reaction of indoline with (I) and with methyl trifluoropyruvate (II), which we studied earlier in C-alkylation reactions of arylamines of various types [4, 5].

Indoline, dissolved in $CHCl_3$, reacts vigorously with (I), even under cooling (−60 → 20°C), with formation of 7-(2-hydroxyhexafluoroprop-2-yl)indoline (III) in a yield of 92%. Thus, under mild conditions the substitution proceeds regiospecifically at the position ortho to the amino group. Reaction of the reagents in boiling $(CHCl_2)_2$ was accompanied by resinification and led to a mixture of products. According to HPLC analysis, the C^5 (IV) and C^7 (III) isomers were present in the ratio of 1:1. The C^5 isomer was isolated by crystallization in a yield of 25%. Reaction of indoline with an excess of ketone (I) (1:2.2) in $CHCl_3$ at 20°C yields 5,7-di(2-hydroxyhexafluoroprop-2-yl)indoline (V), which was isolated in a yield of 90%.

*For previous Communication, see [1].

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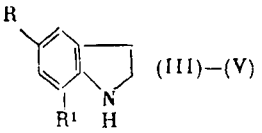
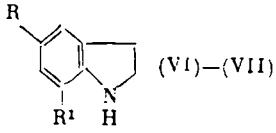


(III)–(V)

R = H, $R^1 = C(CF_3)_2OH$ (III); R = $C(CF_3)_2OH$, R^1 = H (IV); R = $R^1 = C(CF_3)_2OH$ (V).

The data obtained allow it to be assumed that C^7-alkylation is realized via an oriented transition state, in which the course of the C-alkylation is controlled by the activation entropy of the reaction.

On reacting indoline with (II) in $CHCl_3$ at 20°C a mixture of the C^5- (VI) and C^7-alkylation (VII) products is formed, with predominance (5:1) of isomer (VI). The low regioselectivity in this case may be explained by the great volume of ketoester (II) in comparison with ketone (I) or by intramolecular interaction of indoline with ketoester (II) through its carbomethoxy group, which hampers the formation of an oriented transition state of the reaction.

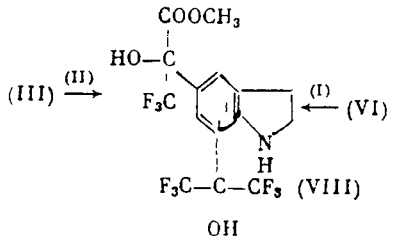


(VI)–(VII)

R = $C(CF_3)(COOCH_3)OH$, R^1 = H(VI); R = H, $R^1 = C(CF_3)(COOCH_3)OH$(VII).

In contrast to the corresponding derivatives of tetrahydroquinoline [5], compound (VII) is not converted to a cyclic amide, not even on melting.

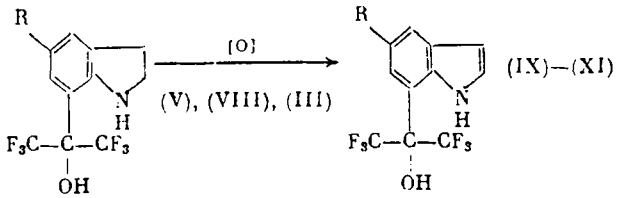
Reaction of indoline (VI) with (I) yielded 5-(1-hydroxy-1-carbomethoxytrifluoroethyl)-7-(2-hydroxyhexafluoroprop-2-yl)indoline (VIII), which was also prepared retrosynthetically from compound (III) and ketoester (II).



(III) (II) → (VI) ← (I); (VIII)

OH

Indolines (V) and (VIII) were dehydrated with active MnO_2 [6] to the corresponding indoles (IX) and (X). Dehydrogenation of indoline (III) in this way is accompanied by resinification of the reaction mixture. The use of 2,3-dicyano-5,6-dichloroquinone gives better results, but also in that case we did not succeed in preparing an analytically pure sample of indoline (XI).

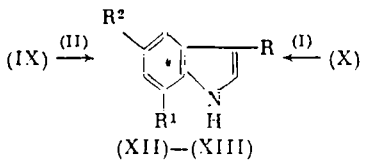


[O] (V), (VIII), (III) (IX)–(XI)

OH OH

R = $C(CF_3)_2OH$(V), (IX); R = $C(CF_3)(COOCH_3)OH$(VIII), (X); R = H(III), (XI).

On reacting indole (IX) with ketoester (II), and indole (X) with ketone (I), the corresponding C^3-alkylation products (XII) and (XIII) were obtained.



(IX) (II) → ← (I) (X)

(XII)–(XIII)

R = $C(CF_3)(COOCH_3)OH$, $R^1 = R^2 = C(CF_3)_2OH$(XII); R = $R^1 = C(CF_3)_2OH$, R^2 = = $C(CF_3)(COOCH_3)OH$(XIII).

TABLE 1. Compounds (III)-(XVI)

Compound	Yield, %	mp, °C	R_f	Found / calculated, % C	H	N	F	Empirical formula	M+
(III)	92	118–119	0.64	46.48 / 46.33	3.18 / 3.18	5.20 / 4.91	39.79 / 40.00	$C_{11}H_9F_6NO$	285
(IV) *	22	143–144	0.30	–	–	–	–	$C_{11}H_9F_6NO$	–
(V)	90	159–160	0.31	37.00 / 37.27	2.01 / 2.01	3.42 / 3.10	50.47 / 50.52	$C_{14}H_9F_{12}NO_2$	451
(VI)	50	141–143	0.31	52.29 / 52.36	4.44 / 4.36	4.87 / 5.09	20.99 / 20.73	$C_{12}H_{12}F_3NO_3$	–
(VII)	6	121–123	0.56	52.27 / 52.36	4.52 / 4.36	4.70 / 5.09	20.70 / 20.73	$C_{12}H_{12}F_3NO_3$	275
(VIII)	86	148–150	0.36	40.56 / 40.82	2.44 / 2.72	3.00 / 3.18	38.51 / 38.78	$C_{15}H_{12}F_9NO_3$	–
(IX)	89	119–121	0.30	37.18 / 37.42	1.68 / 1.56	2.96 / 3.12	50.50 / 50.78	$C_{14}H_7F_{12}NO_2$	–
(X)	90	99–101	0.33	39.76 / 41.00	2.48 / 2.28	3.51 / 3.19	38.71 / 38.95	$C_{15}H_{10}F_9NO_3$	439
(XI) **	71	–	0.60	–	–	–	–	$C_{11}H_7F_6NO$	283
(XII)	86	136–138	0.27	35.82 / 35.70	1.63 / 1.65	2.23 / 2.31	47.81 / 47.11	$C_{18}H_{10}F_{15}NO_5$	–
(XIII)	88	133–135	0.25	35.35 / 35.70	1.87 / 1.65	2.03 / 2.31	–	$C_{18}H_{10}F_{15}NO_5$	–
(XIV)	80	118–120	0.24	35.26 / 35.70	1.98 / 1.65	2.56 / 2.31	46.89 / 47.11	$C_{18}H_{10}F_{15}NO_5$	–
(XVI)	23	148–150	0.21	39.12 / 39.16	2.13 / 2.11	2.44 / 2.69	43.52 / 43.76	$C_{17}H_{11}F_{12}NO_4$	521

*See [2].
**Analytically pure sample not obtained.

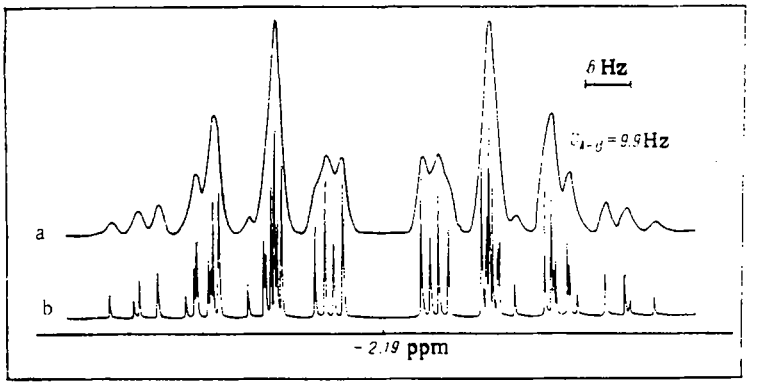
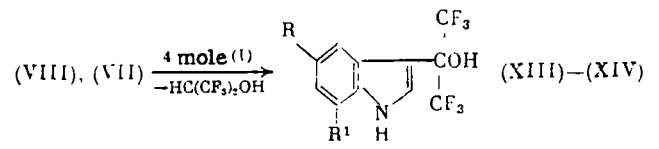


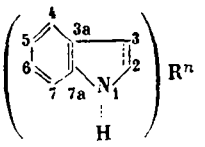
Fig. 1. A_3B_3 system in the ^{19}F NMR spectrum of compound (XIV): a) experiment, b) theory.

On reacting substituted indolines (VII) and (VIII) with an excess of (I) the 3,5,7-trisubstituted indoles (XIII) and (XIV) are produced in high yield, that is aromatization of the dihydropyrrole ring accompanied by substitution of a hexafluoroisopropanol group takes place. The first reactions of this type were described by us with the example of tetrahydroquinoline derivatives [5].



R = $C(CF_3)_2OH$, R^1 = $C(CF_3)(COOCH_3)OH$ (XIV).

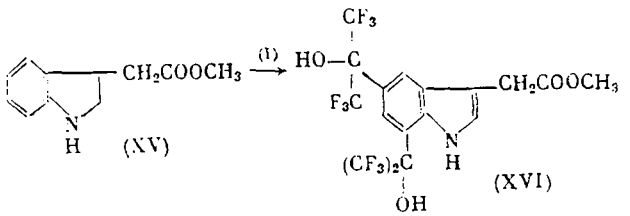
TABLE 2. ^1H and ^{19}F NMR Spectra of Compounds (III), (V)-(XIV), and (XVI)



Compound	Chemical shifts, δ, ppm (in acetone-d_6)								
	^1H (J, Hz)								^{19}F
	1	2	3	4	5	6	7	OCH_3	
(III)		3.54 t (8,5)	2.94 t	7.15 dd (7,2)	6.67 dd	7.13 dd (8,3)	–	–	2.81 s
(V)	–	3.59 t (8,6)	3.00 t	7.43 d (1.3)	–	7.41 d	–	–	–2.79 s –2.41 s (1 : 1)
(VI)	–	3.56 t (8.6)	2.98 t	7.39 br.s	–	7.29 d (8,5)	6.64 d	3,84 s	–1.51 s
(VII)	–	3.53 t (8,5)	2.93 t	7.06 dd (7.4)	6.58 dd	7.11 dd (8,2)	–	3.84 s	–1.62 s
(VIII)	–	3.56 t (8,4)	2.98 t	7.50 d (1,4)	–	7.46 d	–	3,87 s	–2.50 s –1.48 s (2 : 1)
(IX)	11.03 br.s	8.00 t (3.3)	7.21 t	8.78 br.s	–	8.54 br.s	–	–	–3.01 s –2.64 s (1 : 1)
(X)	11.32 br.s	8.19 br.s	7.39 m	8.84 br.s	–	8.59 br.s	–	4.69 s	–3.31 s –1.50 s (2 : 1)
(XI)	10.83 br.s	7.33 t (3.1)	6.51 t	7.72 d (7.5)	7.08 t	7.26 br.d (8.0)	–	–	–3.04 s
(XII)	10,89 br.s	8.51 br.s	–	7.80 br.s	–	7.59 br.s	–	3.80 s	–2.90 s –2.24 s –1.92 s (2 : 2 : 1)
(XIII)	10.82 br.s	8.50 s	–	7.85 br.s	–	7.63 s	–	3.79 s	–3.26 s –2.20 s –1.44 s (2 : 2 : 1)
(XIV)	10.91 br.s	8.54 br.s	–	7.78 br.s	–	7.61 br.s	–	3.83 s	–3.24 s –2.1; –2.3 ** –1.58 s (2 : 2 : 1)
(XVI) *	10.59 br.s	8.20 br.s	–	7.84 br.s	–	7.42 br.s	–	3.62 s	–3.64 s –3.57 s (1 : 1)

*δCH_2 3.81 ppm (s).
**See Fig. 1.

Similar oxidation-reduction reactions were used for the modification of (indol-3-yl)acetic acid, the methyl ester of which was converted to indoline (XV) by means of $PyBH_3$ by the method described for other indole derivatives [7]. Indoline (XV), without isolation, was treated with an excess of (I) in CCl_4 at 50°C to give methyl [5,7-di(2-hydroxyhexafluoroprop-2-yl)indol-3-yl]acetate (XVI), obtained in a yield of 23.3%.



Characteristics of compounds (III)-(XIV) and (XVI) are listed in Table 1. Their structures were established on the basis of ^1H and ^{19}F NMR spectra (Table 2), elemental analysis

(Table 1), mass spectroscopy of compounds (III), (V), (VII), (X)-(XI), and (XVI) (Table 1), and ^{13}C NMR spectra of compounds (III), (V)-(VIII), (X), (XIII)-(XIV), and (XVI) (Table 3). Determination of the place of substitution was carried out on the basis of analysis of the spin systems in the PMR spectra and also of the chemical shifts in the ^{13}C NMR spectra.

The signals of the CF_3 groups in the ^{19}F NMR spectra of compounds (X)-(XIII) and (XVI) are singlets. In the spectrum of compound (XIV) we succeeded in observing the magnetic nonequivalence of the CF_3 groups of the hexafluoroisopropanol residue, which is characteristic of the presence of an asymmetric center in the molecule (Fig. 1).

EXPERIMENTAL

^1H, ^{19}F, and ^{13}C NMR spectra were recorded on a Bruker WP-200SY spectrometer operating at 200.13, 188.31, and 50.31 MHz, respectively. Chemical shifts were determined relative to TMS (internal standard) (^1H and ^{13}C) and CF_3COOH (external standard) (^{19}F). The theoretical parameters of the ^{19}F spectrum of (XIV) were obtained by iterative automatic calculation with the PANIC standard program until a value of the mean-square error of the iteration of 0.02 Hz. Mass spectra were taken on an AEI MS-30 spectrometer. R_f values of the prepared compounds are given for Silufol UV-254 plates in the system CCl_4—acetone 4:1; spots were visualized in UV light.

7-(2-Hydroxyhexafluoroprop-2-yl)indoline (III). Into a solution of 7.75 g of indoline in 25 ml of absolute $CHCl_3$ in a glass ampul was condensed 10.80 g of (I), the ampul was sealed and kept at 20°C for 16 h. The solvent was evaporated and the residue was recrystallized from hexane to yield 17.0 g of (III).

5-(2-Hydroxyhexafluoroprop-2-yl)indoline (IV). A solution of 5.0 g of indoline in 40 ml of refluxing carbon tetrachloride was saturated with argon and then, in the course of 6 h, 6.7 g of (I) was bubbled in. The solvent was evaporated under vacuum, the residue was dissolved in chloroform, filtered over silica gel, and the $CHCl_3$ was evaporated under vacuum. Repeated fractional crystallization from hexane yielded 2.7 g of (IV).

5,7-Di-(2-hydroxyhexafluoroprop-2-yl)indoline (V) was prepared under the conditions of the synthesis of (III) from 3.5 g of indoline and 11.0 g of (I). After crystallization from a 1:1 mixture of $CHCl_3$ and CCl_4 12.1 g of (V) was obtained.

5-(1-Hydroxy-1-carbomethoxytrifluoroethyl)indoline (VI) and 7-(1-hydroxy-1-carbomethoxytrifluoroethyl)indoline (VII). To a solution of 11.9 g of indoline in 100 ml of dry $CHCl_3$ was added 16.0 g of ketoester (II), the mixture was kept at 20°C for one day, the solvent was evaporated, and the residue was crystallized from hexane and freon 113 to yield 13.8 g of (VI) and 1.6 g of (VII).

5-(1-Hydroxy-1-carbomethoxytrifluoroethyl)-7-(2-hydroxyhexafluoroprop-2-yl)indoline (VIII). a) A glass ampul was charged with a solution of 5.7 g of (IV) in 50 ml of Freon 113, 3.6 g of (I) was condensed into it, the ampul was sealed and stored at 20°C for 24 h, and the precipitate was filtered off and washed with pentane. Yield 7.6 g of (VIII).

b) To a solution of 2.8 g of (III) in 30 ml of CCl_4 was added 1.6 g of (II), the mixture was stored at 20°C for 24 h, and the precipitate was filtered off and washed with pentane. Yield 3.7 g of (VIII).

5,7-Di-(2-hydroxyhexafluoroprop-2-yl)indole (IX). To a solution of 4.5 g of (V) in 100 ml of abs. benzene was added 15 g of active MnO_2 and the mixture was refluxed for 2 h with azeotropic distillation of the water produced, MnO_2 was filtered off and washed with 20 ml hot benzene, the solution was concentrated to 25 ml, the precipitate was filtered off, and washed with pentane to yield 4.0 g of (IX).

5-(1-Hydroxy-1-carbomethoxytrifluoroethyl)-7-(2-hydroxyhexafluoroprop-2-yl)indole (X) was prepared under the conditions of the synthesis of (IX) from 4.4 g of (VIII) and 14 g of MnO_2. Crystallization from CCl_4 yielded 3.9 g of (X).

7-(2-Hydroxyhexafluoroprop-2-yl)indole (XI). To a solution of 1.4 g of (III) in 20 ml of dry benzene was added at 25°C a suspension of 1.15 g of 2,3-dicyano-5,6-dichloroquinone in 10 ml of dry benzene the mixture was allowed to stand for 10 min, the precipitate was filtered off, the solution was evaporated, and chromatographed on silica gel plates with the system CCl_4—acetone 4:1. The zones with R_f 0.60 were eluted with acetone. Yield 1.0 g of (XI) in the form of an oil.

TABLE 3. ^{13}C NMR Spectra of Compounds (III), (V-VIII), (X), (XIII), (XIV), and (XVI)

Compound	δ, ppm, in acetone												$^1J_{C-F}$, Hz
	2	3	3a	4	5	6	7	7a	CF_3	C OH	C=O	OCH_3	
(III)	46,8	29,0	133,5	126,1	125,4	118,4	111,0	151,7	124,0	79,8	–	–	287,5
(V)	47,6	29,2	133,4	116,5	121,5	124,8	119,4	154,0	124,4	78,1	–	–	281,7
									124,6	80,4			281,7
(VI)	45,8	28,0	125,6	124,3	122,8	121,3	106,6	152,3	124,8	79,4	167,8	51,5	284,5
(VII)	47,4	29,5	132,0	125,9	117,8	125,9	114,4	151,6	125,2	80,5	169,4	53,5	285,6
(VIII)	47,5	29,1	133,1	124,6	121,5	125,2	109,0	153,4	124,4	79,0	169,5	53,6	282,6
									124,6	79,9			282,8
(X)	134,6	102,1	118,6	121,3	124,5	127,1	113,4	130,4	123,9	79,1	168,9	53,1	281,0
									124,1	80,1			283,1
(XIII)	133,7	104,3	118,5	119,8	124,4	125,4	112,6	126,8	122,4	77,3	167,5	51,9	278,7
									123,7	78,4			281,5
									124,2	79,6			283,1
(XIV)	135,4	106,4	120,0	123,4	123,0	120,4	117,9	128,5	124,1	77,5	168,4	54,0	280,1
									124,4	79,1			280,9
									124,6	80,1			282,5
(XVI) *	134,8	107,3	117,5	125,2	125,0	119,0	112,4	128,3	124,1	78,0	170,4	49,9	282,1
									124,1	78,1			282,1

*δCH_2 29.1 ppm.

3-(1-Hydroxy-1-carbomethoxytrifluoroethyl)-5,7-di-(2-hydroxyhexafluoroprop-2-yl)indole (XII). A solution of 2.2 g of (IX) and 1.5 g of ketoester (II) in 20 ml of dry benzene was heated in a glass ampul at 120°C for 8 h; the precipitate was filtered off and washed with hexane. Yield 2.6 g of (XII).

3,7-Di-(2-hydroxyhexafluoroprop-2-yl)-5-(1-hydroxy-1-carbomethoxytrifluoroethyl)indole (XII). a) Prepared under conditions (a) of the synthesis of (VIII) from 1.0 g of (X) and 0.8 g of (I). The yield of (XIII) was 1.2 g after crystallization from CCl_4. b) Prepared under conditions (a) of the synthesis of (VIII) from 1.0 g of (VIII) and 3 g of (I). After crystallization from benzene 1.2 g of (XIII) was obtained.

3,5-Di-(2-hydroxyhexafluoroprop-2-yl)-7-(1-hydroxy-1-carbomethoxytrifluoroethyl)indole (XIV). Prepared under conditions (a) of the synthesis of (VIII) from 0.9 g of (VII) and 2.2 g of (I). Yield 1.6 g of (XIV).

Methyl [5,7-di-(2-hydroxyhexafluoroprop-2-yl)-indol-3-yl]acetate (XVI). Prepared under the conditions for the synthesis of (III) from 4.0 g of methyl (indolin-3-yl)acetate (XV) and 15.0 g of (I). After evaporation of the solvent the mixture was chromatographed over a column with 250 g silica gel 40/100 by elution with a 6:1 mixture of CCl_4 and methyl ethyl ketone; yield 3.2 g of (XVI).

The authors express their thanks to M. V. Galakhov for the figure and help in interpretation of the NMR spectra.

CONCLUSIONS

1. Depending on the ratio of the reactants in the reaction of indoline with hexafluoroacetone and with methyl trifluoropyruvate, mono- and di-$C^{5,7}$ alkylation products of indoline, and also tri-$C^{3,5,7}$-alkylated indoline are formed.

2. By dehydrogenation of the products of C-alkylation of indoline with trifluorocarbonyl compounds a number of substituted indoles have been prepared.

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