Monatshefte für Chemie 135, 23–30 (2004)
DOI 10.1007/s00706-003-0117-y

Monatshefte für Chemie
Chemical Monthly
Printed in Austria

Synthesis and Tautomeric Equilibrium of Polyfluoroacyl-Containing 1,5-Benzodiazepines

Danil S. Yachevskii*, **Dmitry L. Chizhov, Mikhail I. Kodess,** and **Kazimir I. Pashkevich**

Institute of Organic Synthesis, Ural Branch of Russian Academy of Sciences, Ekaterinburg, 620219, GSP-147, Russian Federation

Received July 12, 2003; accepted (revised) July 23, 2003
Published online November 27, 2003

Summary. The reaction of bis(polyfluoroalkyl)-containing 1,3,5-triketones with *o*-phenylenediamine yielded 2-polyfluoroacylmethylene-4-polyfluoroalkyl-1,3- or 1,5-dihydro-1,5-benzodiazepines. The tautomeric equilibrium of the obtained benzodiazepines in $CDCl_3$, CD_3CN, *DMSO*, and *DMF* solution was studied.

Keywords. 1,3,5-Triketones; *o*-Phenylenediamine; NMR; Tautomerism.

Introduction

It is well known, that the interaction between β-diketones and *o*-phenylendiamine (*o-PDA*) gives 3*H*-1,5-benzodiazepines existing solely in the bisimino form, rather than in the conjugated imino-enamine one [1]. This is not affected by the presence of electron withdrawing substituents, such as polyfluoroalkyls, at 2- or 4-position of these compounds [2]. On the other hand, incorporation of an acyl group, which is capable of enolization and hydrogen bonding, into the β-position relative to the nitrogen atom of the diazepine ring may substantially influence the tautomeric equilibrium of 1,5-benzodiazepines. From this point of view it was of particular interest to study the interaction of 1,3,5-triketones with *o-PDA* in order to obtain acylmethylene substituted 1,5-benzodiazepines. The presence of carbonyl along with two β,δ-imino groups in the same molecule creates the possibility for several tautomeric forms, which can be stabilized by different hydrogen bonds. Hence, such compounds may serve as models for investigation of iminoenol–ketoenamine tautomerism in the series of amino derivatives of 1,3,5-triketones. The first and only example of such compounds previously obtained from heptane-2,4,6-trione is

* Corresponding author. E-mail: yad@ios.uran.ru

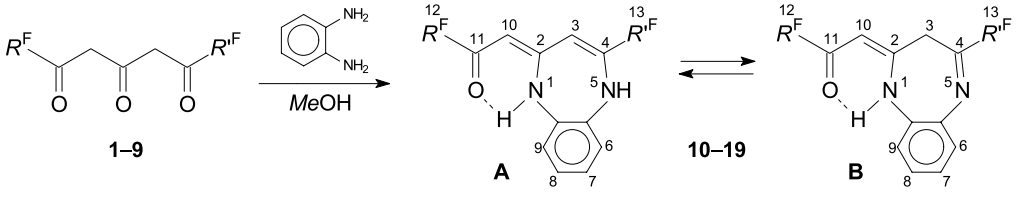
2-acetonyl-4-methyl-3*H*-1,5-benzodiazepine [3], but its assigned bis(imino)enol structure is somewhat ambiguous, because the authors did not offer convincing evidences of enolization of carbonyl versus imino group. Also there are no references concerning fluorocontaining analogues of this compound in literature.

Results and Discussion

2-Polyfluoroacylmethylene-4-polyfluoroalkyl-1,5-benzodiazepines **10**–**19** were synthesized by the reaction of bis(polyfluoroalkyl)-containing 1,3,5-triketones **1**–**9** [4] with *o-PDA* in absence of an acid catalyst.

The yields and the time of reaction slightly depend on the chain length of the polyfluoroalkyl group (the smaller the substituent, the higher the yield), but are very sensitive to the temperature. The reactions are completed upon refluxing in 10–15 min in 52–68% yields, while at room temperature it takes about two to three days, in the latter case yields being lower by 10–15%. The course of the reaction of unsymmetrical triketones (**2**, **4**–**6**) with *o-PDA* was found to be controlled by the steric factor; an addition occurs to the less hindered dicarbonyl moiety of a triketone. In all cases the interaction proceeded regiospecifically leading to 4-trifluoromethyl substituted benzodiazepines except in the case of **2**, where formation of two regio isomers **11** and **12** was observed. But even in that case the reaction was regioselective and 4-difluoromethyl substituted product was predominant (ratio **11**:**12** was 3.5:1). Compound **19** was not isolated in a pure state, but the ^{1}H NMR spectrum of the reaction mixture exhibits signals corresponding to the 2-tetrafluoroethyl substituted species, a choice favored by comparison with the spectra of diazepines **17** and **18**. Column chromatography of the reaction mixture yielded 2-tetrafluoroethyl benzimidazole [5], a result of decomposition of **19**, which serves as an additional evidence for its assigned structure.

It is noteworthy, that diazepines **10**–**14**, **17**, and **18** precipitated from methanol solutions in a different solid form. The former are colored intensely dark violet, whereas the latter are colorless or pale yellow. Compounds **15** and **16** did not crystallize from methanol solutions, but recrystallization of the reaction mixture from carbogal furnished pale yellow crystals with a little admixture of violet colored ones. It should be also noted, that **13** was turned into the colorless form



R^F / R'^F = CF_2H / CF_2H (**1, 10**), CF_2H / CF_3 (**2, 11**), CF_3 / CF_2H (**12**), CF_3 / CF_3 (**3, 13**), C_2F_4H / CF_3 (**4, 14**), C_3F_7 / CF_3 (**5, 15**), C_6F_{13} / CF_3 (**6, 16**), C_2F_4H / C_2F_4H (**7, 17**), C_4F_9 / C_4F_9 (**8, 18**), C_4F_9 / C_2F_4H (**9, 19**)

Scheme 1

by continuous boiling in carbogal or *n*-hexane (conversion completes faster in presence of acetic acid).

Spectroscopic ^{1}H, ^{19}F, and ^{13}C NMR data (Tables 1, 2) show that compounds **10**–**19** in solutions in $CDCl_3$, CD_3CN, *DMSO*, and *DMF* exist in the two tautomeric forms – ketodienamine **A** and ketoenaminoimine **B**. The tautomer **A** is confirmed by ^{1}H NMR ($CDCl_3$) spectra. Two broadened one-proton singlets at $\delta = 11.59$–11.76 (H-1 atom involved in the formation of the intramolecular hydrogen bond) and 5.39–5.50 ppm (H-5), and two sharp singlets corresponding to resonances of olefinic protons at $\delta = 5.28$–5.41 (H-10) and 4.54–4.91 ppm (H-3) are observed. The latter triplet is due to a spin–spin coupling with both NH-protons. In fact this signal consists of a doublet of doublets with similar coupling constants ($^{4}J_{H-NH} \approx 1.6$–2.3 Hz). In the double resonance spectra $^{1}H\{^{1}H\}$ of **13** corresponding coupling disappears under irradiation of either H-1 or H-5 and the triplet collapsed into a doublet with $^{4}J = 2.30$ or 1.87 Hz. Singlets observed in the ^{1}H NMR spectra of benzodiazepines **10**–**19** at $\delta = 12.56$–12.70 (H-1), 5.56–5.67

Table 1. ^{1}H NMR chemical shifts (δ, ppm) and coupling constants (J, Hz) for benzodiazepines in $CDCl_3$ solution[a] (25°C)

	R^F / R'^F	Taut.	NH^1	$=CH^3$ ($^{4}J_{H-H}$)	NH^5	$=CH^{10}$	R^F ($^{2}J_{H-F}/^{3}J_{H-F}$)	R'^F ($^{2}J_{H-F}/^{3}J_{H-F}$)
10	CF_2H	**A**	11.65	4.54 (t, 1.8)	5.50	5.28	5.75 (t, 55.0)	5.85 (t, 54.7)
	CF_2H	**B**	12.67	3.27		5.57[b]	5.83 (t, 54.9)	6.21 (t, 54.9)
11	CF_3	**A**	11.56	4.51 (t, 1.7)	5.49	5.24		5.84 (t, 54.7)
	CF_2H	**B**	12.60	3.28		5.58		6.22 (t, 54.8)
12	CF_2H	**A**	11.67	4.93 (dd, 1.7/1.9)	5.38	5.37	5.77 (t, 55.0)	
	CF_3	**B**	12.66	3.29		5.56	5.83 (t, 54.8)	
13	CF_3	**A**	11.59	4.90 (t, 1.9)[c]	5.43	5.33		
	CF_3	**B**	12.56	3.31		5.56		
14	C_2F_4H	**A**	11.69	4.91 (t, 2.0)	5.41	5.43	6.08 (tt, 53.1/5.2)	
	CF_3	**B**	12.67	3.31		5.66	6.10 (tt, 53.0/5.2)	
15	C_3F_7	**A**	11.69	4.89 (t, 1.8)	5.39	5.36		
	CF_3	**B**	12.65	3.31		5.61		
16	C_6F_{13}	**A**	11.68	4.89 (dd, 1.6/2.0)	5.39	5.37		
	CF_3	**B**	12.63	3.31		5.61		
17	C_2F_4H	**A**	11.73	4.79 (dd, 1.8/2.2)	5.43	5.41[b]	5.86 (tt, 53.7/4.2)	6.34 (tt, 52.8/5.3)
	C_2F_4H	**B**	12.70	3.34		5.67[b]	6.10 (tt, 53.1/5.2)	6.08 (tt, 52.6/5.2)
18	C_4F_9	**A**	11.76	4.92 (dd, 1.8/2.0)	5.43	5.40		
	C_4F_9	**B**	12.68	3.56		5.59		
19[d]	C_4F_9	**A**	11.72	4.77 (dd, 1.5/2.0)	5.46	5.34	Not identified	
	C_2F_4H	**B**	12.67	3.35		5.62		

[a] In all benzodiazepines multiplets of aromatic protons appeared in region of $\delta = 6.40$–6.49 (H-9), 6.61–6.69 (H-6), 6.80–6.95 (H-7,8) for tautomer **A**, and 7.21–7.29 (H-6), 7.28–7.44 (H-7,8), 7.42–7.56 (H-9) ppm for tautomer **B**; [b] t, $^{4}J_{H-F} = 1.17$; [c] dd, $^{4}J_{H1-H3} = 1.87$ Hz, $^{4}J_{H5-H3} = 2.30$ Hz (from the double resonance spectra); [d] from the spectrum of the reaction mixture

Table 2. Selected chemical shifts (δ, ppm) and coupling constants (J, Hz) for benzodiazepines in CD_3CN, *DMSO*-d_6, and *DMF*-d_6 solutions

Compound	Tautomer (solvent)	NH^1	$=CH^3$ ($^4J_{H-H}$)	NH^5	$=CH^{10}$
13	**A** (CD_3CN)	11.49	5.01 (dd, 1.8/2.0)	6.82	5.44
	A (*DMF*)	11.47	5.24 (t, 1.6)	9.25	5.68
	A (*DMSO*)	11.32	5.16 (t, 1.5)	8.73	5.63
	B (CD_3CN)	12.45	3.45		5.70
	B (*DMF*)	12.45	3.86		5.95
	B (*DMSO*)	12.27	3.73		5.88
14	**A** (CD_3CN)	11.60	5.03 (dd, 1.8/2.0)	6.80	5.52
	A (*DMF*)	11.59	5.22	ND[a]	5.72
	B (CD_3CN)	12.57	3.47		5.77
	B (*DMF*)	ND[a]	3.84		5.97
16	**A** (*DMF*)	11.57	5.28 (d, 1.6)	ND[a]	5.76
	B (*DMF*)	12.51	3.88		6.02
17	**A** (CD_3CN)	11.62	4.89 (dd, 2.0/2.1)	ND[a]	5.47[b]
	A (*DMF*)	11.62	5.06 (broad)	ND[a]	5.63
	B (CD_3CN)	12.57	3.46		5.74[c]
	B (*DMF*)	ND[a]	3.81		5.93
18	**A** (*DMSO*)	11.47	5.30 (dd, 1.8/2.0)	8.52	5.75
	B (*DMSO*)	12.33	3.79		5.87

[a] Signal not detected; [b] t, $^4J_{H-F} = 1.2$ Hz; [c] t, $^4J_{H-F} = 1.3$ Hz

(H-10), and 3.27–3.55 ppm (H-3, CH_2) with the integral ratio of 1:1:2 fit the tautomer **B**. Enolization of the central imino group, rather than the terminal one in **B** is also supported by the ^{13}C NMR spectra (CD_3CN) of compounds **13** and **14**. While signals of the enolized carbonyl group adjacent to the R^F-substituents in 1,3,5-triketones appear in the region of $\delta = 160$–166 ppm [4, 6], a quartet and a triplet corresponding to the resonance of C-11 (due to the coupling with CF_3 and CF_2 groups) of the carbonyl group are observed at $\delta = 178.9$ and 182.9 ppm, and its locations are practically unchanged for both tautomers. When passing from enamine moiety in **A** toward the ketimine **B** the quartet of the C-4 atom in both cases undergoes a downfield shift by $\approx$9 ppm, which is consistent with an sp^2-hybridized N-5 and the imino group involved in the conjugation with the benzene ring. The same characteristic is detected in the ^{19}F NMR spectra, especially of CF_3-substituted benzodiazepines (spectra of compounds with higher polyfluorosubstituents are complicated to interpret due to the multiplicity of signals and low content of the minor tautomers). The double set of signals is observed in those spectra: strong field pair related to the resonance of fluorosubstituents at the carbonyl group appears at $\delta \approx 84.7$ ppm with differences in chemical shifts of 0.22–0.29 ppm, whereas for downfield pair belonging to the 4-fluoroalkyls in the diazepinium ring that difference ranges from 1.12–1.16 ppm and signals appear at $\delta \approx 89.7$ and 88.5 ppm for **A** and **B**.

Table 3. Content of tautomer **A** in different solvents (%)*

	$CDCl_3$	CD_3CN	*DMF*-d_6	*DMSO*-d_6
10	95/9			
11	90/10			
12	90/10			
13	100/15	37/40	86	90/83
14	89/62	23/30	87	
15	3			
16	3/15		88	
17	0/4	86/73	75	
18	0/5			78
2i	13			

* Freshly prepared solution/after 1 month standing

For further confirmation of the assigned tautomer structures ^{19}F and ^{13}C NMR spectra of the previously synthesized CF_3 containing aminoenones [7, 8] were recorded. Thus, it was shown that signals of a trifluoromethyl group adjacent to carbonyl and amino group are observed at $\delta \approx 84$ and 89–98 ppm. In addition, the ^{13}C NMR spectrum exhibits the signals of $(CF_3)C{=}O$ groups in the region of $\delta = 177$–190 ppm.

In order to assign quaternary fluoro substituted carbons in benzodiazepines, **13** was chosen as a model and the HMBC experiments were run to reveal long-range connectivities over two and three bonds. Carbons C-12 and C-13 were identified due to the cross-peaks with H-10 and H-3. In addition, H-1 was observed to correlate to carbons C-3 and C-10, whereas H-5 correlated only to C-3, thus confirming the double resonance experiment data described above.

Ratio of tautomers was found to be sensitive to solvent polarity and particularly to basicity, and to a lesser extent to polyfluorosubstituent effects in benzodiazepines. The effect of solvents on the chemical shifts is summarized in Table 3. The content of tautomer **A** increases with increase in basicity of the solvent. In lowly polar and nonbasic deuterochloroform a slow tautomerization takes place and the state of equilibrium is achieved in one to three weeks with the ketoenamine form **B** as the major tautomer (85–96%). It was shown for **13** that the initial proportion of tautomers depends on type of crystals of benzodiazepine from which solutions were made. Thus, in the ^1H NMR spectrum of a freshly prepared solution of the violet colored compound only signals of tautomer **A** were observed, while a fresh solution of the colorless one was proven to correspond to tautomer **B**. In highly basic *DMSO* and *DMF* all benzodiazepines tautomerized rapidly and the predominant tautomer is **A** ($\approx$90%). This may be caused by some extra stabilization of the C(3)–C(4)–N(5)–enamine fragment due to the intermolecular hydrogen bonding between the amine H-5 proton and molecules of the solvent. The fact that signals of this proton in *DMSO* and *DMF* are observed at lower field as compared to those in $CDCl_3$ (see Tables 1, 2) also confirmed this suggestion. In acetonitrile, which is intermediate in its dielectric properties among the solvents used, tautomerization completed in a few days and the proportion of the tautomers are approximately average between those in $CDCl_3$ and *DMSO* or *DMF*.

In conclusion, addition of *o*-phenylenediamine occurs regioselective to the less hindered dicarbonyl moiety of bis(polyfluoroalkyl)-containing 1,3,5-triketones leading to the corresponding 1,5-benzodiazepines, which in solutions exist in ketodienamine (**A**) and ketoenaminoimine (**B**) tautomeric forms. The former (**A**) was found to be more thermodynamically stable in non-polar solvents, whereas in polar aprotic solvents the predominant tautomer is **B**. It appeared, that depending on polyfluorosubstituents either 1,3-dihydro- or 1,5-dihydro-1,5-benzodiazepines could be isolated in a pure solid state.

Experimental

NMR spectra were recorded on a Bruker DRX 400 (400.13 MHz ^{1}H, 100.61 MHz ^{13}C) and a Tesla BS-587A (75.3 MHz ^{19}F) instruments in $CDCl_3$ solutions with Me_4Si (^{1}H and ^{13}C) and C_6F_6 (^{19}F) as internal standards. ^{19}F NMR data are given only for CF_2H, CF_3, and C_2F_4H substituents. All the protonated carbons were directly assigned through the $^{1}J_{CH}$ connectivities provided by the HETCOR experiment. Infrared spectra were recorded on a Specord 75IR spectrometer, samples were investigated in Vaseline oil and CCl_4 solution. Elemental analyses (C, H, N, F) were conducted using the Perkin Elmer Elemental Analyzer 2400; their results agreed with the calculated values within experimental error.

*General Procedure for the Synthesis of Compounds **10–18***

The mixture of 1,3,5-triketone (2 mmol), 2 mmol of *o*-phenylenediamine, and 3 cm^3 of methanol was refluxed for 15 min, cooled, and after evaporation to dryness the residue was recrystallized from methanol or ethanol (**10–14**), carbogal (**15**, **16**), or *n*-hexane (**17**, **18**). Benzodiazepines **10–14** form deep-violet colored crystals, whereas the latter have pale-yellow color (**15**, **16** with a little admixture of colored ones). The reaction of triketon **2** yielded an inseparable mixture of **11** and **12** in overall yield of 52% and with ratio 3.5:1.

1,1-Difluoro-3-(4-difluoromethyl-1,5-dihydrobenzo[b][1,4]diazepin-2-ylidene)propan-2-one
(**10**, **A**, $C_{13}H_{10}F_4N_2O$)

Yield 68%, mp 188–189°C; ^{19}F NMR: $\delta = 35.73$ (dd, 2F, $COCF_2H$, $^{2}J_{H-F} = 54.3$ Hz, $^{4}J_{H-F} = 1.0$ Hz), 40.09 (d, 2F, $CNCF_2H$, $^{2}J_{H-F} = 54.1$ Hz) ppm; IR: $\bar{\nu} = 3300$, 3175, 3145, 3110, 3060, 3025, 1670, 1635, 1610, 1590, 1535, 1500 cm^{-1}.

(**10**, **B**): ^{19}F NMR: $\delta = 36.08$ (dd, 2F, $COCF_2H$, $^{2}J_{H-F} = 54.8$ Hz, $^{4}J_{H-F} = 1.0$ Hz), 41.74 (d, 2F, $CNCF_2H$, $^{2}J_{H-F} = 54.8$ Hz) ppm.

1,1,1-Trifluoro-3-(4-difluoromethyl-1,5-dihydrobenzo[b][1,4]diazepin-2-ylidene)propan-2-one
(**11**, **A**, $C_{13}H_9F_5N_2O$)

^{19}F NMR: $\delta = 40.80$ (d, 2F, CF_2H, $^{2}J_{H-F} = 55.0$ Hz), 84.65 (s, 3F, CF_3) ppm.
(**11**, **B**): ^{19}F NMR: $\delta = 41.87$ (d, 2F, CF_2H, $^{2}J_{H-F} = 54.7$ Hz), 84.88 (s, 3F, CF_3) ppm.

1,1-Difluoro-3-(4-trifluoromethyl-1,5-dihydrobenzo[b][1,4]diazepin-2-ylidene)-propan-2-one
(**12**, **A**, $C_{13}H_9F_5N_2O$)

^{19}F NMR: $\delta = 36.18$ (d, 2F, CF_2H, $^{2}J_{H-F} = 54.9$ Hz), 89.86 (s, 3F, CF_3) ppm.
(**12**, **B**): ^{19}F NMR: $\delta = 36.15$ (d, 2F, CF_2H, $^{2}J_{H-F} = 52.7$ Hz), 88.54 (s, 3F, CF_3) ppm.
IR (**11** + **12**): $\bar{\nu} = 3310$, 3185, 3115, 3055, 3025, 1655, 1605, 1580, 1540, 1525 cm^{-1}.

1,1,1-Trifluoro-3-(4-trifluoromethyl-1,5-dihydrobenzo[b][1,4]diazepin-2-ylidene)propan-2-one (**13**, **A**, $C_{13}H_8F_6N_2O$)

Yield 65%, mp 189–190°C; ^{19}F NMR: $\delta = 84.54$ (s, 3F, $COCF_3$), 89.74 (s, 3F, $CNCF_3$) ppm; ^{13}C NMR (CD_3CN): $\delta = 94.90$ (q, C^{10}, $^3J_{C-F} = 1.2$ Hz), 98.86 (q, C^3, $^3J_{C-F} = 4.7$ Hz), 118.75 (q, C^{12}, $^1J_{C-F} = 288.1$ Hz), 121.50 (q, C^{13}, $^1J_{C-F} = 276.0$ Hz), 123.13, 124.77, 127.22, 127.88, 131.98, 136.25 (Ph), 143.49 (q, C^4, $^2J_{C-F} = 32.3$ Hz), 163.68 (C^2), 178.92 (q, C^{11}, $^2J_{C-F} = 33.2$ Hz) ppm; IR: $\bar{\nu} = 3295$, 3170, 3100, 1655, 1600, 1570, 1545 cm^{-1}; IR (CCl_4): $\bar{\nu} = 3400$, 3020, 1660, 1620, 1590, 1550 cm^{-1}.

1,1,1-Trifluoro-3-(4-trifluoromethyl-1,3-dihydrobenzo[b][1,4]diazepin-2-ylidene)propan-2-one (**13**, **B**, $C_{13}H_8F_6N_2O$)

Benzodiazepine **2c** (tautomer **A**) was refluxed in carbogal in presence of acetic acid for several h. The hot solution was filtered off and cooled. Tautomer **B** precipitated as pale yellow needles, mp 125–127°C; ^{19}F NMR: $\delta = 84.85$ (s, 3F, $COCF_3$), 88.64 (s, 3F, $CNCF_3$) ppm; ^{13}C NMR (CD_3CN): $\delta = 35.41$ (C^3), 90.37 (q, C^{10}, $^3J_{C-F} = 1.4$ Hz), 118.82 (q, C^{12}, $^1J_{C-F} = 288.1$ Hz), 120.73 (q, C^{13}, $^1J_{C-F} = 276.5$ Hz), 125.03, 128.21, 130.60, 130.86, 131.84, 139.46 (Ph), 152.63 (q, C^4, $^2J_{C-F} = 35.5$ Hz), 163.45 (C^2), 179.23 (q, C^{11}, $^2J_{C-F} = 33.5$ Hz) ppm; IR: 1625, 1605, 1560, 1510 cm^{-1}.

3,3,4,4-Tetrafluoro-1-(4-trifluoromethyl-1,5-dihydrobenzo[b][1,4]diazepin-2-ylidene)butan-2-one (**14**, **A**, $C_{14}H_9F_7N_2O$)

Yield 63%, mp 170°C; ^{19}F NMR: $\delta = 23.07$ (dt, 2F, $CF_2\underline{CF_2}H$, $^2J_{H-F} = 52.9$ Hz, $^3J_{F-F} = 7.2$ Hz), 36.07 (m, 2F, $\underline{CF_2}CF_2H$), 89.63 (s, 3F, CF_3) ppm; ^{13}C NMR (CD_3CN): $\delta = 95.41$ (C^{10}), 98.44 (q, C^3, $^3J_{C-F} = 4.7$ Hz), 110.64 (tt, C^{14}, $^1J_{C-F} = 248.3$ Hz, $^2J_{C-F} = 33.5$ Hz), 110.96 (tt, C^{12}, $^1J_{C-F} = 258.7$ Hz, $^2J_{C-F} = 27.6$ Hz), 120.97 (q, C^{13}, $^1J_{C-F} = 276.2$ Hz), 122.53, 124.16, 126.59, 127.19, 131.44, 135.68 (Ph), 142.78 (q, C^4, $^2J_{C-F} = 32.3$ Hz), 162.40 (C^2), 182.90 (t, C^{11}, $^2J_{C-F} = 24.9$ Hz) ppm; IR: $\bar{\nu} = 3430$, 3030, 1655, 1620, 1595, 1585, 1540, 1525 cm^{-1}; IR (CCl_4): $\bar{\nu} = 3430$, 3030, 1665, 1610, 1585, 1550 cm^{-1}.

3,3,4,4-Tetrafluoro-1-(4-trifluoromethyl-1,3-dihydrobenzo[b][1,4]diazepin-2-ylidene)butan-2-one (**14**, **B**, $C_{14}H_9F_7N_2O$)

^{19}F NMR: $\delta = 23.16$ (dt, 2F, $CF_2\underline{CF_2}H$, $^2J_{H-F} = 53.3$ Hz, $^3J_{F-F} = 7.0$ Hz), 36.36 (m, 2F, $\underline{CF_2}CF_2H$), 88.46 (s, 3F, CF_3) ppm; ^{13}C NMR (CD_3CN): $\delta = 34.87$ (C^3), 90.86 (C^{10}), 111.03 (tt, C^{14}, $^1J_{C-F} = 258.7$ Hz, $^2J_{C-F} = 27.6$ Hz), 111.18 (tt, C^{12}, $^1J_{C-F} = 258.7$ Hz, $^2J_{C-F} = 27.6$ Hz), 120.19 (q, C^{13}, $^1J_{C-F} = 276.2$ Hz), 124.84, 127.55, 130.00, 130.28, 131.34, 138.92 (Ph), 152.16 (q, C^4, $^2J_{C-F} = 35.7$ Hz), 162.31 (C^2), 183.20 (t, C^{11}, $^2J_{C-F} = 24.9$ Hz) ppm.

3,3,4,4,5,5,5-Heptafluoro-1-(4-trifluoromethyl-1,3-dihydrobenzo[b][1,4]diazepin-2-ylidene)pentan-2-one (**15**, **B**, $C_{15}H_8F_{10}N_2O$)

Yield 58%, mp 88–89°C; ^{19}F NMR: $\delta = 88.52$ (s, 3F, CF_3) ppm; IR: $\bar{\nu} = 1618$, 1594, 1562, 1515 cm^{-1}. (**15**, **A**): ^{19}F NMR: $\delta = 89.68$ (s, 3F, CF_3) ppm.

3,3,4,4,5,5,6,6,7,7,8,8,8-Tridecafluoro-1-(4-trifluoromethyl-1,3-dihydrobenzo[b][1,4]diazepin-2-ylidene)octan-2-one (**16**, **B**, $C_{18}H_8F_{16}N_2O$)

Yield 52%, mp 98°C; ^{19}F NMR: $\delta = 88.51$ (s, 3F, CF_3) ppm; IR: $\bar{\nu} = 1620$, 1590, 1555, 1505 cm^{-1}. (**16**, **A**): ^{19}F NMR: $\delta = 89.66$ (s, 3F, CF_3).

3,3,4,4-Tetrafluoro-1-[4-(1,1,2,2-tetrafluoroethyl)-1,3-dihydrobenzo[b]-[1,4]diazepin-2-ylidene]butan-2-one (**17**, **B**, $C_{15}H_{10}F_8N_2O$)

Yield 59%, mp 114°C; ^{19}F NMR: $\delta = 23.23$ (dt, 2F, CO$\underline{CF_2}CF_2H$, $^2J_{H-F} = 53.1$ Hz, $^3J_{F-F} = 6.9$ Hz), 23.76 (dt, 2F, CN$\underline{CF_2}CF_2H$, $^2J_{H-F} = 52.8$ Hz, $^3J_{F-F} = 4.5$ Hz), 36.42 (m, 2F, $COCF_2\underline{CF_2}H$), 42.40 (m, 2F, $CNCF_2\underline{CF_2}H$) ppm; IR: $\bar{\nu} = 3005$, 1610, 1590, 1545 cm^{-1}.

(**17**, **A**): ^{19}F NMR: $\delta = 23.04$ (dt, 2F, CO$\underline{CF_2}CF_2H$, $^2J_{H-F} = 53.3$ Hz, $^3J_{F-F} = 7.2$ Hz), 27.76 (dt, 2F, CN$\underline{CF_2}CF_2H$, $^2J_{H-F} = 53.6$ Hz, $^3J_{F-F} = 4.1$ Hz), 36.11 (m, 2F, $COCF_2\underline{CF_2}H$), 40.35 (m, 2F, $CNCF_2\underline{CF_2}H$) ppm.

3,3,4,4,5,5,6,6,6-Nonafluoro-1-(4-nonafluorobutyl-1,3-dihydrobenzo[b][1,4]diazepin-2-ylidene)hexan-2-one (**18**, **B**, $C_{19}H_8F_{18}N_2O$)

Yield 60%, mp 60°C; IR: $\bar{\nu} = 1590$, 1545 cm^{-1}.

References

[1] Lloyd D, Cleghorn HP (1974) Adv Heterocycl Chem **17**: 27
[2] Pashkevich KI, Saloutin VI, Postovskii IYa (1980) Bull Acad Sci USSR, Div Chem Sci **29**: 438
[3] Furuhashi A, Aoki K, Sugimoto M (1979) Bull Chem Soc Jpn **52**: 2157
[4] Yachevskii DS, Chizhov DL, Ratner VG, Pashkevich KI (2001) Russ Chem Bull **50**: 1233
[5] Pashkevich KI, Saloutin VI, Postovskii IYa (1980) Bull Acad Sci USSR, Div Chem Sci **5**: 1172
[6] Sevenard DV, Khomutov OG, Kodess MI, Pashkevich KI (1999) Russ Chem Bull **48**: 400
[7] Pashkevich KI, Filyakova VI, Postovskii IYa (1981) Bull Acad Sci USSR, Div Chem Sci **10**: 2346
[8] Pashkevich KI, Filyakova VI, Postovskii IYa (1981) Bull Acad Sci USSR, Div Chem Sci **11**: 2651