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The reaction of binucleophilic reagents containing 1,4-nucleophilic centers with perfluoro-2-methylpent-2-ene and perfluoro-5-azanon-4-ene

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Abstract

Reaction between perfluoro-2-methylpent-2-ene or perfluoro-5-azanon-4-ene and the compounds of H_2NCH_2CXYZH (Z = O, NH; X = H, CH_3; Y = H, CH_3, C_2H_5) type in the presence of triethylamine give 7-membered heterocycles with two and three heteroatoms. Reaction of ethylenediamine with perfluoro-2-methylpent-2-ene results in 9-fluoro-5,9-bis(pentafluoroethyl)-6,8,8-tris(trifluoromethyl)-1,4-diazabicyclo[5.2.0]nona-4,6-diene and with perfluoro-5-azanon-4-ene leads only to 2,4-bis(heptafluoro-propyl)-6,7-dihydro-1H[1.3.5]-thiazepine. Reaction of ethylene glycol with perfluoro-2-methylpent-2-ene results in 2-fluoro-2,4-bis-(heptafluoropropyl)-6,7-dihydro-2H[1.5.3]dioxazepine. The routes of formation for these products have been discussed and the role of triethylamine in these reactions is elucidated.

Keywords: Perfluoro-2-methylpent-2-ene; Perfluoro-5-azanon-4-ene; Nucleophilic addition; Nucleophiles; Cyclization; Ethanolamines; Ethylenediamine; Ethylene glycol; 7-Membered heterocycles

1. Introduction

The introduction of fluorine atoms into organic compounds is of great scientific and practical interest in the field of design of new effective biologically active substances and materials. Heterocyclic compounds with perfluoroalkyl groups (especially trifluoromethyl) are attractive as intermediates for obtaining pharmaceutical and agricultural agents [1–3]. Such compounds are generally known to be more biologically active than the analogous molecules containing alkyl groups [4].

The development of methods for introduction of perfluoroalkyl groups into organic molecules and creation of heterocyclic systems has achieved substantial progress in recent years. Noticeable successes are known in the fields of reactions between perfluoroolefins and nucleophilic reagents leading to 4–6 membered heterocyclic compounds containing one or two heteroatoms [5]. The 7-9-membered heterocycles can be synthesized by similar methods, but in the last case the yield of products is low and complex mixtures of reaction products are obtained. Thus, the interaction between perfluoro-2-methylpent-2-ene and ethylene glycol leads to a 5-membered heterocycle (2-pentafluoroethyl-2-hexafluoroisopropyl-1,3-dioxolane) and 7-membered heterocyclic compounds (5-pentafluoroethyl-6-trifluoromethyl-5,7-difluoro (or 7,7-difluoro)-1,4-dioxacyclohept-6-ene) [6]. The reaction of perfluoro-2-methylpent-2-ene with 2-mercaptoethanol in the presence of K_2CO_3 leads to 5,7-difluoro-5-pentafluoroethyl-6-trifluoromethyl-3,5-dihydro-2H-[1,4]oxathiepine (32% yield) [7]. The reactions of perfluoro-3,4-dimethylhex-3-ene with ethylene glycol and monoethanolamine lead to 5-pentafluoroethyl-5,6,7-tris(trifluoromethyl)-1,4-dioxacyclohept-6-ene (58% yield) and 5-pentafluoethyl-5,6,7-tris(trifluoromethyl)-1-oxa-4-azacyclohept-6-ene (8% yield), respectively [8], while perfluoropent-2-ene, reacting with ethylenediamine, forms 5,7-bis(trifluoromethyl)-6-fluoro-2,3-dihydro-1H[1,4]-diazepin (yield 74 %) [9–12].

Better results are achieved in the case of interaction of perfluoro-2-methylpent-2-ene and perfluoro-2,4-dimethylhept-3-ene with such nucleophilic reagents as *ortho*-bifunctional

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benzenes leads to the formation of new types of 5-, 7- and 9-membered benzoheterocycles [13–15]. For example, 2-aminophenol with these compounds gives 4-fluoro-2-pentafluoroethyl-3-trifluoromethyl-1,5-benzooxazepine and 7(perfluoro-1-methylethyl)-8-pentafluoroethyl-9,14-benzooxapino-[4,3-b]-1,6-benzooxazepine, respectively [13].

We suppose that binucleophilic agents with 1,4-nucleophilic centers (a-b-c-d) and NH_2-group on the end of the chain will form 7-membered heterocycles. An amino-group provides the formation of an intermediate compound with N=C groups, facilitating, in turn, the generation of new C=C bonds. So, to prove this thesis and develop the synthesis of 7-membered heterocycles, containing heteroatoms and perfluoroalkyl groups, we have investigated the reactions of perfluoro-2-methylpent-2-ene (**1**) and perfluoro-5-azanon-4-ene (**2**) with the compounds of the $NH_2CH_2CH_2YH$ (Y = O, NH) type in the presence of triethylamine.

The reaction of compound **1** with monoethanolamine in the presence of triethylamine in MeCN leads smoothly to heterocycles (**3**–**5**) (Scheme 1). The first stage of this reaction includes the attack of monoethanolamine on the nucleophilic centers of the double bonds C=C and C=N in compounds **1** and **2** with further elimination of HF under the action of Et_3N, leading to C- and N-anions. Their effective stabilization can be achieved by elimination of fluoride ion. This stage, in turn, leads to the formation of new compounds with C=C and C=N bonds, possessing a fluorine atom, active towards nucleophiles. That atom provides the intramolecular nucleophilic cyclization via participation of a second nucleophilic center (oxygen atom) to yield finally the 7-membered heterocycles **3**–**5** (Scheme 2).

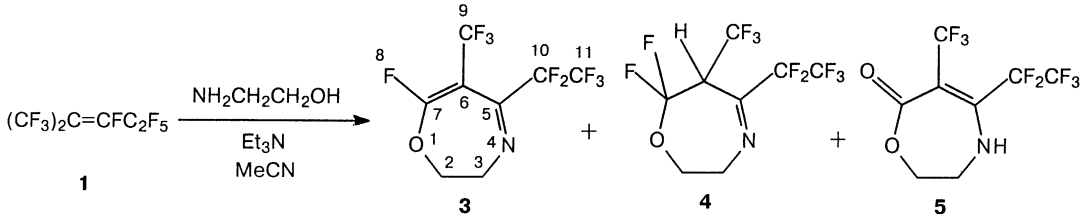
The initial addition of the N-containing nucleophile to the double bond leads to generation of carbanion **A**. Nitrogen atom possesses stronger nucleophilicity than oxygen, so primary attack (in the absence of alkali) directs to the nitrogen atom. In the paper of Chambers et al. [8], the possibility of subsequent attack of perfluoro-3,4-dimethylhex-3-ene by nitrogen and oxygen nucleophilic centers of monoethanolamine has been shown. The latter can be stabilized by elimination of fluoride ion from CF_3 group into γ-position to form olefins **6**, **7** or **8** containing the double bond allylic with respect to the initial center of nucleophilic addition. The following intramolecular nucleophilic attack on the carbon atom of double bond in the highly reactive terminal perfluoroolefin by the O-containing nucleophilic center leads to the cyclisation to give C-carbanion **B**. The interaction between **B** and the proton from system leads to compound **4**. The elimination of fluoride ion from carbanion **B** yields, in turn, product **3**, hydrolyzed with formation of compound **5** because of the high nucleophilic activity of fluorine atom in the position 7 (Scheme 2). The similar transformation has been established for various reactions of perfluoroolefins with amines (see, e.g. [6,9,10,14]).

Compound **1** is known to isomerize with bases into perfluoro-2-methylpent-1-ene (**9**) [5]. The latter has more active fluorine atoms bonded with carbon atoms of terminal C=C bond than olefin **1**. Such isomerization can take also place with compound **2**, but it leads to an azaalkene with a C=N bond and the rate of interaction with nucleophilic agent in this variant should be practically the same. Monoethanolamine, being strong base, is able to catalyze the isomerization of compound **1**. At the same time triethylamine should react with compound **1** to give the triethylammonium salt (**10**) [15], making the transformation of compound **1**–**5** difficult (Scheme 3). The salt **10** was not isolated, but its structure was confirmed by ^{19}F NMR data and chemical transformations [15].

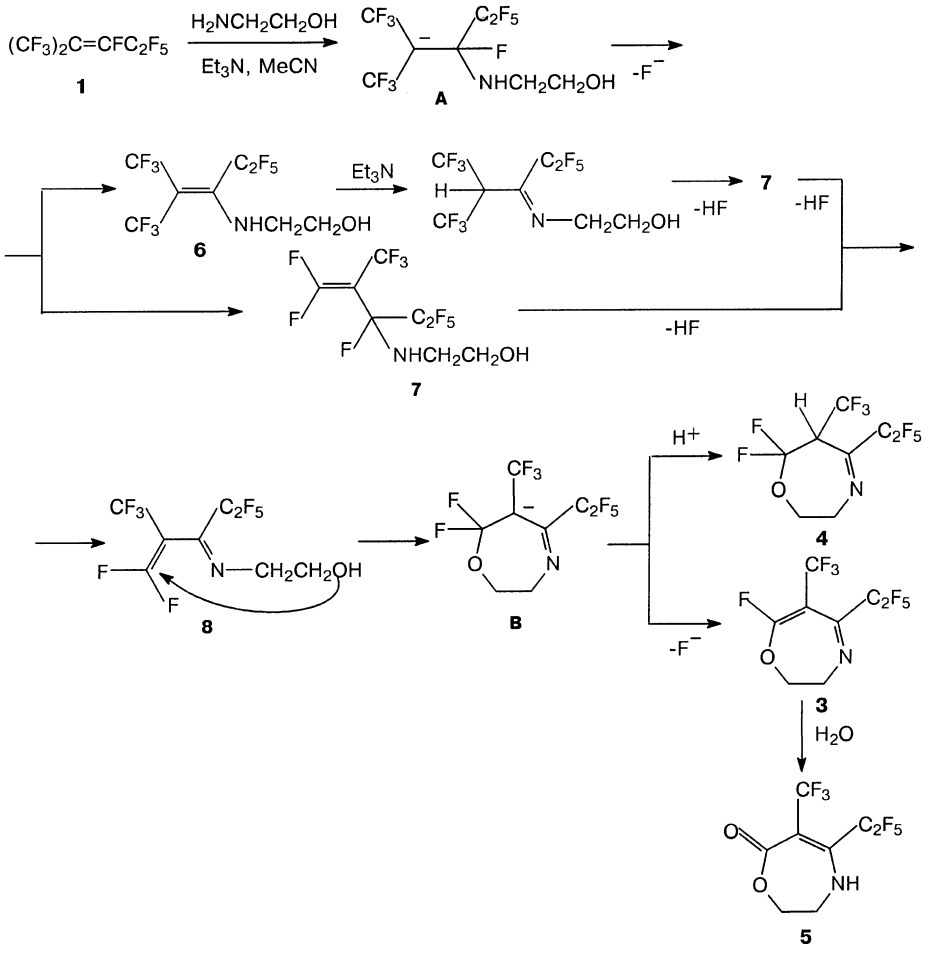
A number of authors have been found the action of secondary amines [16] and phenylhydrazine [17] on salt type **10** to lead to the attack on the α-carbon atom of double bond to give enamines. Therefore, the formation of salt **10** seems not to change the route of interaction of compound **1** with monoethanolamine. However, in the case of the presence of alkyl groups bonded to these with carbon atom with respect to the amino group, steric hindrance is able to change the direction of primary attack. To check this thesis, we used the substituted derivatives of monoethanolamine $NH_2CH(C_2H_5)CH_2OH$ and $NH_2C(CH_3)_2CH_2OH$. These reagents possess a C_2H_5 group and two methyl groups α to the N-nucleophilic center.

The products of reactions with these compounds have been characterized as isomeric heterocycles (**11a**,**b**) and (**12b**), (isomers **11a**,**b** being preferential in this case) and **13a**,**b**. The heterocyclic system is formed by the attack on the internal double bond by the N-nucleophilic center (Scheme 4).

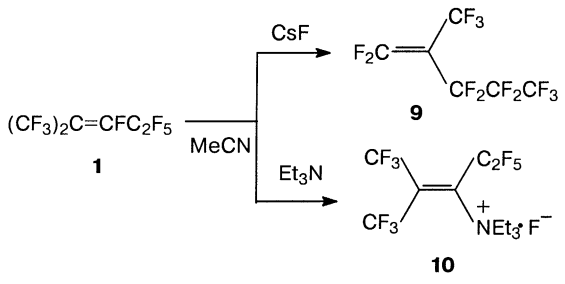
The formation of **12b** can be presented in two ways (Scheme 5). First, direct attack of the N-nucleophilic center of monoethanolamine of C=C bond in the product **9** (being formed intermediately from **1** by the action of Et_3N) with subsequent cyclization. The second route consists of the direct attack of monoethanolamine as nucleophile by C=C



Scheme 1.

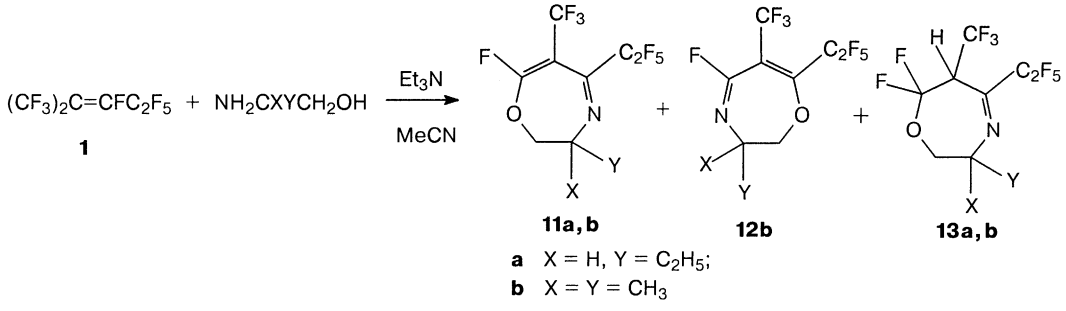


Scheme 2.

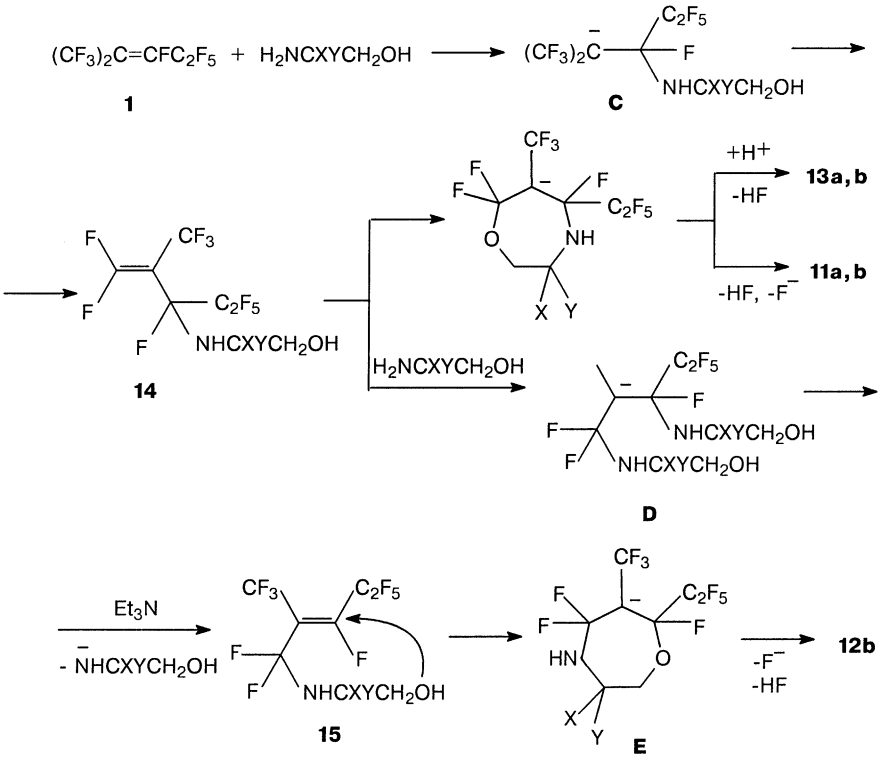


Scheme 3.

bond of compound **1**. The intermediate **C** in this case undergoes the elimination of fluoride-ion from the CF_3-group to yield olefin (compound **14**). Further, because of the high nucleophilic mobility of fluorine at the terminal double bond, the second molecule of monoethanolamine joins on this addition and gives an anion **D**. The stabilization of carbanion **D** can occur via either elimination of fluoride ion from CF_2 group, or elimination of N-anion $[NHCXY\text{-}CH_2OH]^-$ to give compound **15**. The O-nucleophilic attack by the carbon atom of double bond in compound **15** leads



Scheme 4.



Scheme 5.

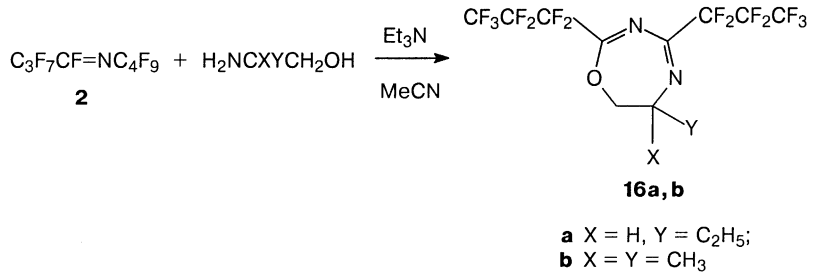
to the cyclic carbanion **E**. Elimination of HF and fluoride-ion from carbanion **E** yields the product **12b** (Scheme 5). These processes depend on a number of factors, including steric ones.

The ratio of isomers **11a**,**b** and **12b** probably depends on the ratio of the elimination rates of fluoride-ion and HF from C-carbanion **C**. An increased rate of elimination of HF over that for fluoride ion leads to increase of yield of **11a**,**b** over yield of **12b**. The formation of **11a**,**b** and **13a**,**b** can be presented as direct attack of the O-nucleophilic center of the terminal C=C bond.

The interaction of monoethanolamine derivatives with the compound **2** leads to the formation of compounds **16a**,**b** with perfluoropropyl groups (Scheme 6). The interesting nucleophile for these reactions is hydroxylamine, where N- and O-nucleophilic centers are not divided by carbon atoms. In this case, the formation of isoxazole **17** could be expected. However, the reaction of compound **1** with hydroxylamine in the presence of the triethylamine leads to derivatives of [1.2]oxazepine **18** and **19** and only in small amounts — to isoxazole **17** (Scheme 7).

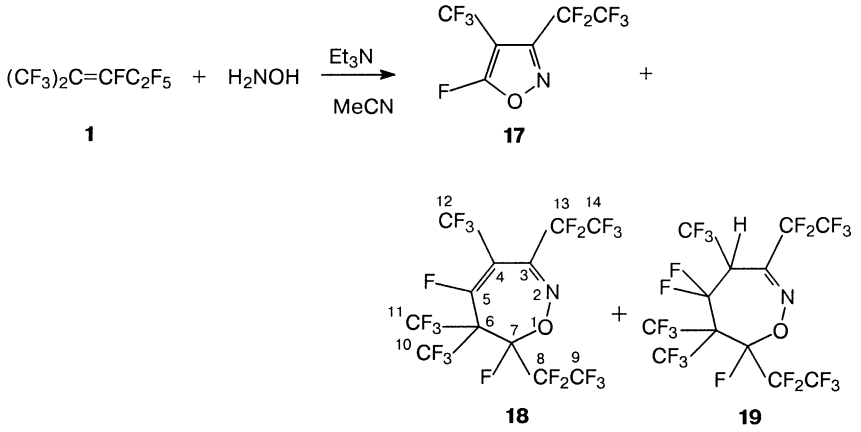
It is likely that attack occurs by the N-nucleophilic center of hydroxylamine on the carbon atom of the double bond of internal perfluoroolefin **1** to form an intermediate C-carbanion. Isoxazole **17a** reacts with internal perfluoro-olefin, yielding the products of an intramolecular nucleophilic cyclization — 7-membered heterocycle (compounds **18** and **19**) instead of intramolecular nucleophilic cyclization with formation of 5-membered heterocycle **17** (Scheme 8).

Ethylenediamine has been shown earlier to react with compound **1** to give 9-fluoro-5,9-bis(pentafluoro-ethyl)-6,8,8-tris(trifluoromethyl)-1,4-diazabicyclo[5.2.0]nona-4,6-diene (**20**) and not 7-fluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro-1H[1,4]diazepine (**21**). The structure of **20** was confirmed by X-ray structural analysis [18]. The formation of compound **20** can probably be explained

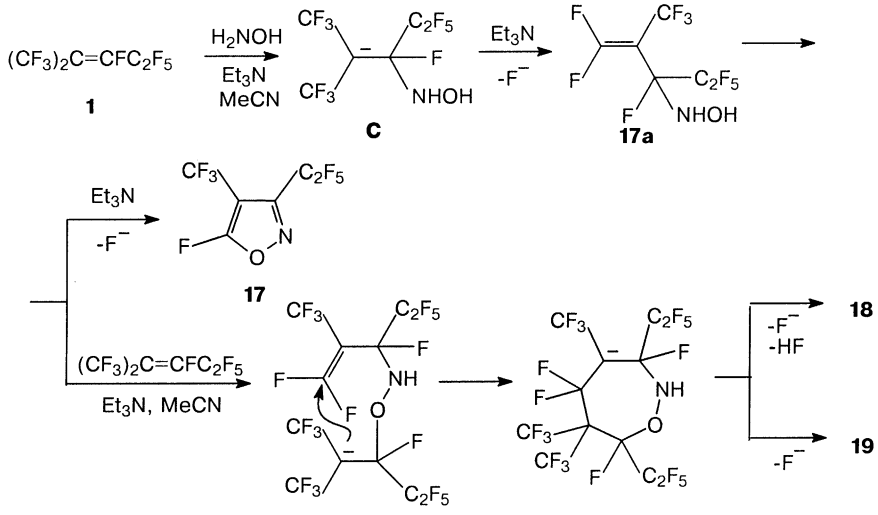


a X = H, Y = C_2H_5;
b X = Y = CH_3

Scheme 6.

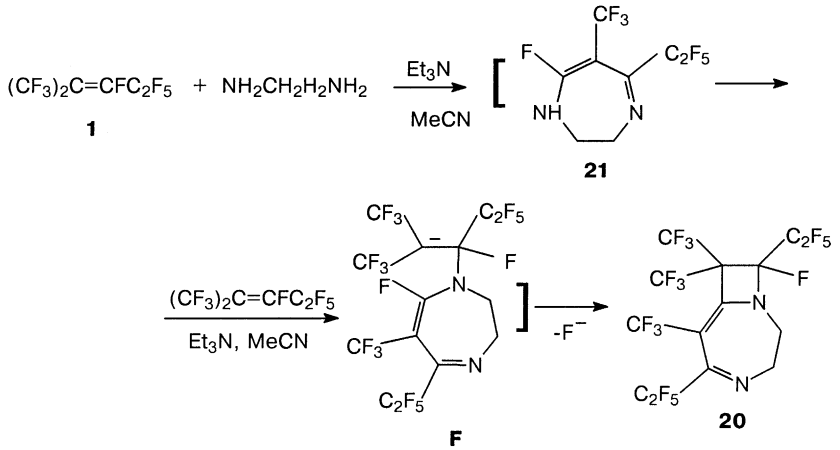


Scheme 7.

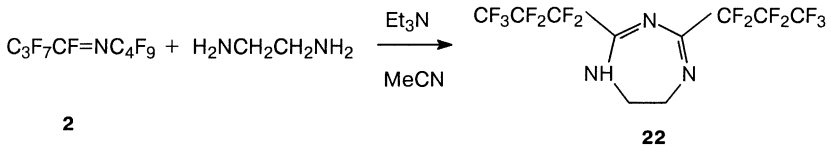


Scheme 8.

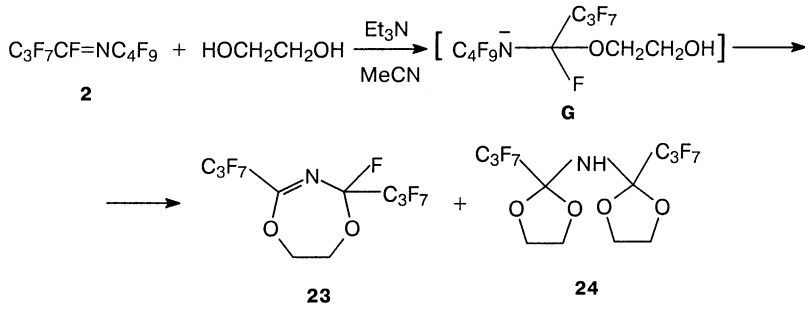
(Scheme 9) in terms of the initial formed compound **21**, reacting further with a second molecule of compound **1**. The latter process can occur because of generation of the active nucleophilic center by the NH group of the 7-membered heterocycle leading to the formation of a C-carbanion (**F**). The intramolecular nucleophilic cyclization of this carbanion **F** and a C=C double bond provides the formation of a second ring (product **20**, Scheme 9).



Scheme 9.



Scheme 10.



Scheme 11.

The reaction of ethylenediamine with **2** leads solely to a **7**-membered heterocycle (**22**) (Scheme 10). Further transformations of compound **22** have not been investigated. Perfluoro-2-methylpent-2-ene reacts with ethylene glycol leads to both 5-membered heterocycle (derivative 1,3-dioxolane) and only 5–7% of the 7-membered heterocycle. As against this **2** interacts with ethyleneglycol in acetonitrile in the presence of triethylamine to give two products compounds **23** and **24** (Scheme 11).

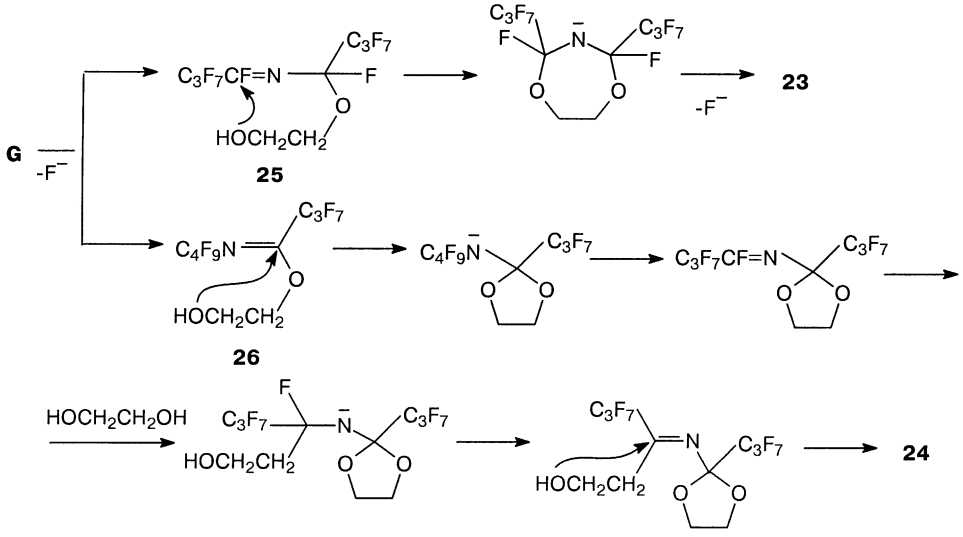
The following route has been proposed for this reaction (Scheme 12). The stabilization of N-anion **G** can occur by either elimination of fluoride-ion from the CF_2-fragment, or from CF-one. In both cases a C=N bond generates, leading to compounds **25** and **26**. Further cyclization of compound **25** yields **23**, and the same transformation of compound **26** yields **24**. The cyclization by the latter route is known [6,19,20].

Therefore, the reaction of internal perfluoroolefins with binucleophilic agents with 1,4-nucleophilic centers (one of which is a NH_2 group) occurs easily to give, as a rule, 7-membered heterocycles. The nature of the second nucleophilic center has only weak influence on the process occurring in intramolecular nucleophilic cyclization.

2. Experimental

2.1. Instrumentation

The ^{19}F and ^{1}H NMR spectra were recorded in ppm downfield from internal standards C_6F_6 and $SiMe_4$ in $CDCl_3$ using a Bruker WP 200SY spectrometer operating at 188.324 and 200 MHz. ^{13}C NMR spectra were recorded



Scheme 12.

in $CDCl_3$ in ppm downfield from internal standard Me_4Si, on a Bruker AM 400 spectrometer operating at 100.614 MHz in $CDCl_3$ (J_{CH} not recorded). Coupling constants are given in Hz. Infrared (IR) spectra were recorded on a Bruker vector spectrometer (5% in CCl_4). GC-MS spectra were obtained at 70 eV in the electron impact mode and are reported as *m/z* (relative intensity) using a Finnigan MAT model 8200 spectrometer. Mass spectra were determined with gas chromatograph electron ionization detector (Hewlett-Packard G 1800A GCD system), 30 mm capillary column 0.25 mm with co-polymer 5%-diphenyl- (95%)-dimethylsilicate (HP-5), gas–helium, 1 ml/min, T 280°C. All reactions were monitored routinely by ^{19}F NMR spectroscopy. Column chromatography was performed using silica gel 60, a 0.063–0.2 mm (70–230 ASTM), and were used for TLC analysis with the indicated solvents. Melting points were recorded at atmospheric pressure and are uncorrected. All commercially available reagents were of analytical grade and were used without further purification and all solvents were dried before use. The analysis of a reaction mixture was conducted by mass spectrometer, and the individual products were separated from each other by preparative silica gel chromatography using hexane-CH_2Cl_2 (5:1). All starting materials were either obtained commercially (Aldrich) or prepared by literature procedures and all solvents were dried before use.

2.2. Reaction compound **1** with ethanolamine and some its derivatives

2.2.1. Synthesis of 7-fluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro[1,4] oxazepine (**3**), 7, 7-difluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3,6, 7-tetrahydro[1,4]oxazepine (**4**) and 5-pentafluoroethyl-6-trifluoromethyl-3,6-dihydro-2H[1,4]-oxazepin-7-one (**5**)

To a solution of **1** (15 g, 0.05 mol) and Et_3N (15.15 g, 0.15 mol) in MeCN (60 ml) at 0°C was added dropwise a solution of monoethanolamine (3.05 g, 0.05 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at 0°C, 1.5 h at room temperature and then for 2 h at 45°C. The reaction mixture was diluted with water (200 ml), neutralized with 5% aqueous H_2SO_4 and extracted with CH_2Cl_2 (3 × 50 ml). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chramatography (hexane-CH_2Cl_2 (5:1)).

The 7-fluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro-[1,4]oxazepine (**3**) (8.1 g, 54% yield), bp 45–47°C (0.4 Torr). ^1H NMR ($CDCl_3$) δ_H: 4.52 (H^2, 2H) and 3.72 (H^3, 2H); ^{19}F NMR ($CDCl_3$) δ_F: 110.3 (F^7, 1F, q, 18), 103.4 (F^8, 3F, dt, 18, 16), 82.5 (F^{10}, 3F, s), 47.8 (F^9, 2F, q, 16). Found, %: C 31.84, 31.67; H 1.24, 1.28; F 58.94, 60.02; N 4.48, M (mass) 301. $C_8H_4F_9NO$. Cal.: C 31.89; H 1.33; F 58.81; N 4.65%; M 301.

The 7,7-difluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3,6,7-tetrahydro[1,4]oxazepine (**4**) (2.4 g, 15% yield), bp 48–49°C (0.4 Torr). ^1H NMR ($CDCl_3$) δ_H: 4.53 (H^2, 2H), 3.70 (H^4, 2H) and 4.02 (H^6, 1H); ^{19}F NMR ($CDCl_3$) δ_F: 102.8 (F^7, 2F), 101.7 (F^8, 3F), 83.2 (F^{10}, 3F), 52.2 and 49.8 (F^9, 2F, AB-system, $J_{FF} = 278$).

The 5-pentafluoroethyl-6-trifluoromethyl-3,6-dihydro-2H[1,4]-oxazepin-7-one (**5**) (2 g, 13% yield), mp 135–137°C (hexane). ^1H NMR ($CDCl_3$) δ_H: 6.50 (H^4, 1H, NH, m), 4.58 (H^2, 2H, t), 3.67 (H^3, 2H, m); ^{19}F NMR ($CDCl_3$) δ_F: 111.5 (F^8, 3F, tq, 10, 18), 83.7 (F^{10}, 3F, q, 10), 52.1 (F^9, 2F, q, 18); ^{13}C NMR ($CDCl_3$) δ_C: 166.1 (C^6), 142 (C^5, $^2J_{CF} = 25.5$), 123.8 (C^8, $^1J_{CF} = 269.4$), 118.4 (C^{10}, $^1J_{CF} = 288.1$; $^2J_{CF} = 36.3$), 111.9 (C^9, $^1J_{CF} = 261.3$; $^2J_{CF} = 39.6$), 92.5 (C^6, $^2J_{CF} = 34.7$), 63.3 (C^2), 47.3 (C^3). HRSM calcd. 299.0192 for $C_8H_5F_8NO$ found 299.0182. MS, *m/e* (I_{rel} (%)): 299 $[M]^+$ (43.29), 280 $[M–F]^+$ (0.83), 271 $[M–O]^+$ (3.95), 269 $[M–HCH_3]^+$ (16.40), 256 $[M–HCH_2CH_2]^+$ (3.31), 242 $[M–(O)OCH]^+$ (100), 230 $[M–F_3]^+$ (0.70), 180 $[M–_2F_5]^+$ (6.64), 119 $[C_2F_5]^+$ (7.71), 69 $[CF_3]^+$ (14.91), 59 $[NHCH_2CH_2O]^+$ (0.38). IR 3300 (NH), 3100 (C–H), 1700 and 1715 (C=O), 1560 and 1595 (C=C), 1605 (C=N), 1390 (C–N), 1300 and 1315 (C–O), 1120–1200 (C–F).

2.2.2. Synthesis of 7-fluoro-3-ethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro-[1,4]oxazepine (**11a**) and 3-ethyl-7,7-difluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3,6,7-tetrahydro[1,4]oxazepine (**13a**)

To a solution of **1** (15 g, 0.05 mol) and Et_3N (15.2 g, 0.15 mol) in MeCN (50 ml) at 0°C was added dropwise 2-amino-1-butanol (4.45 g, 0.05 mol) in MeCN (10 ml) with stirring. After the addition, stirring was continued for 1 h at 0°C and then for 2 h at room temperature. The reaction mixture was diluted with water (2 × 80 ml), neutralized with 5% aqueous H_2SO_4 and extracted with CH_2Cl_2 (3 × 40 ml). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)).

The 7-fluoro-3-ethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro-[1,4]oxazepine (**11a**) (6.4 g, 39% yield), bp 47–48°C (2 Torr). ^1H NMR ($CDCl_3$) δ_H: 4.52 (H^2, 1H, d), 4.37 (H^2, 1H, td), 3.79 (H^3, 1h, td), 1.71 (H^{11}, 2H, q), 1.01 (H^{12}, 3H, t); ^{19}F NMR ($CDCl_3$) δ_F: 112.2 (F^5, 1F, q, 18), 107.4 (F^6, 3F, td, 16, 18), 82.7 (F^{10}, 3F, s), 48.7 (F^9, 2F, q, 16); ^{13}C ($CDCl_3$) δ_C: 164 (C^7, $^1J_{CF} = 278.9$), 154.5 (C^5, $^2J_{CF} = 37.5$; $^3J_{CF} = 4.9$), 128.7 (C^6, $^2J_{CF} = 82.2$), 122.1 (C^8, $^1J_{CF} = 267.8$), 119.1 (C^{10}, $^1J_{CF} = 286.4$; $^2J_{CF} = 36.2$), 109.8 (C^9, $^1J_{CF} = 257.3$; $^2J_{CF} = 36.2$), 84.3 (C^3), 61.7 (C^2), 24.5 (C^{11}), 9.5 (C^{12}). HRMS calcd. 329.0462 for $C_{10}H_8F_9NO$ found 329.0466. MS, *m/e* (I_{rel} (%)): 329 $[M]^+$ (41.46), 314 $[M–CH_3]^+$ (8.44), 310 $[M–F]^+$ (17.48), 300 $[M–C_2F_5]^+$ (39.77), 281 $[M–C_2F_5–F]^+$ (6.47), 273 $[M–C_2H_5CH=CH_2]^+$ (92.12), 260 $[M–CF_3]^+$ (6.13), 232 $[M–CF_3–C_2H_4]^+$ (20.96), 230 $[M–CF_3–C_2H_6]^+$ (29.52), 119 $[C_2F_5]^+$ (7.32), 69 $[CF_3]^+$ (27.28), 55 $[C_2H_5C=CH_2]^+$ (100), 41 $[CH_3CH=CH]^+$ (26.65), 29 $[C_2H_5]^+$ (26.09). IR 2970, 2930, 2860 (C–H), 1660 (C=C), 1610 (C=N), 1400 (C–N), 1320 (C–O), 1220–1060 (C–F).

The 3-ethyl-7,7-difluoro-5-pentafluoroethyl-6-trifluoromethyl-2,3,6,7-tetrahydro[1,4]oxazepine (**13a**) (8.9 g, 51% yield), bp 55–56°C (2 Torr). ^{1}H NMR ($CDCl_3$) δ_H: 4.42 (H^3, 1H), 4.32 (H^2, 1H), 420 (H^6, 1H), 3.79 (H^2, 1H), 1,74 (H^{11}, 2H, q), 1.05 (H^{12}, 2H, t); ^{19}F NMR ($CDCl_3$) δ_F: 102.6 (F^7, 2F, q, 18), 101.8 (F^8, 3F, dt, 18, 16), 82.9 (F^{10}, 3F, s), 51.7 and 48.9 (F^9, 2F, AB-system $J_{FF} = 285.4$). HRMS calcd. 349.0524 for $C_{10}H_9F_{10}NO$ found 349.0529.

2.2.3. Synthesis 7-fluoro-3,3-dimethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro[1,4]oxazepine (**11b**), 5-fluoro-3,3-dimethyl-7-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro-[1,4]oxazepine (**12b**) and 7, 7-difluoro-3,3-dimethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3,6,7-tetrahydro[1,4]oxazepine (**13b**)

To a solution of **1** (15 g, 0.05 mol) and Et_3N (15.3 g, 0.15 mol) in MeCN (45 ml) at 0°C was added 2-amino-2-methyl-1-propanol (4.45 g, 0.05 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at 0°C, 2 h at room temperature and 1 h at 45°C. The reaction mixture was washed with water (250 ml), neutralized with 5% aqueous H_2SO_4, extracted with CH_2Cl_2 (3 × 50 ml), and dried ($MgSO_4$). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)).

The 7-fluoro-3,3-dimethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro[1,4]oxazepine (**11b**) (11.5 g, 70% yield), bp 37–38°C (2 Torr). ^{1}H NMR ($CDCl_3$) δ_H: 1.24 and 1.27 ($H^{11,12}$, 6H, t), 4.04 (H^2, 2H, s); ^{19}F NMR ($CDCl_3$) δ_F: 108.0 (F^7, 1F, q, 18), 101.3 (F^8, 2F, dt, 18, 16), 83.0 (F^{10}, 3F, s), 51.5 (F^9, 2F, q, 16); ^{13}C ($CDCl_3$) δ_C: 164 (C^7, $^1J_{CF}$ = 279), 153.2 (C^5, $^2J_{CF} = 36$), 127.9 (C^6, $^2J_{CF} = 80$), 122.0 (C^8, $^1J_{CF} = 266.9$), 119.2 (C^{10}, $^1J_{CF} = 286.3$; $^2J_{CF} = 36.0$), 110.0 (C^9, $^1J_{CF} = 262.3$; $^2J_{CF} = 35.8$), 84.3 (C^3), 62 (C^2), 26.6 ($C^{11,12}$). HRMS calcd. 329.0462 for $C_{10}H_8F_9NO$ found 329.0464. MS, *m/e* (I_{rel} (%)): 329 $[M]^+$ (21.20), 314 $[M–CH_3]^+$ (90.05), 310 $[M–F]^+$ (8.67), 299 $[M–2CH_3]^+$ (100), 260 $[M–CF_3]^+$ (0.89), 258 $[M–(CH_3)_2C{=}CHO]^+$ (33.99), 210 $[M–C_2F_5]^+$ (13.20), 188 $[M–CF_3–(CH_3)_2CCH_2O]^+$ (5.04), 119 $[C_2F_5]^+$ (5.63), 71 $[(CH_3)2CCHO]^+$ (2.56), 69 $[CF_3]^+$ (11.38), 55 $[(CH_3)_2C{=}CH_2]^+$ (26.37), 42 $[(CH_3)_2C]^+$ (78.67). IR 2973 (C–H), 1710 (C=C), 1666 (C=N), 1463 (C–N), 1221–1167 (C–F), 1045 and 1015 (C–O).

The 5-fluoro-3,3-dimethyl-7-pentafluoroethyl-6-trifluoromethyl-2,3-dihydro[1,4]oxazepine (**12b**) (1.3 g, 7.9% yield). ^{1}H NMR ($CDCl_3$) δ_H: 4.03 (H2, 2H, s), 1.27 ($H^{11,12}$, 6H, q); ^{19}F NMR ($CDCl_3$) δ_F: 140.7 (F^5, 1F, q, 22), 102.7 (F^8, 3F, dt, 22, 16), 80.5 (F^{10}, 3F, s), 55.5 (F^9, 2F, q, 16); ^{13}C NMR ($CDCl_3$) δ_C: 142 (C^7,$^1J_{CF} = 270$), 151 (C^5, $^2J_{CF} = 35.2$), 153 (C^6, $^2J_{CF} = 75$), 122 (C^8, $^1J_{CF} = 267$), 119.3 (C^{10}, $^1J_{CF} = 285.9$; $^2J_{CF} = 35.8$), 109.1 (C^9, $^1J_{CF} = 264$; $^2J_{CF} = 34.9$), 79.7 (C^2), 46.9 (C^3), 26.4 ($C^{11,12}$). IR 2970 (C–H), 1710 (C=N), 1665 (C=C), 1460 (C–N), 1350 and 1360 (C–O), 1170–1210 (C–F). MS, *m/e*: 329 $[M]^+$, 314 $[M–CH_3]^+$, 310 $[M–F]^+$, 273 $[M–(CH_3)_2H{=}CH_2]^+$, 230, 210 $[M–C_2F_5]^+$, 180, 154, 119 $[C_2F_5]^+$, 93, 69 $[CF_3]^+$, 57, 42 $[C(CH_3)_2]^+$.

The 7,7-difluoro-3,3-dimethyl-5-pentafluoroethyl-6-trifluoromethyl-2,3,6,7-tetrahydro[1,4]oxazepine (**13b**) (2.5 g, 14.3% yield), bp 51–52°C (2 Torr). ^{1}H NMR ($CDCl_3$) δ_H: 4.02 (H^2, 2H, s), 317 (H^6, 1H, m), 1.24 ($H^{11,12}$, 6H, q); ^{19}F NMR ($CDCl_3$) δ_F: 102.7 (F^7, 2F), 101.3 (F^8, 3F), 83 (F^{10}, 3F, s), 51.3 and 48.4 (F^9, 2F, AB-system $J_{FF} = 284.2$ Hz). HRMS calcd. 349.0524 for $C_{10}H_9F_{10}NO$ found 349.0527. MS, *m/e*: 349 $[M]^+$, 334 $[M–CH_3]^+$, 319 $[M–2CH_3]^+$, 306 $[M–(CH_3)_2CH]^+$, 278 $[M–(CH_3)_2CCHO]^+$, 250, 230 $[M–C_2F_5]^+$, 119 $[C_2F_5]^+$, 69 $[CF_3]^+$, 57, 42 $[(CH_3)_2CH]^+$.

2.2.4. Synthesis of 6-ethyl-2,4-bis(heptafluoropropyl)-6,7-dihydro[1,3,5]oxadiazepine (**16a**)

To a solution of **2** (10 g, 0.023 mol) and Et_3N (7 g, 0.069 mol) in MeCN (25 ml) at −20°C was added 2-amino-1-butanol (2.1 g, 0.023 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at −20°C, 2 h at 0°C, 3 h at room temperature and 1 h at 60°C. The reaction mixture was washed with water (250 ml), neutralized with 5% aqueous H_2SO_4, extracted with CH_2Cl_2 (3 × 50 ml), and dried ($MgSO_4$). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)) to give compound **16a**, yield 5.8 g (54.2%), bp 96–97°C/2.5 Torr. IR, ν cm^{-1}: 1235–1187 (C–F), 1688 and 1669 (C=N), 2940 and 2976 (C–H). MS, *m/z* (I_{rel} (%)): 444 $[M–H_2O]^+$ (100), 443 $[M–F]^+$ (74.48), 425 $[M–H_2O–F]^+$ (27.85), 325 $[M–H_2O–C_2F_5]^+$ (38.31), 324 $[M–F–C_3F_7]^+$ (13.00), 275 $[M–H_2O–C_3F_7]^+$ (2.55), 267 $[C_3F_7CNOCH_2CHC_2H_5]^+$ (1.48), 237 $[C_3F_7CNCH(C_2H_5)]^+$ (10.28), 169 $[C_3F_7]^+$ (11.75), 119 $[C_2F_5]^+$ (7.28), 100 $[CF_2{=}CF_2]^+$ (4.71), 69 $[CF_3]^+$ (30.95), 55 $[CH{=}C(CH_3)_2]^+$ (23.58). Found $[M–H_2O]^+$: mole weight 444.03132. $C_{12}H_6F_{14}N_2$. Calc.: mole weight 444.03073. ^{19}F NMR ($(CD_3)_2CO$), δ: 82.8 (6 F, F-10, 13); 47.3 (4 F, F-8, 11); 37.4 (4 F, F-9, 12). ^{1}H NMR, δ: 3.64 (H-7), 3.10 (H-6), 1.61 (H-14), 1.33 (H-15).

2.2.5. Synthesis 2,4-bis(heptafluoropropyl)-6,6-dimethyl-6,7-dihydro[1,3,5]oxadiazepine (**16b**)

To a solution of **2** (10 g, 0.023 mol) and Et_3N (7 g, 0.069 mol) in MeCN (25 ml) at −30°C was added 2-amino-2-methyl-1-propanol (2.1 g, 0.023 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at −30°C, 2 h at room temperature and 1 h at 60°C. The reaction mixture was washed with water (250 ml), neutralized with 5% aqueous H_2SO_4, extracted with CH_2Cl_2 (3 × 50 ml), and dried ($MgSO_4$). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)) to give compound **16b**, yield 5.3 g (49.5%), bp 63–64°C/2.5 Torr. IR, ν cm^{-1}: 1235–1187 (C–F), 1688 and 1669 (C=N), 2940 and 2976 (C–H). MS, *m/z* (I_{rel} (%)): 462 $[M]^+$ (12.30), 443 $[M–F]^+$ (1.11), 431 $[M–CH_4–CH_3]^+$ (15.03), 406 $[M–CH_2C(CH_3)_2]^+$ (7.39), 293 $[M–C_3F_7]^+$ (12.67),

251 $[M–C_3F_7–CNC(CH_3)_2CH_2]^+$ (8.14), 237 $[C_3F_7CNC(CH_3)_2]^+$ (53.46), 209 $[C_3F_7CNN]^+$ (12.10), 169 $[C_3F_7]^+$ (8.92), 119 $[C_2F_5]^+$ (3.49), 100 $[CF_2{=}CF_2]^+$ (2.40), 69 $[CF_3]^+$ (21.70), 55 $[CH{=}C(CH_3)_2]^+$ (55.00), 42 $[C(CH_3)_2]^+$ (100). Found: mole weight 462.04260. $C_{12}H_8F_{14}N_2O$. Calc.: mole weight 462.04129. ^{19}F NMR ($(CD_3)_2CO$), δ: 82.9 (6 F, F-10, 13); 48.5 (4 F, F-8, 11); 37.7 (4 F, F-9, 12). ^{13}C NMR (CD_2Cl_2), δ: 152.9 (C-2, 4, $^2J_{CF} = 248.8$ Hz); 117.4 (C-10, 13; $^1J_{CF} = 285.2$ Hz; $^2J_{CF} = 34$ Hz); 110.0 (C-8, 11, $^1J_{CF} = 261.2$; $^2J_{CF} = 30.2$ Hz); 108.2 (C-9, 12, $^1J_{CF} = 268.0$; $^2J_{CF} = 38.0$ Hz); 80.1 (C-7); 63.9 (C-6), 26.4 and 23.0 (C-14). ^{1}H NMR, δ: 4.43 (H-7), 1.30 (H-14).

2.2.6. Synthesis of 5,7-difluoro-3,7-bis-(pentafluoroethyl)-4,6,6-tris-trifluoromethyl-6,7-dihydro-[1,2]oxazepine (**18**), 5,5,7-trifluoro-3,7-bis-(pentafluoroethyl)-4,6,6-tris-trifluoromethyl-2,5,6,7-tetrahydro-[1,2]oxazepine (**19**) and 5-fluoro-3-(pentafluoroethyl)-4-trifluoromethyl-isoxazole (**17**)

To a suspension of $H_2NOH{\cdot}HCl$ (2.32 g, 0.033 mol) in MeCN (30 ml) was added Et_3N (13.45 g, 0.133 mol) in MeCN (25 ml) at −30°C stirred for 0.5 h was added **1** (10 g, 0.033 mol) at −30°C in MeCN (10 ml). The resulting solution was stirred for 1 h at 0°C, 2 h at room temperature and 0.5 h at 60°C. The reaction mixture was washed with water (250 ml) and dried ($MgSO_4$). This was distilled to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)) to give compound **18**, yield 5.3 g (49.5%), bp 85–86°C/4.5 Torr. IR, ν cm^{-1}: 1235–1187 (C–F), 1688 and 1669 (C=N), 2940 and 2976 (C–H). MS, *m/z* (I_{rel} (%)): 554 $[M–F]^+$ (27.72), 466 $[M–F–CF_4]^+$ (13.87), 454 $[M–C_2F_5]^+$ (4.52), 316 $[(CF_3)_2C(O)FC_2F_5]^+$ (3.96), 226 $[C_6F_8HN]^+$ (2.52), 119 $[C_2F_5]^+$ (68.94), 112 $[CF_3CCF]^+$ (1.38), 100 $[CF_2{=}CF_2]^+$ (4.15), 69 $[CF_3]^+$ (100), 76 $[CF_2CN]^+$ (2.88). Found: mole weight 553.9660. $C_{12}F_{20}NO$. [M–F]. Calc.: mole weight 553.9660. ^{19}F NMR ($(CD_3)_2CO$), δ_F: 105.9 (1 F, F-5); 105.8 (3 F, F-12); 83.4 and 83.2 (3 F, F-11; 3 F, F-12), 81.7 (3 F, F-9), 80.4 (1 F, F-7), 80.1 (3 F, F-14), 43.8 (2 F, F-8), 41.4 (2 F, F-13).

Compound **19**, yield 3.0 g, bp 132–134°C. IR, ν cm^{-1}: 1235–1170 (C–F), 1302 (O–C), 1390 and 1343 (N–C), 1654 (C=C), 3440 (N–H). Found: mole weight 553.9660. $C_{12}F_{20}NO$. [M–F]. Calc.: mole weight 553.9660. ^{13}C NMR ($CDCl_3$), δ_C: 149.3 (C-3, $^2J_{CF} = 32.3$ Hz); 120.2 (C-12, $^1J_{CF} = 272.2$ Hz); 120.0 (C-10, 11, $^1J_{CF} = 286.7$ Hz); 118.4 (C-14, $^1J_{CF} = 286.9$; $^2J_{CF} = 34.8$ Hz); 118.1 (C-9, $^1J_{CF} = 286.9$; $^2J_{CF} = 33.7$ Hz); 114.5 (C-5, $^1J_{CF} = 271.2$ Hz); 113.1 (C-7, $^1J_{CF} = 263.3$; $^2J_{CF} = 36.5$ Hz); 109.5 (C-6, $^2J_{CF} = 38.5$ Hz); 109.4 (C-8, 13, $^1J_{CF} = 262.3$; $^2J_{CF} = 35.4$ Hz); 107.1 (C-4, $^2J_{CF} = 38.2$ Hz). ^{19}F NMR ($(CD_3)_2CO$), δ_F: 105.9 (3 F, F-12); 103.6 (6 F, F-11, 12); 82.9 (3 F, F-14), 81.3 (3 F, F-9), 80.4 (1 F, F-7), 57.9 (2 F, F-8), 55.0 (2 F, F-13), 41.2 (2 F, F-5). ^{1}H NMR, δ: 7.23 and 7.00 (N–H). Found, %: C, 23.98; 23.87; F, 70, 36; 70.14; N, 2.21. $C_{12}HF_{22}NO$. Calc. %: C, 24.28; F, 70.49; N, 2.36. [M–F–HF] (mass-spectrometry) 554.

Compound **17**, yield 1.0 g, bp 44–45°C/4 Torr. ^{19}F NMR ($(CD_3)_2CO$), δ_F: 106.1 (1 F, F-5); 105.9 (3 F, F-6); 81.3 (3 F, F-8), 44.1 (2 F, F-7). Found, %: C, 26.24; 26.17; F, 62, 76; 62.54; N, 5.01. C_6F_9NO. M (mass-spectrometry) 273. Calc. %: C, 26.37; F, 62.64; N, 5.13; M 273.

2.2.7. Synthesis of 5,9-bis(pentafluoroethyl)-6,8,8-tris-(tri-fluoromethyl)-9-fluoro-1,4-diazabicyclo[5.2.0]nona-4,6-diene (**20**)

Ethylenediamine (3 g, 50 mmol) was added over a period of 0.5 h with stirring and cooled to −30°C to a solution of compound **1** (15 g, 50 mmol) and Et_3N (10.1 g, 100 mmol) in THF (40 ml). Then, the temperature was raised to 20°C and the mixture was kept for 2 h and poured into water. The product was extracted with CH_2Cl_2 and the extract was dried with $MgSO_4$. After evaporation of the solvent, the residue was passed through a column of silica gel with hexane-CH_2Cl_2 (5:1) to give compound **20**, yield 8.7 g (60%), mp 56–57°C (from hexane). IR, ν cm^{-1}: 1250–1150 (C–F), 1620 (C=N), 1676 (C=C), 2980 (C–H). MS, *m/z* (I_{rel} (%)): 580 $[M]^+$ (73.40), 561 $[M–F]^+$ (75.52), 552 $[M–CH_2CH_2]^+$ (33.54), 532 $[M–CH_2CH_2–HF]^+$ (18.35), 511 $[M–CF_3]^+$ (23.63), 461 $[M–C_2F_5]^+$ (100), 441 $[M–C_2F_5–HF]^+$ (11.00), 416 $[M–C_2F_5CF{=}N]^+$ (2.70), 402 $[M–C_2F_5CF{=}NCH_2]^+$ (4.98), 314 $[C_2F_5CFNC(CF_3)_2C]^+$ (2.20), 192 $[C_2F_5CF{=}NCH_2CH_2]^+$ (50.79), 178 $[C_2F_5CF{=}NCH_2]^+$ (15.43), 164 $[C_2F_5CF{=}N]^+$ (1.68), 145 $[C_2F_5CN]^+$ (0.78), 119 $[C_2F_5]^+$ (7.76), 100 $[CF_2{=}CF_2]^+$ (1.34), 69 $[CF_3]^+$ (40.20). Found: mole weight 580.0047. $C_{14}H_4F_{20}N_2$. Calc.: mole weight 580.0055. ^{19}F NMR ($(CD_3)_2CO$), δ: 107.6 (3 F, F-14); 100.4 (3 F, F-12); 98.3 (3 F, F-13); 82.4 (3 F, F-11); 81.3 (3 F, F-16); 48.9 and 46.5 (2 F, F-15, AB-system, $J_{FF} = 286.1$ Hz); 45.8 and 40.6 (2 F, F-10, AB-system, $J_{FF} = 293.6$ Hz); 25.5 (1 F, F-9). ^{13}C NMR (CD_2Cl_2), δ: 153.9 (C-5, $^2J_{CF} = 46.2$ Hz); 146.5 (C-7); 118.4 (C-12, $^1J_{CF} = 285.2$ Hz); 118.2 (C-13, $^1J_{CF} = 283.6$ Hz); 117.2 (C-16, $^1J_{CF} = 286.5$; $^2J_{CF} = 40.1$ Hz); 116.1 (C-11, $^1J_{CF} = 290.7$; $^2J_{CF} = 39.1$ Hz); 113.2 (C-6, $^2J_{CF} = 35.1$ Hz); 108.1 (C-15, $^1J_{CF} = 262.9$; $^2J_{CF} = 34.8$ Hz); 103.2 (C-15, $^1J_{CF} = 261.8$; $^2J_{CF} = 35.1$ Hz); 102.5 (C-9, $^1J_{CF} = 289.3$; $^2J_{CF} = 39.1$ Hz); 98.1 (C-8, $^2J_{CF} = 38.6$ Hz); 28.1 (C-2); 21.1 (C-3).

2.2.8. Synthesis 2,4-bis(heptafluoropropyl)-6,7-dihydro-1H[1,3,5]thiazepine (**22**)

To a solution of **2** (10 g, 0.023 mol) and Et_3N (7 g, 0.069 mol) in MeCN (25 ml) at 0°C was added ethylenediamine (1.4 g, 0.023 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at 0°C, 2 h at room temperature and 1 h at 45°C. The reaction mixture was washed with water (250 ml), neutralized with 5% aqueous H_2SO_4, extracted with CH_2Cl_2 (3 × 50 ml), and dried ($MgSO_4$). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column

chromatography (hexane-CH_2Cl_2 (5:1)) to give compound **22**, 6.5 g (65%), mp 108–109°C (from hexane). IR, ν cm^{-1}: 1229–1173 (C–F), 1642 and 1612 (C=N), 3210 and 3051 (C–H), 3403 (N–H). MS, *m/z* (I_{rel} (%)): 433 $[M]^+$ (73.76), 405 $[M–NCH_2]^+$ (100), 385 $[M–NCH_2–HF]^+$ (12.56), 285 $[M–NCH_2–HF–CF_2=CF_2]^+$ (10.14), 264 $[M–C_3F_7]^+$ (11.73), 222 $[M–C_3F_7–CH_3CHN]^+$ (4.67), 211 $[C_3F_7CNNH]^+$ (1.20), 209 $[C_3F_7CNNH]^+$ (91.35), 169 $[C_3F_7]^+$ (7.24), 119 $[C_2F_5]^+$ (5.40), 100 $[CF_2=CF_2]^+$ (2.93), 69 $[CF_3]^+$ (25.71), 42 $[CH_3CHN]^+$ (26.40). Found: mole weight 433.02599. $C_{10}H_5F_{14}N_3$. Calc.: mole weight 433.02598. ^{19}F NMR ($(CD_3)_2CO$), δ: 83.0 (6 F, F-10, 13); 48.4 (4 F, F-9, 12); 38.0 (4 F, F-8, 11). ^{13}C NMR (CD_2Cl_2), δ: 151.1 (C-2, 4, $^2J_{CF} = 24.5$ Hz); 117.3 (C-10, 13, $^1J_{CF} = 287.0$ Hz; $^2J_{CF} = 34.2$ Hz); 109.8 (C-8, 11, $^1J_{CF} = 260.1$; $^2J_{CF} = 29.7$ Hz); 108.3 (C-9, 12, $^1J_{CF} = 267.2$; $^2J_{CF} = 37.8$ Hz); 59.5 (C-7); 49.8 (C-6).

*2.2.9. Synthesis of 2-fluoro-2,4-bis(heptafluoropropyl)-6, 7-dihydro-2H[1.5.3]dioxazepine (**23**) and bis-[2-(heptafluoropropyl-[1,3]dioxolan-2-yl]-amine (**24**)*

To a solution of **2** (10 g, 0.023 mol) and Et_3N (7 g, 0.069 mol) in MeCN (25 ml) at 0°C was added ethylene glycol (1.5 g, 0.023 mol) in MeCN (10 ml). The resulting solution was stirred for 1 h at 0°C, 2 h at room temperature and 1.5 h at 45°C. The reaction mixture was washed with water (250 ml), neutralized with 5% aqueous H_2SO_4, extracted with CH_2Cl_2 (3×50 ml), and dried ($MgSO_4$). The concentrate was distilled under reduced pressure to give a liquid, which was further purified by column chromatography (hexane-CH_2Cl_2 (5:1)) to give compound **23**, yield 8.3 g (79%) IR, ν cm^{-1}: 1229–1173 (C–F), 1642 and 1612 (C=N), 3210 and 3051 (C–H), 3403 (N–H). MS, *m/z* (I_{rel} (%)): 436 $[M–F]^+$ (3.62), 386 $[M–CF_3]^+$ (0.84), 336 $[M–C_2F_5]^+$ (0.79), 286 $[M–C_3F_7]^+$ (22.06), 241 $[M–F–C_3F_7–CN]^+$ (100), 214 $[C_3F_7CFN]^+$ (0.91), 169 $[C_3F_7CNNH]^+$ (91.35), 169 $[C_3F_7]^+$ (7.24), 119 $[C_2F_5]^+$ (5.40), 100 $[CF_2=CF_2]^+$ (2.93), 69 $[CF_3]^+$ (25.71), 42 $[C_3F_7]^+$ (61.09), 119 $[C_2F_5]^+$ (5.26), 100 $[CF_2=CF_2]^+$ (4.33), 69 $[CF_3]^+$ (39.92), 44 $(C_2H_5O]^+$ (10.77), 43 $[CH_3CO]^+$ (15.83). Found: mole weight 436.0032. $C_{10}H_4F_{14}NO_2$ $[M–F]^+$. Calc.: mole weight 436.0018. ^1H NMR, δ: 4.23 and 4.12 (H-6, 7); ^{19}F NMR ($(CD_3)_2CO$), δ: 82.7 (6 F, F-10, 13); 41.4 (4 F, F-9, 12); 39.4 (1 F, F-4); 37.6 (4 F, F-8, 11). ^{13}C NMR (CD_2Cl_2), δ: 150.7 (C-2, 4, $^2J_{CF} = 28.5$ Hz); 117.9 (C-10, $^1J_{CF} = 287.3$ Hz; $^2J_{CF} = 33.6$ Hz); 118.1 (C-13, $^1J_{CF} = 287.6$ Hz; $^2J_{CF} = 34.3$ Hz); 114.3 (C-4, $^1J_{CF} = 240.3$ Hz; $^2J_{CF} = 29.8$ Hz); 109.2 (C-8, 11, $^1J_{CF} = 267.5$; $^2J_{CF} = 32.2$ Hz); 108.3 (C-9, 12, $^1J_{CF} = 267.2$; $^2J_{CF} = 37.8$ Hz); 67.2 (C-7); 65.4 (C-6).

Compound **24**, yield 1.1 g, mp 106–107°C (sublimation 80°C/4 Torr) (hexane). ^1H NMR, δ: 7.97 and 7.68 (N–H), 3.64 (C–H); ^{19}F NMR ($(CD_3)_2CO$), δ: 83.0 (3 F, F-8); 43.9 (2 F, F-7); 37.0 (2 F, F-6); ^{13}C NMR (CD_2Cl_2), δ_C: 158.6 (C-1, $^2J_{CF} = 26.2$ Hz); 116.8 (C-8, $^1J_{CF} = 287.1$ Hz; $^2J_{CF} = 33.7$ Hz); 107.7 (C-6, $^1J_{CF} = 266.0$ Hz; $^2J_{CF} = 32.0$ Hz); 107.4 (C-7, $^1J_{CF} = 266.1$ Hz; $^2J_{CF} = 32.1$ Hz); 76.6 (C-3); 65.1 (C-4). Found, %: C, 28.74; 28.67; H, 1.67; 1.76; F, 53.34; 53.24; N, 2.61. C_{12} $HF_{14}NO_4$. Calc. %: C, 28.97; H, 1.81; F, 53.52; N, 2.82; [M–F] (mass-spectrometry) 478.

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