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Synthesis of new 1-substituted 4-perfluoroalkyl tetrazol-5-ones

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ABSTRACT

1,3-Dipolar cycloaddition of perfluoroalkyl ethyle azides **1** with isocyanates **2** afforded 1-perfluoroalkyl-4-(*n*-Bu, phenyl or mesitylsulfonyl) tetrazol-5-ones **3** in good yields. The use of perfluoroalkyl ethyl azides extends the reaction to the less reactive *n*-butyl isocyanate.

1. Introduction

Tetrazoles are widely used due to their applications as pesticides [1–4], antihypertensive, antialergic, antibiotic and anticonvulsant agents [5–8]. They have also found use in cancer, AIDS and obesity treatments [9–13]. These various applications are presumably due to the metabolic stability of the tetrazole ring which led to a wider use of their derivatives, including those containing the 5-oxo-substituent (tetrazolones) [14].

1,4-Disubstituted tetrazolin-5-ones are indirectly synthesized from reaction of azide ion [15] or trimethylsilylazide [16] with isocyanates. The reaction yields initially monosubstituted tetrazol-2-ones, which via an alkylation reaction, leads to the formation of a mixture of *N*-alkylation and *O*-alkylation products [17] (Scheme 1).

Direct synthesis of 1,4-disubstituted tetrazol-5-ones [18] from isocyanates and azides have been less reported due to the long reaction time, poor yields and unreactivity of some alkyl isocyanates [19]. Both alkyl and arylsulfonyl isocyanates were used on several occasions [18–20], particularly in 1,3-dipolar cycloaddition reactions [21]. Perfluoroalkyl azides have been, in their turn, used as intermediates in the preparation of corresponding perfluoroalkyl imines [22], amines [23] and triazoles [24] as well as in the synthesis of compounds that have interesting surface properties [25].

On the other hand, it has been shown that fluorine-containing compounds, especially fluorinated heterocycles have good and extensive biological activities allowing their possible applications in pharmaceuticals and pesticides [26]. The development of an efficient method for the synthesis of perfluoroalkylated heterocycles is thus of growing interest due to their wide potential bioactivities and commercial applications [27–29].

We have previously shown that isocyanates, aryl and alkoxysulfonyl isocyanates reacted with alcohols [30], thiols [31] and amines [32] to give acyclic compounds.

Herein we report the direct synthesis of 1-substituted 4-perfluoroalkyl tetrazol-5-ones **3** via the reaction of isocyanates **2** with fluorinated alkyl azides **1**. These new fluoroheterocyclic compounds were obtained in good to excellent yields.

2. Results and discussion

Perfluoroalkyl azides **1** react readily with isocyantes **2** to give the 1-substituted 4-perfluoroalkyl tetrazol-5-ones in good yields (Scheme 2).

The long reaction time known for this type of reactions [18,19] is observed with *n*-butyl isocyanate. As expected, a significant increase in the reaction rate occurs with the more reactive phenyl and arylsulfonyl isocyanates, leading at the same time to better reaction yields (see Table 1).

n-Butyl isocyanate was found to be unreactive toward azides including the most reactive one, *n*-butyl azide [19]. In contrast, it is shown in Table 1 that perfluoroalkyl azides do react with *n*-butyl isocyanate to form products **3a** and **3b**. This can be expected since the introduction of a perfluoroalkyl group in a molecule may remarkably modify its chemical properties and biological activity [33,34]. The better reactivity of the perfluoroalkyl azides as compared to non-fluorinated analogs is thought to arise from the electron withdrawing effects of the perfluoroalkyl group which

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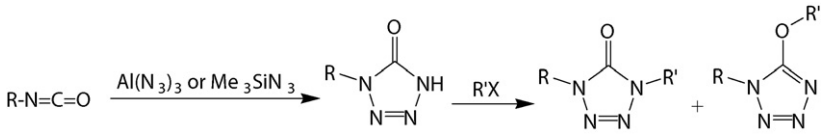
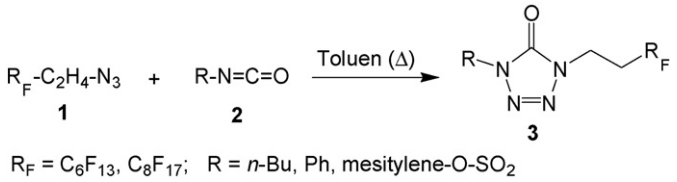
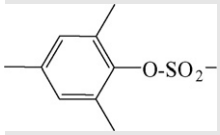


Scheme 1.



Scheme 2.

Table 1
Perfluoroalkylated tetrazol-5-ones **3**

R	R_F	Tetrazol-5-one **3**	Reaction time (day)	Yield (%)
n-Bu	C_6F_{13}	**3a**	14	77
	C_8F_{17}	**3b**	15	80
C_6H_5	C_6F_{13}	**3c**	2	90
	C_8F_{17}	**3d**	2	97
	C_6F_{13}	**3e**	1	95
	C_8F_{17}	**3f**	1	97

would favor the canonical form, responsible for such cycloaddition reactions.

3. Conclusion

New 1-substituted 4-perfluoroalkyl tetrazol-5-ones were prepared directly from isocyanates and perfluoroalkyl azides in good to excellent yields. The use of perfluoroalkyl azide extends the reaction of azides to *n*-butyl isocyanate. The possible biological activity of these new fluorinated heterocyclic compounds is under investigation.

4. Experimental

IR spectra were recorded on PerkinElmer Paragon 1000 PC spectrometer. ^1H, ^{13}C and ^{19}F NMR spectra were recorded in $CDCl_3$ on a Bruker AC 300 spectrometer at 300, 75 and 282 MHz, respectively, for ^1H (TMS), ^{13}C (TMS) and ^{19}F ($CFCl_3$). HRMS spectra in chemical ionization mode were carried out on a MAT 95 SBE spectrometer. The silica gel used is of Merck 7734 type. The HRMS spectra were performed at the "Institut National de Recherche et d'Analyse Physico-chimique (INRAP), Laboratoire d'analyses, Pole Technologique, Sidi Thabet-2020-Tunisia".

Perfluoroalkyl ethyl azides **1** were prepared as previously described in the literature [24].

4.1. Preparation of 4-substitueted 1-perfluoroalkyl tetrazol-5-ones (3)

4.1.1. 1-Butyl-4-(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)-1H-tetrazol-5(4H)-one (3a)

A mixture of perfluoroalkyl azide **1a** (3 mmol, 1.17 g) and *n*-butyl isocyanate **2a** (3 mmol, 0.30 g) in 15 mL of dry toluene was heated at 70 °C for 14 days. Toluene was evaporated and the crude product was purified by column chromatography, using initially petroleum ether to eliminate impurities, then a petroleum ether/diethyl ether mixture (90/10) to obtain tetrazol-5-one **3a** as a viscous oil; IR: ν 1720 cm^{-1} (C=O); ^1H NMR, δ 0.94 (t, 3H, CH_3–, $^3J_{HH}$ = 7.2), 1.37 (m, 2H, CH_2–CH_2–CH_3), 1.51 (m, 2H, CH_2), 2.46 (tt, 2H, CH_2–CF_2, $^3J_{HH}$ = 6.3, $^3J_{HF}$ = 17.9), 3.19 (m, 2H, CH_2–N), 4.39 (t, 2H, CH_2–N, $^3J_{HH}$ = 6.1); ^{13}C NMR, δ 13.9 (s, 1C, $\underline{C}H_3$–) 20.1 (s, 1C, $\underline{C}H_2$–CH_3), 31.1 (t, 1C, $\underline{C}H_2$–CF_2, $^2J_{CF}$ = 21.2), 31.6 (s, 1C, $CH_2\underline{C}H_2$–CH_2), 41.3 (s, 1C, $\underline{C}H_2$–N), 57.1 (s, 1C, $\underline{C}H_2$–N), 106–124 (m, 6CF), 156.1 (s, 1C = O); ^{19}F NMR, δ −113.2 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 18.39 Hz), −121.8 (m, $CF_{2\beta}$), −123.7 (m, $CF_{2\gamma}$), −123.1 (m, $CF_{2\delta}$), −127.2 (m, $CF_{2\omega}$), −82.1 (tt, CF_3, $^3J_{CF3}$ = 9.17 Hz); HRMS: calcd. for $C_{13}H_{13}F_{13}N_4O$: 488.08828; found 488.08796.

4.1.2. 1-Butyl-4-(3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10,-heptadecfluorodecyl)-1H-tetrazol-5(4H)-one (3b)

A mixture of perfluoroalkyl azide **1b** (3 mmol, 1.47 g) and *n*-butylisocyanate **2a** (3 mmol, 0.30 g) was reacted and the product purified in the same manner as for **3a** to obtain tetrazol-5-one **3b** as a white solid; m.p. = 48 °C; IR: ν 1721 cm^{-1} (C=O); ^1H NMR, δ 0.93 (t, 3H, $^3J_{HH}$ = 7.1), 1.36 (m, 2H), 1.49 (m, 2H), 2.45 (m, 2H, $^3J_{HH}$ = 6.2, $^3J_{HF}$ = 18.4), 3.18 (m, 2H), 4.37 (t, 2H, $^3J_{HH}$ = 6.3); ^{13}C NMR, δ 13.5 (s, 1C) 19.8 (s, 1C), 30.9 (t, 1C, $^2J_{CF}$ = 21.5), 31.2 (s, 1C), 40.8 (s, 1C), 56.6 (s, 1C), 106–124 (m, 8CF), 155.9 (s, 1C=O); ^{19}F NMR, δ −114.9 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 18.4 Hz), −123.0 (m, $CF_{2\beta}$), −124.9 (m, $CF_{2\gamma}$), −124.1 (m, $CF_{2\delta}$), −123.2 (m, $2CF_{2\varepsilon}$), −127.5 (m, $CF_{2\omega}$), −82.3 (tt, CF_3, $^3J_{CF3}$ = 9.2 Hz); HRMS: calcd. for $C_{15}H_{13}F_{17}N_4O$: 588.08189; found 588.08127.

4.1.3. 1-Phenyl-4-(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl)-1H-tetrazol-5(4H)-one (3c)

A mixture of perfluoroalkyl azide **1a** (3 mmol, 1.17 g) and phenylisocyanate **2b** (3 mmol, 0.36 g) in 15 mL of dry toluene was heated at 100 °C for 2 days. The crude product was purified as described for **3a** to obtain tetrazol-5-one **3c** as a viscous oil; IR: ν 1722 cm^{-1} (C=O); ^1H NMR, δ 2.72 (tt, 2H, $^3J_{HH}$ = 6.2, $^3J_{HF}$ = 18.4), 4.48 (t, 2H, $^3J_{HH}$ = 6.2); 7.04–7.65 (m, 5H, arom); ^{13}C NMR, δ 31.3 (s, 1C, $^2J_{CF}$ = 21.8 Hz), 57.3 (s, 1C), 105–125 (m, 8CF), 119.2 (s, 1C), 123.6 (s, 1C), 129.6 (s, 2C), 139.8 (s, 1C), 153.9 (s, 1C = O); ^{19}F NMR, δ −109.1 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 16.0 Hz), −118.0 (m, $CF_{2\beta}$), −119.3 (m, $CF_{2\gamma}$), −118.3 (m, $CF_{2\delta}$), −117.4 (m, $2CF_{2\varepsilon}$), −121.36 (m, $CF_{2\omega}$), −76.4 (tt, CF_3, $^3J_{CF3}$ = 9.3 Hz); HRMS: calcd. for $C_{15}H_9F_{13}N_4O$: 508.05698; found 508.05729.

4.1.4. 1-(3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10,-heptadecfluorodecyl)-4-Phenyl-1H-tetrazol-5(4H)-one (3d)

A mixture of perfluoroalkyl azide **1b** (3 mmol, 1.47 g) and phenylisocyanate **2b** (3 mmol, 0.36 g) was reacted and the product purified in the same manner as for **3c** to obtain tetrazol-5-one **3d** as a white solid. m.p. = 50 °C; IR: ν 1723 cm^{-1} (C=O); ^1H NMR, δ 2.70 (tt, 2H, $^3J_{HH}$ = 6.3, $^3J_{HF}$ = 18.3), 4.50 (t, 2H, $^3J_{HH}$ = 6.3); 7.05–7.60 (m, 5H, arom); ^{13}C NMR, δ 31.2 (s, 1C, $^2J_{CF}$ = 21.3 Hz), 57.3 (s, 1C), 105–125 (m, 8CF), 119.2 (s, 1C), 123.6 (s, 1C), 129.5 (s, 2C), 139.8 (s, 1C), 153.8 (s, 1C = O); ^{19}F NMR, δ −109.8 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 16.0 Hz), −118.0 (m, $CF_{2\beta}$), −119.96 (m, $CF_{2\gamma}$), −119.09 (m, $CF_{2\delta}$), −118.2 (m, $2CF_{2\varepsilon}$), −122.56 (m, $CF_{2\omega}$), −77.48 (m, CF_3, $^3J_{CF3}$ = 10.0 Hz); HRMS: calcd. for $C_{17}H_9F_{17}N_4O$: 608.05059; found 608.04988.

4.2. Mesityl 5-oxo-4-(3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluororoctyl)-4,5-dihydro-1H-tetrazole-1-sulfonate (3e)

A mixture of perfluoroalkyl azide **1a** (3 mmol, 1.17 g) and 2,4,6-trimethylphenylsulfoxy isocyanate **2c** (3 mmol, 0.72 g) was reacted and the product purified in the same manner as for **3c** to obtain tetrazol-5-one **3e** as a viscous oil; IR: ν 1722 cm^{-1} (C=O); ^1H NMR, δ: 2.28 (s, 3H, $1CH_3$–) 2.42 (s, 6H, $2CH_3$–), 2.75 (tt, 2H, CH_2–CF_2, $^3J_{HH}$ = 6.2, $^3J_{HF}$ = 18.1), 4.55 (t, 2H, CH_2–N, $^3J_{HH}$ = 6.1); 7.03 (s, 2H, arom); ^{13}C NMR, δ 20.8 (s, 1C, CH_3–, arom), 22.1 (s, 2C, $2CH_3$–, arom), 32.2 (s, 1C, $^2J_{CF}$ = 22.1 Hz) 58.1 (s, 1C), 101–125 (m, 6CF), 129.2 (s, 1C, arom), 132.1 (s, 2C, arom), 136.9 (s, 2C, arom), 147.0 (s, 1C, arom), 155.1 (s, 1C = O); ^{19}F NMR, δ −108.7 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 16.0 Hz), −117.1 (m, $CF_{2\beta}$), −118.8 (m, $CF_{2\gamma}$), −117.9 (m, $CF_{2\delta}$), −116.8 (m, $2CF_{2\varepsilon}$), −121.5 (m, $CF_{2\omega}$), −76.2 (m, CF_3, $^3J_{CF3}$ = 9.1 Hz); HRMS: calcd. for $C_{18}H_{15}F_{13}N_4O_4S$: 630.06075; found 630.05994.

4.3. Mesityl 4-(3,3,4,4,5,5,6,6,7,7,8,8,9,9,10,10,10-heptadecafluorodecyl)-5-oxo-4,5-dihydro-1H-tetrazole-1-sulfonate (3f)

A mixture of perfluoroalkyl azide **1a** (3 mmol, 1.47 g) and 2,4,6-trimethylphenylsulfoxy isocyanate **2c** (3 mmol, 0.72 g) was reacted and the product purified in the same manner as for **3c** to obtain tetrazol-5-one **3f** as a yellowish solid. m.p. = 96 °C; **3f**: IR: ν 1721 cm^{-1} (C=O); ^1H NMR, δ: 2.29 (s, 3H, $1CH_3$–) 2.40 (s, 6H, $2CH_3$–), 2.77 (tt, 2H, $^3J_{HH}$ = 6.1, $^3J_{HF}$ = 18.4), 4.51 (t, 2H, $^3J_{HH}$ = 6.1), 6.95 (s, 2H, arom.); ^{13}C NMR, δ 20.9 (s, 1C, CH_3–, arom), 21.9 (s, 2C, $2CH_3$–, arom), 31.7 (s, 1C, CF_2–CH_2–$^2J_{CF}$ = 22.2 Hz), 57.9 (s, 1C, CH_2–N), 100–127 (m, 8CF), 129.8 (s, 1C, arom), 132.1 (s, 2C, arom), 136.8 (s, 2C, arom), 147.1 (s, 1C), 154.4 (s, 1C=O); ^{19}F NMR, δ −107.8 (m, $CF_{2\alpha}$, $^3J_{FH}$ = 16.0 Hz), −116.0 (m, $CF_{2\beta}$), −117.9 (m, $CF_{2\gamma}$), −117.1 (m, $CF_{2\delta}$), −116.3 (m, $2CF_{2\varepsilon}$), −120.6 (m, $CF_{2\omega}$), −75.5 (m, CF_3, $^3J_{CF3}$ = 9.1 Hz); HRMS: calcd. for $C_{20}H_{15}F_{17}N_4O_4S$: 730.05436; found 730.05366.

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References

[1] M.J. Schocken, R.W. Creekmore, G. Theodoridis, G.J. Nystrom, R.A. Robinson, Appl. Environ. Microbiol. 55 (1989) 1220–2122.
[2] G.I. Sandmann, C. Schneider, P. Boger, Z. Naturforsch, C 51 (1996) 534.
[3] A. Yanagi, Pflanzenschutz Nachrichten Bayer 54 (2001) 1–11.
[4] S.J. Lim, Y. Sunohara, H. Matsumoto, J. Pestic. Sci. 32 (3) (2007) 249–254, and references therein.
[5] (a) F. Janssens, J. Torremans, P.A.J. Janssen, J. Med. Chem. 29 (1986) 2290–2297; (b) T. Mavromoustakos, A. Kolocouris, M. Zervou, P. Roumelioti, J. Matsoukas, R. Weisemann, J. Med. Chem. 42 (1999) 1714–1722; (c) Y. Hashimoto, R. Ohashi, Y. Kurosawa, K. Minami, H. Kaji, K. Hayashida, H. Narita, S. Murata, J. Cardiovasc. Pharm. 31 (1998) 568–575.
[6] (a) H.D. Klaubert, J.H. Sellstedt, C.J. Guinosso, S.C. Bell, R.J. Capetola, J. Med. Chem. 24 (1981) 748–752; (b) M. Anselmi, L. Bellussi, D. Passali, Acta Otorhinolaryngol. Ital. Suppl. 14 (1994) 95–103.
[7] (a) J.H. Toney, P.M.D. Fitzgerald, N. Grover-Sharma, S.H. Olson, W.J. May, J.G. Sundelof, D.E. Vanderwall, K.A. Cleary, S.K. Grant, J.K. Wu, J.W. Kozarich, D.L. Pompliano, G.G. Hammond, Chem. Biol. 5 (1998) 185–196; (b) A. De Desarro, D. Ammendola, M. Zappala, S. Grasso, G.B. De Sarro, Antimicrob. Agents Chemother. 39 (1995) 232–237.
[8] S. Berghmans, J. Hunt, A. Roach, P. Goldsmith, Epilepsy Res. 75 (2007) 18–28.
[9] Y. Tamura, F. Watanabe, T. Nakatani, K. Yasui, M. Fuji, T. Komurasaki, H. Tsuzuki, R. Maekawa, T. Yoshioka, K. Kawada, K. Sugita, M. Ohtani, J. Med. Chem. 41 (1998) 640–649.
[10] (a) E. Muraglia, O.D. Kinzel, R. Laufer, M.D. Miller, G. Moyer, V. Munshi, F. Orvieto, M.C. Palumbi, G. Pescatore, M. Rowley, P.D. Williams, V. Summa, Bioorg. Med. Chem. Lett. 16 (2006) 2748–2752; (b) J.A. O'Meara, A. Jakalian, S. La Plante, P.R. Bonneau, R. Coulombe, A.-M. Faucher, I. Guse, S. Landry, J. Racine, B. Simoneau, B. Thavonekham, C. Yoakim, Bioorg. Med. Chem. Lett. 17 (2007) 3362–3366; (c) A. Savarino, Retrovirology 4 (2007), art. no. 21.
[11] T.L. Shih, M.R. Candelore, M.A. Cascieri, S.-H.L. Chiu, L.F. Colwell Jr., L. Deng, W.P. Feeney, M.J. Forrest, G.J. Hom, D.E. MacIntyre, R.R. Miller, R.A. Stearns, C.D. Strader, L. Tota, M.J. Wyvratt, M.H. Fisher, A.E. Weber, Bioorg. Med. Chem. Lett. 9 (1999) 1251.
[12] R.J. Mathvink, J.S. Tolman, D. Chitty, M.R. Candelore, M.A. Cascieri, L.F. Jr. Colwell, L. Deng, W.P. Feeney, M.J. Forrest, G.J. Hom, D.E. MacIntyre, R.R. Miller, R.A. Stearns, L. Tota, M.J. Wyvratt, H. Fisher, A.E. Weber, in: F. Ahmed, E.C. Breinlinger, B.C. Follows, W.B. Geiss (Eds.), Potent, Selective and Orally Bioavailable 3-Pyridylethanolamine-3 Adrenergic Receptor Agonists Possessing a Thiazole Benzenesulfonamide Pharmacophore, vol. 4, no., 48, Albany Molecular Research, Inc. Technical Reports, 220th American Chemical Society National Meeting, Washington, D.C., August 20–24, 2000, Medicinal Chemistry Department, Albany Molecular Research, Inc., Albany, NY, 28 pp.
[13] J.Y.L. Chung, G.-J. Ho, M. Chartrain, C. Roberge, D. Zhao, J. Leazer, R. Farr, M. Robbins, K. Emerson, D.J. Mathre, J.M. McNamara, D.L. Hughes, E.J.J. Grabowski, P.J. Reider, Tetrahedron Lett. 40 (1999) 6739–6743.
[14] R.J. Mathvink, J.S. Tolman, D. Chitty, M.R. Candelore, M.A. Cascieri, L.F. Colwell Jr., L. Deng, W.P. Feeney, M.J. Forrest, G.J. Hom, D.E. MacIntyre, R.R. Miller, R.A. Stearns, L. Tota, M.J. Wyvratt, M.H. Fisher, A.E. Weber, Bioorg. Med. Chem. Lett. 10 (2000) 1971.
[15] (a) J.P. Horwitz, B.E. Fisher, A.J. Tomasewski, J. Org. Chem. 81 (1959) 3076–3079; (b) A. Yanagi, Y. Watanabe, S. Narabu, JP Y7-97372-A (Nihon Bayer Agrochem K.K.), 1995.
[16] O. Tsuge, S. Urano, K. Oe, J. Org. Chem. 45 (1980) 5130–5136.
[17] A.C. Rupert, J.F. Patricia, US Patent no. 4 618 365 (1986); applied from Uniroyal Chem. Company, Inc.
[18] G. Denecker, G. Smets, G. L'Abbé, Tetrahedron 31 (1975) 765–775.
[19] J.-M. Vandensavel, G. Smets, G. L'Abbé, J. Org. Chem. 38 (1973) 675–678.
[20] (a) K. Laali, V. Gold, J. Org. Chem. 51 (1986) 2395–2397; (b) A.G.M. Barrett, M.J. Betts, A. Fenwick, J. Org. Chem. 50 (1985) 169–175.
[21] S. Ozaki, Chem. Rev. 72 (1972) 457–496.
[22] (a) F. Guenouni, F. Szönyi, A. Cambon, J. Fluorine Chem. 104 (2000) 143–148; (b) Y. Wu, Q. Sun, J. Deng, W. Tian, J. Fluorine Chem. 127 (2006) 1152–1157.
[23] (a) F. Szönyi, F. Guenouni, A. Cambon, J. Fluorine Chem. 55 (1991) 85; (b) H. Trabelsi, F. Szönyi, N. Michelangeli, A. Cambon, J. Fluorine Chem. 69 (1994) 115.
[24] Y.-M. Wu, J. Deng, X. Fang, Q.-Y. Chen, J. Fluorine Chem. 125 (2004) 1415–1423.
[25] E. Mayot, C. Gérardin-Charbonnier, C. Selve, J. Fluorine Chem. 126 (2005) 715–720, and references therein.
[26] X. Qian, J. Tang, W. Chen, R. Zhang, Chem. J. Chin. Univ. 15 (1994) 224–227.
[27] (a) J.T. Kuethe, A. Wong, C. Qu, J. Smitrovich, I.W. Davies, D.L. Hughes, J. Org. Chem. 70 (2005) 2555–2567; (b) M.C. Van Zandt, M.L. Jones, D.E. Gunn, L.S. Geraci, J.H. Jones, D.R. Sawicki, J. Sredy, J.L. Jacot, A.T. Dicioccio, T. Petrova, A. Mitschler, A.D. Podjarny, J. Med. Chem. 48 (2005) 3141–3152; (c) J.J. Li, G.W. Gribble, in: J. Baldwin, R.M. Williams (Eds.), Palladium in Heterocyclic Chemistry, vol. 20, Pergamon Press, New York, 2000, pp. 73–181.
[28] V.A. Soloshonok, Enantiocontrolled Synthesis of Fluoro-Organic Compounds: Stereochemical Challenges and Biomedical Targets, Wiley, New York, 1999.
[29] V.P. Kukhar, V.A. Soloshonok, Fluorine-Containing Amino Acids: Synthesis and Applications, Wiley, New York, 1995.
[30] M. El Kateb, M. Beji, A. Baklouti, J. Fluorine Chem. 81 (1997) 139.
[31] M. Beji, H. Sbihi, A. Baklouti, J. Fluorine Chem. 99 (1999) 17.
[32] M. El Kateb, M. Beji, A. Baklouti, J. Fluorine Chem. 94 (1999) 119.
[33] C. Santaella, P. Vierling, J.G. Riess, T. Gulik-Krzywicki, A. Gulik, B. Monasse, Biochim. Biophys. Acta (BBA) Biomembr. 1190 (1994) 25–39.
[34] (a) J.B. Nivet, M. le Blanc, J. Riess, Eur. J. Med. Chem. 26 (1991) 953–960; (b) A.M. Mahe, J. Manoux, A. Valla, R. Follana, L. Zarif, J. Greiner, P. Vierling, J.G. Riess, Biomater. Artif. Cells Immobil. Biotechnol. 19 (1991) 426.