Synthesis of polyfluoroalkylated bicyclic and tricyclic heterocyclic compounds

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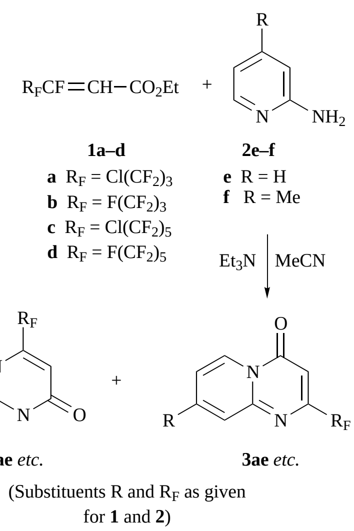
In the presence of base, ethyl 2-hydropolyfluoroalk-2-enoates 1 are converted into polyfluoroalkylated pyrido[1,2-*a*]pyrimidines 3, 4 by reactions with 2-aminopyridine derivatives 2 and into polyfluoroalkylated pyrimido[2,1-*b*]benzothiazole 8 or thiazolo[3,2-*a*]pyrimidine 10, 11 derivatives using 2-aminobenzothiazole 7 or 2-amino-1,3-thiazole 9 derivatives in moderate to good yields. Under different basic conditions, polyfluoroalkenylimidazo[1,2-*a*]pyridine derivatives 5 or polyfluoroalkylated 1,3-thiazino-[3,2-*a*]benzimidazol-4-one 14 are formed, respectively, from the reaction of 2-aminopyridine derivatives 2 or 2-mercaptobenzimidazole 12 with ethyl polyfluoroalk-2-enoates 1 in moderate yields.

Introduction

Recently, much attention has been focused on the synthesis of fluorine-containing organic compounds particularly in the fields of medicinal and agricultural chemistry and of material science. The replacement of hydrogen by a polyfluoroalkyl group in organic compounds may profoundly influence their physical and biological properties.[1] Consequently, considerable efforts have been devoted to the development of new methodologies for the synthesis of fluorine-containing compounds. Various 2*H*-pyrido[1,2-*a*]pyrimidin-2-ones, 4*H*-pyrido[1,2-*a*]pyrimidin-4-ones and imidizo[1,2-*a*]pyrimidines have been reported to possess significant biological activity, such as hypotensive, analgesic, CNS stimulant and bactericidal, amongst others;[2,3,4] thiazolo[3,2-*a*]pyrimidine and pyrimido[2,1-*b*]benzothiazole derivatives have also shown remarkable fungicidal, analgesic, anti inflammatory, anticonvulsant and pesticidal activity *etc.*[5–8] However, to the best of our knowledge, there has been little work on the synthesis of fluoroalkylated derivatives of these heterocycles except for the reported preparation of trifluoromethyl substituted imidazo[1,2-*a*]pyridines.[9] In an earlier study, we developed a new efficient method for the preparation of ethyl 2,2-dihydropolyfluoroalkanoates from readily available polyfluoroalkyl iodides.[10] We found that in the presence of base, the former eliminated HF readily to give the corresponding 2-hydropolyfluoroalk-2-enoates, which are versatile intermediates for the synthesis of fluoroalkylated heterocycles. Upon treatment with 2-aminopyridine, 2-amino-1,3-thiazole or 2-amino-1,3-benzothiazole derivatives, which are known to possess nucleophilic centres on both nitrogen atoms of the molecule, or 2-mercaptobenzimidazole, with the nucleophilic centre on the mercapto or nitrogen atom of the molecule, the corresponding heterocycles were formed in moderate to good yields. In the case of the 2-aminopyridine derivatives, the reaction products depend on the base used. The detailed results are reported herein.

Results and discussion

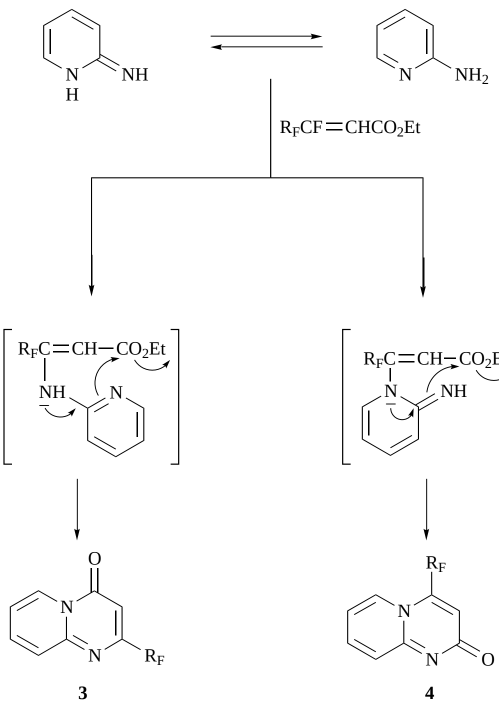
In the presence of triethylamine, ethyl 2-hydropolyfluoroalk-2-enoates **1** were allowed to react with >2 equiv. of 2-aminopyridine in acetonitrile at 90 °C for *ca.* 50 h. Spectral examination of the reaction products revealed that two isomeric heterocyclic compounds **3** and **4**, separable by column chromatography, were formed with the latter as the major product. Taking compounds **3ae** and **4ae** as examples: the ^{19}F NMR spectrum of compound **3ae** revealed the presence of three CF_2 resonances at δ 66.2, 113.9 and 118.9 while that of compound **4ae** showed resonances at δ 66.8, 106.2 and 116.9, suggesting a 3-chlorohexafluoropropyl chain in both cases. The ^{1}H NMR spectrum showed only the presence of five aromatic or ethylenic protons and the absence of an ethoxy group, which indicated that both compounds were intramolecular cyclization products. The ^{1}H NMR of compound **3ae** showed resonances at δ 6.81 (s, 1 H, 3-H), 7.30 (m, 1 H), 7.87 (m, 2 H) and 9.12 (d, J_{HH} 7.2, 6-H). The downfield chemical shift of 6-H is the characteristic proton signal for these 4-oxo compounds, attributable to the anisotropic effect of the carbonyl group.[11] The other product **4ae** showed resonances at δ 7.05 (s, 1 H, 3-H) and 6.92–8.06 (m, 4 H, ArH). The mass spectrum of both compounds **3ae** and **4ae** showed *m*/*z* 330 (M^+), 302 ($M^+ - CO$) and 167 ($M^+ - CO - C_4F_4Cl$). Furthermore, by comparison with the IR carbonyl absorption of a nonfluoro analogue,[3,4,11] we assigned compound **3ae** (ν_{max} 1710 cm^{-1}) as 4-oxo and compound **4ae** (ν_{max} 1640 cm^{-1}) as 2-oxo isomers (see Scheme 1 and Experimental section).



Scheme 1

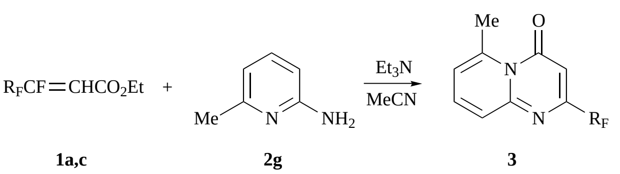
Formation of the isomeric 2- and 4-oxo compounds was the result of Michael addition of the ring nitrogen atom or the amino nitrogen atom on the fluorinated ester, followed by intramolecular cyclization, respectively (see Scheme 2).

2-Amino-4-methylpyridine reacted similarly whereas 2-amino-6-methylpyridine **2g** yielded only the 4-oxo product in



Scheme 2 Substituent R_F as given in Scheme 1

moderate yield apparently due to the steric effect of the 6-methyl group which hindered the Michael addition of the ring nitrogen to the unsaturated esters **1**.

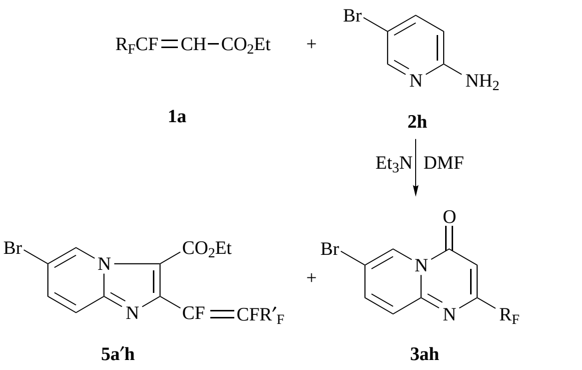


Scheme 3 Substituent R_F as given in Scheme 1

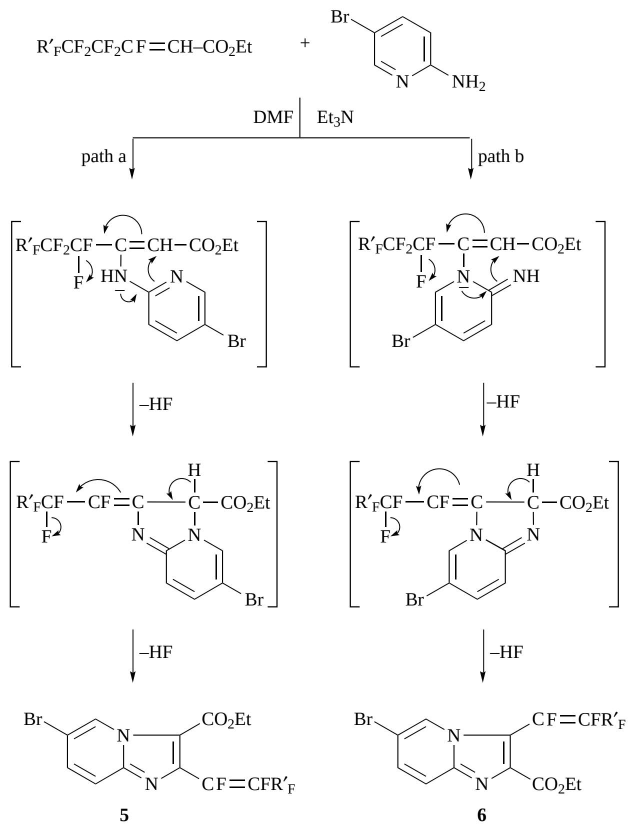
In the case of 2-amino-5-bromopyridine, because of its low solubility in acetonitrile, the reaction was carried out in *N*,*N*,-dimethylformamide at 90 °C for 60 h; 4*H*-pyrido[1,2-*a*]pyridin-4-one was formed as expected in moderate yield, accompanied by a small amount of a by-product **5**. The structure of **5** was established through comparison of its ^{13}C NMR spectrum with that of a known analogous compound reported in the literature[4b,4d] and the examination of its spectra. Taking compound **5a′h** as an example, its ^{19}F NMR spectrum revealed resonances at δ 55.5 (m, 2 F, CF_2Cl), 135.6 (d, J_{FF} 141, 1 F) and 148.9 (d, J_{FF} 141, 1 F) which suggested a 3-chlorotetrafluoropropenyl chain. The ^1H NMR spectrum showed the presence of an ethoxy group with resonances at δ 1.36 (3 H, t, J_{HH} 7.1, CH_3) and 4.42 (2 H, q, J_{HH} 7.1, CH_2) and three aromatic protons at δ 7.55 (2 H, AB, J_{AB} 8.6, 7,8-H) and 8.13 (1 H, s, 5-H). The mass spectrum showed *m*/*z* 416 ($M^+ + 2$), 414 (M^+) and 385 ($M^+ - OEt$). The IR spectrum showed a carbonyl absorption at 1730 cm^{-1} (see Experimental section), so we assigned it to be an imidazo[1,2-*a*]pyridine derivative.

The formation of the imidazo[1,2-*a*]pyridine derivative may be depicted as shown in Scheme 5.

No cyclic nitrogen addition product **4** or **6** was obtained during the reaction, possibly because of the electronic effect of the bromo substituent. Further study showed that by employing K_2CO_3 in place of Et_3N as the base, the reaction of 2-aminopyridine and ethyl 2-hydropolyfluoroalk-2-enoate took place smoothly and gave imidazo[1,2-*a*]pyridine derivative **5** as the sole product in moderate yields. The detailed results are shown in Table 1.



Scheme 4 Substituent R_F as given in Scheme 1 and R'_F as given in Scheme 6



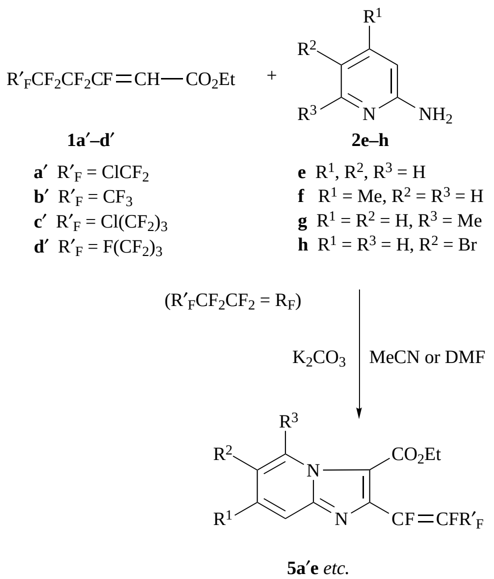
Scheme 5 Substituent R'_F as given in Scheme 6

For the synthesis of polyfluoroalkenylimidazo[1,2-*a*]pyridine, the reaction could be greatly accelerated by ultrasonic irradiation. In the presence of K_2CO_3, a mixture of 1 equiv. of 2-hydropolyfluoroalk-2-enoates and 3 equiv. of 2-aminopyridine in acetonitrile was subjected to ultrasonic irradiation (125 W) for 2 h, after which in all cases the reaction was complete and gave a similar product to that in the thermal reactions. The detailed results are shown in Table 2.

Acetonitrile and *N*,*N*-dimethylformamide (DMF) are the solvents of choice. Furthermore, a substituent on the pyridine ring seems to have no effect.

It is noteworthy that the concentration of nucleophiles plays an important role in these reactions. Only when more than 2 equiv. of nucleophiles were used could the reaction proceed smoothly with later recovery of the excess reagents.

This reaction was also applied to a series of 2-aminobenzothiazole derivatives. Generally, in the presence of a base (*e.g.* K_2CO_3 or triethylamine), a mixture of 2-hydropolyfluoroalk-2-enoates (1 mmol) and a 2-aminobenzothiazole derivative (1.5 mmol) was heated in acetonitrile or DMF for 12 h and the



Scheme 6

Table 1 Synthesis of 4-polyfluoroalkylated 2*H*-pyrido[1,2-*a*]-pyrimidin-2-ones, 2-polyfluoroalkylated 4*H*-pyrido[1,2-*a*]pyrimidin-4-ones and polyfluoroalkenylimidazo[1,2-*a*]pyridine

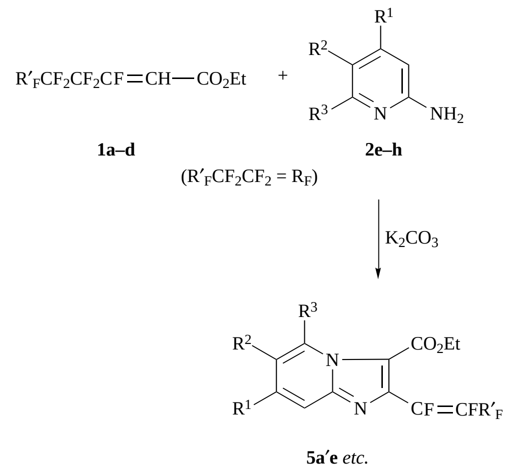
					Isolated yields of the products (%)[a]		
R_F	R^1	R^2	R^3	Base	3	4	5
1a	H	H	H	Et_3N	**3ae**, 18	**4ae**, 50	
1b	H	H	H	Et_3N	**3be**, 16	**4be**, 54	
1c	H	H	H	Et_3N	**3ce**, 23	**4ce**, 42	
1d	H	H	H	Et_3N	**3de**, 16	**4de**, 43	
1a	CH_3	H	H	Et_3N	**3af**, 18	**4af**, 53	
1c	CH_3	H	H	Et_3N	**3cf**, 25	**4cf**, 39	
1a	H	H	CH_3	Et_3N	**3ag**, 42		
1c	H	H	CH_3	Et_3N	**3cg**, 47		
1a	H	Br	H	Et_3N	**3ah**, 44		**5a′h**, 8
1a	H	H	H	K_2CO_3			**5a′e**, 63
1b	H	H	H	K_2CO_3			**5b′e**, 57
1c	H	H	H	K_2CO_3			**5c′e**, 55
1a	Me	H	H	K_2CO_3			**5a′f**, 57
1b	Me	H	H	K_2CO_3			**5b′f**, 58
1c	Me	H	H	K_2CO_3			**5c′f**, 51
1a	H	H	CH_3	K_2CO_3			**5a′g**, 40
1a	H	Br	H	K_2CO_3			**5a′h**, 32
1c	H	Br	H	K_2CO_3			**5c′h**, 30

[a] Isolated yields after chromatography based on **1**.

mixture was then worked up to give exclusively products **8** in good yield.

Under similar conditions, the reaction of 2-amino-1,3-thiazole with 2-hydropolyfluoroalk-2-enoate gave two isomers **10** and **11** separable by column chromatography. Their structure was established through ^{1}H NMR, ^{19}F NMR and mass spectra and elemental analyses. The detailed results are shown in Table 3.

Since 2-mercaptobenzimidazole possesses a similar structure to 2-aminothiazole, the possibility of the synthesis of polyfluoroalkylated[1,3]thiazino[3,2-*a*]benzimidazol-4-one by this reaction sparked our interest. In the presence of triethylamine, the reaction of 1.5 equiv. of 2-mercaptobenzimidizole with 1 equiv. of 2-hydropolyfluoroalk-2-enoates resulted in a complex mixture, presumably as a result of the enhanced nucleophilicity of the mercapto group in the presence of triethylamine. When $NaHCO_3$ was used as the base in place of triethylamine, the reaction mixture was first heated at 50 °C for 6 h and then at 90 °C for 10 h. Upon monitoring the reaction by ^{19}F NMR spectroscopy, we found that only one product was formed, the

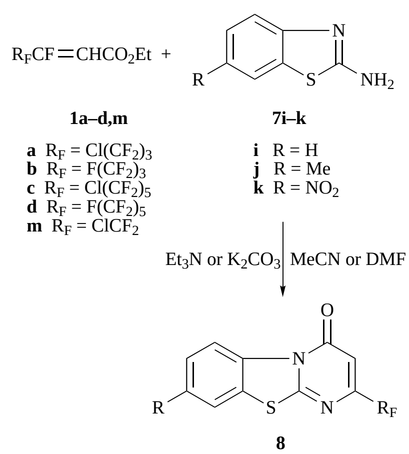


Scheme 7 R_F as given in Scheme 1 and R'_F as given in Scheme 6; R^1, R^2 and R^3 are given in Table 1 together with **a**′, **b**′, **c**′

Table 2 Synthesis of polyfluoroalkenylimidazo[1,2-*a*]pyridine by ultrasonic irradiation

R_F	Nucleophile	Reaction time (*t*/min)	Isolated yield of the products (%)[a]	
1a	**2e**	40	**5a′e**	53
1b	**2e**	60	**5b′e**	59
1b	**2f**	60	**5b′f**	48
1a	**2g**	70	**5a′g**	46
1c	**2h**	120	**5c′h**	33

[a] Isolated yield based on **1** after chromatography.



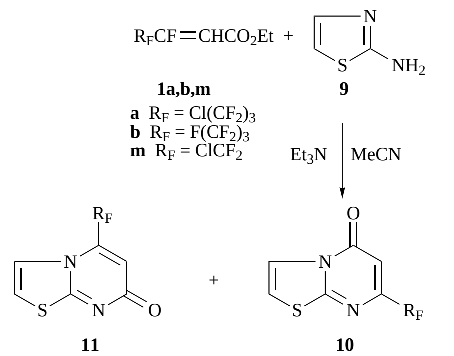
Scheme 8

structure of which was established as 2-polyfluoroalkyl[1,3]-thiazino[3,2-*a*]benzimidazol-4-one **14c** upon the basis of its ^{1}H NMR, ^{19}F NMR, IR and mass spectra together with its elemental analysis.

In summary, a convenient new one-step method for the selective synthesis of new 2-polyfluoroalkyl-4*H*-pyrido[1,2-*a*]-pyrimidin-4-ones **3**, 4-polyfluoroalkyl-2*H*-pyrido[1,2-*a*]pyrimidin-2-ones **4**, 2-fluoroalkenylimidazo[1,2-*a*]pyrimidines **5**, 2-fluoroalkyl-4*H*-pyrimido[2,1-*b*]benzothiazol-4-ones **8**, 7-fluoroalkyl-5*H*-1,4-thiazolo[3,2-*a*]pyrimidin-5-ones **10**, 5-fluoroalkyl-7*H*-thiazolo[3,2-*a*]pyrimidin-7-ones **11** and 2-polyfluoroalkyl-[1,3]thiazino[3,2-*a*]benzimidazol-4-one **14** derivatives directly from ethyl 2-hydropolyfluoroalk-2-enoates is described. The simplicity of the experimental procedure and the readily availability of the starting materials make this synthetic method a practical one.

Experimental

All mps are uncorrected. IR Spectra were recorded on an

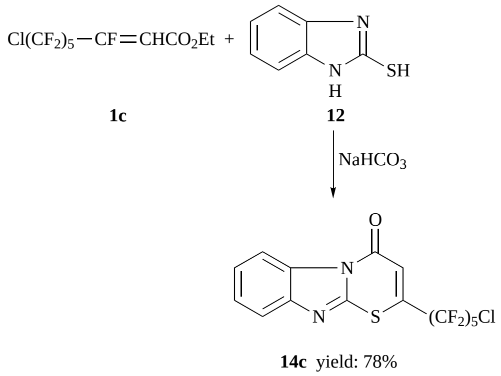


Scheme 9

Table 3 Synthesis of 7-fluoroalkyl-5*H*-1,4-thiazolo[3,2-*a*]pyrimidin-5-ones, 5-fluoroalkyl-7*H*-thiazolo[3,2-*a*]pyrimidin-7-ones and 2-fluoroalkyl-4*H*-pyrimido[2,1-*b*]benzothiazol-4-ones

		Isolated yield (%)†		
R_f	Substrate*	**8**	**10**	**11**
1a	**7i**	**8ai**, 67		
1b	**7i**	**8bi**, 70		
1d	**7i**	**8di**, 70		
1m	**7i**	**8mi**, 74		
1a	**7i**	**8aj**, 83		
1c	**7j**	**8cj**, 82		
1m	**7j**	**8mj**, 73		
1a	**7k**	**8ak**, 71		
1d	**7k**	**8dk**, 73		
1a	**9**		**10a**, 22	**11a**, 49
1b	**9**		**10b**, 13	**11b**, 64
1m	**9**		**10m**, 15	**11m**, 39

* Compounds **7i**,**j**,**k** are given in Scheme 8. † Isolated yields based on **1** after chromatography.



Scheme 10

IR-440 spectrometer, using KBr pellets or CCl_4 liquid films. ^1H NMR Spectra were measured on FX-90Q (90 MHz), Bruker AM 300 (300 MHz) or AMX-600 (600 MHz) machines and ^{13}C NMR spectra were measured on an AMX-600 (600 MHz) spectrometer, using $SiMe_4$ as internal standard. ^{19}F NMR Spectra were recorded on a Varian EM-360L spectrometer (56.4 MHz) using CF_3CO_2H (TFA) as external standard. In ^{19}F NMR spectra, chemical shifts (in ppm) were positive for upfield shifts and the values are reported as $\delta(CFCl_3)$ [$\delta(CFCl_3) = \delta(TFA) + 76.8$]. *J* Values are recorded in Hz. Mass spectra were taken on a Finnegan GC-MS 4021 spectrometer. Column chromatography was performed using silica gel H, particle size 10–40 µm.

Preparation of 4-polyfluoroalkyl-2*H*-pyrido[1,2-*a*]pyrimidin-2-ones and 2-polyfluoroalkyl-4*H*-pyridol[1,2-*a*]pyrimidin-4-ones

Typical procedure. A mixture of 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), 2-aminopyridine derivative **2** (3 mmol), triethylamine (5 mmol) and acetonitrile (5 ml) was stirred at 90 °C for 50 h to give a black reaction product, which was then adsorbed on silica (particle size 100–200 mesh; 5 g) and air dried at 50 °C. The whole mass was then purified by column chromatography using light petroleum–ethyl acetate (8 : 1, v/v) as eluent to give 2-polyfluoroalkyl-4*H*-pyrido[1,2-*a*]pyrimidin-4-one. After that, elution with light petroleum ether–ethyl acetate (2 : 1, v/v) gave first the excess of 2-aminopyridine derivatives **2**, followed by light petroleum–ethyl acetate (1 : 1) as eluent to give 4-polyfluoroalkyl-2*H*-pyrido[1,2-*a*]pyrimidin-2-one as a solid.

Compound 3ae. Mp 134–136 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1100–1200 (CF); δ_H($CDCl_3$) 6.81 (s, 1 H), 7.30 (m, 1 H), 7.87 (m, 2 H) and 9.12 (d, $^3J_{HH}$ 7.2, 1 H); δ_F($CDCl_3$) 66.2 (s, 2 F), 113.9 (s, 2 F) and 118.9 (s, 2 F); *m/z* 330 (M^+, 43.5%), 302 ($M^+ - CO$, 20.2) and 167 ($M^+ - CO - C_2F_4Cl$, 100) (Found: C, 40.2; H, 1.3; N, 8.6; F, 34.1. $C_{11}H_5ClF_6N_2O$ requires C, 40.0; H, 1.5; N, 8.5; F, 34.5%).

Compound 4ae. Mp 115–117 °C; ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1110–1210 (CF); δ_H($CDCl_3$) 7.05 (s, 1 H) and 6.92–8.06 (m, 4 H); δ_F($CDCl_3$) 66.8 (s, 2 F), 106.2 (s, 2 F) and 116.9 (s, 2 F); *m/z* 330 (M^+, 28.3%), 302 ($M^+ - CO$, 13.1) and 167 ($M^+ - CO - C_2F_4Cl$, 100) (Found: C, 40.2; H, 1.5; N, 8.55; F, 34.8. $C_{11}H_5ClF_6N_2O$ requires C, 40.0; H, 1.5; N, 8.5; F, 34.5%).

Compound 3be. Mp 117–119 °C; ν_{max}(KBr)/cm^{-1} 1720 (C=O) and 1120–1240 (CF); δ_H($CDCl_3$) 6.81 (s, 1 H), 7.31 (m, 1 H), 7.88 (m, 2 H) and 9.12 (d, $^3J_{HH}$ 7.2, 1 H); δ_F($CDCl_3$) 79.6 (s, 3 F), 116.4 (s, 2 F) and 125.4 (s, 2 F); *m/z* 314 (M^+, 74.0%), 286 ($M^+ - CO$, 32.4) and 167 ($M^+ - CO - C_2F_5$, 100) (Found: C, 41.95; H, 1.5; N, 8.8; F, 42.5. $C_{11}H_5F_7N_2O$ requires C, 42.1; H, 1.6; N, 8.9; F, 42.3%).

Compound 4be. Mp 104–106 °C; ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1120–1240 (CF); δ_H($CDCl_3$) 6.82–7.97 (m, 4 H) and 7.02 (s, 1 H); δ_F($CDCl_3$) 79.2 (s, 3 F), 107.7 (s, 2 F) and 122.8 (s, 2 F); *m/z* 314 (M^+, 63.0%), 286 ($M^+ - CO$, 28.0) and 167 ($M^+ - CO - C_2F_5$, 100) (Found: C, 42.25; H, 1.5; N, 8.8; F, 42.0. $C_{11}H_5F_7N_2O$ requires C, 42.1; H, 1.6; N, 8.9; F, 42.3%).

Compound 3ce. Mp 118–120 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1110–1220 (CF); δ_H($CDCl_3$) 6.82 (s, 1 H), 7.31 (m, 1 H), 7.87 (m, 2 H) and 9.12 (d, $^3J_{HH}$ 7.1, 1 H); δ_F($CDCl_3$): 67.1 (s, 2 F), 115.0 (s, 2 F) and 119.9 (m, 6 F); *m/z* 430 (M^+, 28.3%), 402 ($M^+ - CO$, 11.5) and 167 ($M^+ - CO - C_4F_8Cl$, 100) (Found: C, 36.25; H, 1.2; N, 6.55; F, 43.8. $C_{13}H_5ClF_{10}N_2O$ requires C, 36.3; H, 1.2; N, 6.5; F, 44.1%).

Compound 4ce. 107–109 °C; ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1140–1230 (CF); δ_H($CDCl_3$) 6.92 (td, $^3J_{HH}$ 1.1, $^3J_{HH}$ 7.4, 1 H), 7.02 (s, 1 H), 7.43 (d, $^3J_{HH}$ 9.1, 1 H), 7.63 (dt, $^3J_{HH}$ 1.1, $^3J_{HH}$ 9.1, 1 H) and 8.02 (d, $^3J_{HH}$ 7.4, 1 H); δ_F($CDCl_3$) 67.4 (s, 2 F), 106.8 (s, 2 F) and 118.9 (m, 6 F); *m/z* 430 (M^+, 11.8%), 395 ($M^+ - Cl$, 10.1) and 167 ($M^+ - CO - C_4F_8Cl$, 100) (Found: C, 36.15; H, 1.0; N, 6.4; F, 43.7. $C_{13}H_5ClF_{10}N_2O$ requires C, 36.3; H, 1.2; N, 6.5; F, 44.1%).

Compound 3de. Mp 97–99 °C; ν_{max}(KBr)/cm^{-1} 1720 (C=O) and 1150–1240 (CF); δ_H($CDCl_3$) 6.81 (s, 1 H), 7.30 (m, 1 H), 7.83 (m, 2 H) and 9.12 (d, $^3J_{HH}$ 7.2, 1 H); δ_F($CDCl_3$) 80.2 (s, 3 F), 115.3 (s, 2 F), 121.2 (m, 4 F) and 125.4 (s, 2 F); *m/z* 414 (M^+, 41.5%), 386 ($M^+ - CO$, 15.5) and 167 ($M^+ - CO - C_4F_9$, 100) (Found: C, 37.8; H, 1.1; N, 7.05; F, 50.8. $C_{13}H_5F_{11}N_2O$ requires C, 37.7; H, 1.2; N, 6.8; F, 50.5%).

Compound 4de. Mp 146–148 °C; ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1140–1240 (CF); δ_H($CDCl_3$) 6.82 (m, 1 H), 7.02 (s, 1 H), 7.44 (m, 2 H) and 8.01 (m, 1 H); δ_F($CDCl_3$) 80.1 (s, 3 F), 106.0 (s, 2 F), 118.0 (s, 2 F), 120.6 (s, 2 F) and 124.3 (s, 2 F); *m/z* 414 (M^+, 27.8%), 386 ($M^+ - CO$, 14.8) and 167 ($M^+ - CO - C_4F_9$, 100) (Found: C, 37.8; H, 1.2; N, 6.9. $C_{13}H_5F_{11}N_2O$ requires C, 37.7; H, 1.2; N, 6.8%).

Compound 3af. Mp 87–89 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1130–1200 (CF); δ_H($CDCl_3$) 2.54 (s, 3 H), 6.73 (s, 1 H), 7.13 (d, $^3J_{HH}$ 7.2, 1 H), 7.62 (s, 1 H) and 9.00 (d, $^3J_{HH}$ 7.2, 1 H);

$\delta_F(CDCl_3)$ 66.5 (s, 2 F), 114.7 (s, 2 F) and 119.6 (s, 2 F); *m/z* 344 (M^+, 45.3%), 316 ($M^+ - CO$, 23.3) and 181 ($M^+ - CO - C_2F_4Cl$, 100) (Found: C, 42.0; H, 1.9; N, 8.1; F, 32.2. $C_{12}H_7ClF_6N_2O$ requires C, 41.8; H, 2.05; N, 8.1; F, 33.1%).

Compound 4af. Mp 168–170 °C (blackens); ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1110–1200 (CF); δ_H([$^2H_6$]acetone) 2.44 (s, 3 H), 6.86 (s, 1 H), 6.95 (d, $^3J_{HH}$ 7.2, 1 H), 7.09 (s, 1 H) and 8.09 (d, $^3J_{HH}$ 7.2, 1 H); δ_F([$^2H_6$]acetone) 68.4 (s, 2 F), 107.6 (s, 2 F) and 118.6 (s, 2 F); *m/z* 344 (M^+, 14.6%), 316 ($M^+ - CO$, 9.5) and 181 ($M^+ - CO - C_2F_4Cl$, 100) (Found: C, 41.6; H, 1.9; N, 8.2; F, 33.2. $C_{12}H_7ClF_6N_2O$ requires C, 41.8; H, 2.05; N, 8.1; F, 33.1%).

Compound 3cf. Mp 116–118 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1150–1210 (CF); $\delta_H(CDCl_3)$ 2.53 (s, 3 H), 6.72 (s, 1 H), 7.09 (d, $^3J_{HH}$ 7.2, 1 H), 7.59 (s, 1 H) and 8.96 (d, $^3J_{HH}$ 7.2, 1 H); $\delta_F(CDCl_3)$ 67.4 (s, 2 F), 115.4 (s, 2 F) and 120.5 (m, 6 F); *m/z* 444 (M^+, 25.4%), 416 ($M^+ - CO$, 11.2) and 181 ($M^+ - CO - C_4F_8Cl$, 100) (Found: C, 38.1; H, 1.6; N, 6.3; F, 42.5. $C_{14}H_7ClF_{10}N_2O$ requires C, 37.8; H, 1.6; N, 6.3; F, 42.7%).

Compound 4cf. Mp 149–151 °C; ν_{max}(KBr)/cm^{-1} 1650 (C=O) and 1140–1200 (CF); $\delta_H(CDCl_3)$ 2.41 (s, 3 H), 6.73 (d, $^3J_{HH}$ 7.5, 1 H), 6.97 (s, 1 H), 7.18 (s, 1 H) and 7.90 (d, $^3J_{HH}$ 7.5, 1 H); $\delta_F(CDCl_3)$ 68.4 (s, 2 F), 106.9 (s, 2 F) and 119.1 (m, 6 F); *m/z* 444 (M^+, 14.2%), 416 ($M^+ - CO$, 6.8) and ($M^+ - CO - C_4F_8Cl$, 100) (Found: C, 37.7; H, 1.4; N, 6.2; F, 43.1. $C_{14}H_7ClF_{10}N_2O$ requires C, 37.8; H, 1.6; N, 6.3; F, 42.7%).

Compound 3ag. Mp 66–68 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1110–1190 (CF); $\delta_H(CDCl_3)$ 3.06 (s, 3 H), 6.60 (s, 1 H), 6.75 (m, 1 H) and 7.52 (m, 2 H); $\delta_F(CDCl_3)$ 66.7 (s, 2 F), 115.2 (s, 2 F) and 119.6 (s, 2 F); *m/z* 344 (M^+, 32.0%), 316 ($M^+ - CO$, 30.4) and 181 ($M^+ - CO - C_2F_4Cl$, 100) (Found: C, 41.9; H, 1.9; N, 8.1; F, 33.0. $C_{12}H_7ClF_6N_2O$ requires C, 41.8; H, 2.05; N, 8.1; F, 33.1%).

Compound 3cg. Mp 51–53 °C; ν_{max}(KBr)/cm^{-1} 1720 (C=O) and 1110–1220 (CF); $\delta_H(CDCl_3)$ 3.06 (s, 3 H), 6.62 (s, 1 H), 6.79 (m, 1 H) and 7.56 (m, 2 H); $\delta_F(CDCl_3)$ 67.3 (s, 2 F), 115.8 (s, 2 F) and 120.4 (m, 6 F); *m/z* 444 (M^+, 27.5%), 416 ($M^+ - CO$, 28.8) and 181 ($M^+ - CO - C_4F_8Cl$, 100) (Found: C, 38.3; H, 1.6; N, 6.4; F, 42.0. $C_{14}H_7ClF_{10}N_2O$ requires C, 37.8; H, 1.6; N, 6.3; F, 42.7%).

Reaction of 2-amino-5-bromopyridine with ethyl 2-hydropolyfluoroalk-2-enoates

A mixture of ethyl 2-hydropolyfluoroalk-2-enoate (1 mmol), 2-amino-5-bromopyridine (3 mmol), triethylamine (5 mmol) and *N*,*N*-dimethylformamide (5 ml) was stirred at 100 °C for 50 h after which the mixture was cooled and extracted with ethyl acetate. The extract was washed with water and saturated brine, dried (Na_2SO_4) and evaporated. The residue was purified by column chromatography using light petroleum–ethyl acetate (10 : 1) as eluent to give 7-bromo-2-fluoroalkyl-4*H*-pyrido[1,2-*a*]pyrimidin-4-one and 6-bromo-2-fluoroalkenyl-3-(ethoxycarbonyl)imidazo[1,2-*a*]pyridine, respectively.

Compound 3ah. Mp 145–147 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1100–1180 (CF); $\delta_H(CDCl_3)$ 6.84 (s, 1 H), 7.70 (d, $^3J_{HH}$ 9.4, 1 H), 7.92 (dt, $^3J_{HH}$ 9.4, $^3J_{HH}$ 1.8, 1 H) and 9.22 (d, $^3J_{HH}$ 1.8, 1 H); $\delta_F(CDCl_3)$ 66.5 (s, 2 F), 114.6 (s, 2 F) and 119.3 (s, 2 F); *m/z* 410 ($M^+ + 2$, 57.0%), 408 (M^+, 40.8), 380 ($M^+ - CO$, 25.6), 247 ($M^+ + 2 - CO - C_2F_4Cl$, 100) and 245 ($M^+ - CO - C_2F_4Cl$, 95.4) (Found: C, 32.3; H, 0.8; N, 6.9; F, 27.8. $C_{11}H_4BrClF_6N_2O$ requires C, 32.3; H, 1.0; N, 6.8; F, 27.8%).

Compound 5a′h. Mp 123–125 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1160–1240 (CF); $\delta_H(CDCl_3)$ 1.36 (t, $^3J_{HH}$ 7.1, 3 H), 4.42 (q, $^3J_{HH}$ 7.1, 2 H), 7.55 (AB, J_{AB} 8.6, 2 H) and 8.13 (s, 1 H); $\delta_F(CDCl_3)$ 55.5 (m, 2 F), 135.6 (d, $^3J_{FF}$ 141, 1 F) and 148.9 (d, $^3J_{FF}$ 1, 41, 1 F); *m/z* 416 ($M^+ + 2$, 40.0%), 414 (M^+, 30.6), 387 ($M^+ + 2 - OEt$, 48.5), 385 ($M^+ - OEt$, 36.0), 353 ($M^+ + 2 - CO - C_2F_4Cl$, 35.7), 351 ($M^+ - CO - Cl$, 35.1), 303 ($M^+ + 2 - CO - CF_2Cl$, 100) and 301 ($M^+ - CO - Cl$, 93.7) (Found: C, 37.5; H, 1.8; N, 6.8; F, 18.4. $C_{13}H_8BrClF_4N_2O_2$ requires C, 37.6; H, 1.9; N, 6.7; F, 18.3%).

Preparation of polyfluoroalkenylimidazo[1,2-*a*]pyridine derivatives 5

Typical procedure. A mixture of ethyl 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), a 2-aminopyridine derivative (3 mmol) and acetonitrile (5 ml) was heated at 90 °C for 60 h. After cooling to room temperature, the reaction mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried (Na_2SO_4) and evaporated. The resulting residue was purified by column chromatography using light petroleum–ethyl acetate (10 : 1) as eluent to give the products.

Compound 5a′e. Mp 123–125 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O), 1640 (C=C) and 1170–1280 (CF); $\delta_H(CDCl_3)$ 1.45 (t, $^3J_{HH}$ 7.1, 3 H), 4.50 (q, $^3J_{HH}$ 7.1, 2 H), 7.11 (t, $^3J_{HH}$ 6.8, 1 H), 7.47 (t, $^3J_{HH}$ 8.9, 1 H), 7.83 (d, $^3J_{HH}$ 8.9, 1 H) and 8.09 (d, $^3J_{HH}$ 6.8, 1 H); $\delta_C(CDCl_3)$ 14.07 (s, 1 C), 61.77 (s, 1 C), 113.27 (d, $^1J_{CF}$ 114, 1 C), 115.53 (s, 1 C), 120.09 (m, 1 C), 119.52 (s, 1 C), 125.03 (s, 1 C), 128.16 (s, 1 C), 138.35 (s, 1 C), 139.77 (m, 1 C), 143.29 (m, 1 C), 146.31 (s, 1 C) and 161.54 (s, 1 C); $\delta_F(CDCl_3)$ 55.3 (s, 2 F), 134.5 (d, $^3J_{FF}$ 142, 1 F) and 150.5 (d, $^3J_{FF}$ 142, 1 F); *m/z* 336 (M^+, 37.0%), 307 ($M^+ - Et$, 48.7), 291 ($M^+ - OEt$, 15.9) and 223 ($M^+ - 113$, 100) (Found: C, 46.0; H, 2.5; N, 8.2; F, 21.7. $C_{13}H_9ClF_4N_2O_2$ requires C, 46.4; H, 2.7; N, 8.3; F, 22.6%).

Compound 5b′e. Mp 119–121 °C; ν_{max}(KBr)/cm^{-1} 1730 (C−O) and 1140–1220 (C–F); $\delta_H(CDCl_3)$ 1.35 (t, $^3J_{HH}$ 7.2, 3 H), 4.40 (q, $^3J_{HH}$ 7.2, 2 H), 7.01 (t, $^3J_{HH}$ 6.7, 1 H), 7.38 (t, $^3J_{HH}$ 8.0, 1 H), 7.74 (d, $^3J_{HH}$ 8.0, 1 H) and 8.01 (d, $^3J_{HH}$ 6.7, 1 H); $\delta_F(CDCl_3)$ 67.5 (s, 3 F), 136.5 (d, $^3J_{FF}$ 141, 1 F) and 156.7 (d, $^3J_{FF}$ 141, 1 F); *m/z* 320 (M^+, 31.2%), 291 ($M^+ - Et$, 65.6), 275 ($M^+ - OEt$, 18.7) and 78 ($M^+ - 242$, 100) (Found: C, 49.4; H, 3.0; N, 9.3; F, 29.1. $C_{13}H_9F_5N_2O_2$ requires C, 48.8; H, 2.8; N, 8.75; F, 29.7%).

Compound 5c′e. Mp 51–53 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1120–1240 (CF); $\delta_H(CDCl_3)$ 1.44 (t, $^3J_{HH}$ 7.1, 3 H), 4.50 (q, $^3J_{HH}$ 7.1, 2 H), 7.11 (t, $^3J_{HH}$ 6.7, 1 H), 7.47 (t, $^3J_{HH}$ 8.5, 1 H), 7.84 (d, $^3J_{HH}$ 8.5, 1 H) and 8.04 (d, $^3J_{HH}$ 6.7, 1 H); $\delta_F(CDCl_3)$ 67.4 (s, 2 F), 115.9 (s, 2 F), 121.3 (s, 2 F), 133.4 (d, $^3J_{FF}$ 141, 1 F) and 153.2 (d, $^3J_{FF}$ 141, 1 F); *m/z* 436 (M^+, 31.8%), 407 ($M^+ - Et$, 29.3), 39.1 ($M^+ - OEt$, 14.8), 251 ($M^+ - C_3F_6Cl$, 15.1) and 223 ($M^+ - 213$, 100) (Found: C, 41.0; H, 1.9; N, 6.4; F, 34.6. $C_{15}H_9ClF_8N_2O_2$ requires C, 41.3; H, 2.1; N, 6.4; F, 34.8%).

Compound 5a′f. 94–96 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1170–1240 (CF); $\delta_H(CDCl_3)$ 1.43 (t, $^3J_{HH}$ 7.2, 3 H), 2.47 (s, 3 H), 4.47 (q, $^3J_{HH}$ 7.1, 2 H), 6.91 (d, $^3J_{HH}$ 7.0, 1 H), 7.54 (s, 1 H) and 7.96 (d, $^3J_{HH}$ 7.0, 1 H); $\delta_F(CDCl_3)$ 56.1 (dd, $^3J_{FF}$ 28, $^4J_{FF}$ 15, 2 F), 134.8 (dt, $^3J_{FF}$ 141, $^3J_{FF}$ 28, 1 F) and 160.7 (dt, $^3J_{FF}$ 141, $^4J_{FF}$ 15, 1 F); *m/z* 350 (M^+, 58.1%), 321 ($M^+ - Et$, 100) and 305 ($M^+ - OEt$, 19.1) (Found: C, 47.8; H, 3.0; N, 7.9; F, 21.6%. $C_{14}H_{11}ClF_4N_2O_2$ requires C, 47.95; H, 3.2; N, 8.0; F, 21.7%).

Compound 5b′f. Mp 122–124 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1140–1220 (CF); $\delta_H(CDCl_3)$ 1.42 (t, $^3J_{HH}$ 7.1, 3 H), 2.47 (s, 3 H), 4.47 (q, $^3J_{HH}$ 7.1, 2 H), 6.91 (d, $^3J_{HH}$ 7.0, 1 H), 7.55 (s, 1 H) and 7.96 (d, $^3J_{HH}$ 7.0, 1 H); $\delta_F(CDCl_3)$ 67.0 (s, 3 F), 135.7 (d, $^3J_{FF}$ 141, 1 F) and 156.5 (d, $^3J_{FF}$ 141, 1 F); *m/z* 334 (M^+, 38.0%), 305 ($M^+ - Et$, 100) and 289 ($M^+ - OEt$, 17.4) (Found: C, 49.6; H, 3.3; N, 7.9; F, 27.9. $C_{14}H_{11}F_5N_2O_2$ requires C, 50.3; H, 3.3; N, 8.4; F, 28.4%).

Compound 5c′f. Mp 85–87 °C; ν_{max}(KBr)/cm^{-1} 1740 (C=O) and 1140–1240 (CF); δ_H([$^2H_6$]acetone) 1.40 (t, $^3J_{HH}$ 7.1, 3 H), 2.49 (s, 3 H), 4.40 (q, $^3J_{HH}$ 7.1, 2 H), 7.11 (d, $^3J_{HH}$ 6.5, 1 H), 7.54 (s, 1 H) and 8.29 (d, $^3J_{HH}$ 6.5, 1 H); δ_F([$^2H_6$]acetone) 68.9 (s, 2 F), 116.8 (s, 2 F), 122.5 (s, 2 F), 133.3 (d, $^3J_{FF}$ 141, 1 F) and 156.8 (d, $^3J_{FF}$ 141, 1 F); *m/z* 450 (M^+, 36.0%), 421 ($M^+ - Et$, 38.7), 405 ($M^+ - OEt$, 15.6) and 92 (100) (Found: C, 42.2; H, 2.3; N, 5.8; F, 33.3. $C_{16}H_{11}ClF_8N_2O_2$ requires C, 42.6; H, 2.5; N, 6.2; F, 33.7%).

Compound 5a′g. Mp 70–72 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1170–1240 (CF); δ_H($CDCl_3$) 1.43 (t, $^3J_{HH}$ 7.0, 3 H), 2.76 (s, 3 H), 4.47 (q, $^3J_{HH}$ 7.0, 2 H), 6.78 (d, $^3J_{HH}$ 7.2, 1 H), 7.37 (m, 1 H) and 7.68 (d, $^3J_{HH}$ 8.9, 1 H); δ_F($CDCl_3$) 155.9 (m, 2 F), 111.6 (d, $^3J_{FF}$ 141, 1 F) and 148.3 (d, $^3J_{FF}$ 141, 1 F); *m/z* 350 (M^+, 63.4%), 321 (M^+ − Et, 100) and 305 (M^+ − OEt, 14.5) (Found: C, 47.7; H, 3.1; N, 7.9; F, 20.9. $C_{14}H_{11}ClF_4N_2O_2$ requires C, 47.95; H, 3.2; N, 8.0; F, 21.7%).

Compound 5c′h. Mp 115–116 °C; ν_{max}(KBr)/cm^{-1} 1730 (C=O) and 1130–1220 (CF); δ_H($CDCl_3$) 1.43 (t, $^3J_{HH}$ 7.0, 3 H), 4.48 (q, $^3J_{HH}$ *J* 7.0, 2 H), 7.59 (AB, J_{AB} 8.8, 2 H) and 8.13 (s, 1 H); δ_F($CDCl_3$) 67.3 (s, 2 F), 115.5 (s, 2 F), 121.0 (s, 2 F), 134.1 (d, $^3J_{FF}$ 141, 1 F) and 151.8 (d, $^3J_{FF}$ 141, 1 F); *m/z* 516 (M^+ + 2, 26.7%), 514 (M^+, 21.3), 487 (M^+ + 2 − Et, 26.6), 485 (M^+ − Et, 19.9), 459 (M^+ + 2 − OEt, 15.5) and 303 (M^+ − 156, 100) (Found: C, 34.9; H, 1.3; N, 5.6; F, 29.7. $C_{15}H_8ClBrF_8N_2O_2$ requires C, 34.9; H, 1.6; N, 5.4; F, 29.5%).

Synthesis of 2-polyfluoroalkyl-4*H*-pyrimido[2,1-*b*]benzothiazol-4-ones

Typical procedure. A mixture of 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), 2-aminobenzothiazole derivative **7i**,**j** (1.5 mmol), triethylamine (5 mmol) and acetonitrile (5 ml) was stirred at 90 °C for 12 h to give a black reaction product, which was then adsorbed onto silica (particle size 100–200 mesh; 5 g) and air dried at 50 °C. The whole mass was then purified by column chromatography using light petroleum–ethyl acetate (10 : 1, v/v) as eluent to give 2-polyfluoroalkyl-4*H*-pyrimido-[2,1-*b*]benzothiazol-4-one.

Compound 8ai. Mp 156–158 °C; ν_{max}(KBr)/cm^{-1} 1690 (C=O) and 1100–1200 (CF); δ_H($CDCl_3$) 6.77 (s, 1 H), 7.61 (m, 3 H) and 9.06 (m, 1 H); δ_F($CDCl_3$) 66.6 (s, 2 F), 114.5 (s, 2 F) and 119.4 (s, 2 F); *m/z* 386 (M^+, 85.3%), 351 (M^+ − Cl, 16.1) and 223 (M^+ − CO − C_2F_4Cl, 100) (Found: C, 40.3; H, 1.3; N, 7.1; F, 29.7. $C_{13}H_5ClF_6N_2OS$ requires C, 40.4; H, 1.3; N, 7.2; F, 29.5%).

Compound 8bi. Mp 147–149 °C; ν_{max}(KBr)/cm^{-1} 1680 (C=O) and 1130–1240 (CF); δ_H($CDCl_3$) 6.79 (s, 1 H), 7.62 (m, 3 H) and 9.07 (m, 1 H); δ_F($CDCl_3$) 79.6 (s, 3 F), 116.3 (s, 2 F) and 125.4 (s, 2 F); *m/z* 370 (M^+, 100%), 351 (M^+ − F, 16.1) and 223 (M^+ − CO − C_2F_5, 88.7) (Found: C, 41.9; H, 1.3; N, 7.5; F, 36.1. $C_{13}H_5F_7N_2OS$ requires C, 42.2; H, 1.4; N, 7.8; F, 35.9%).

Compound 8di. Mp 134–136 °C; ν_{max}(KBr)/cm^{-1} 1700 (C=O) and 1140–1240 (CF); δ_H($CDCl_3$) 6.74 (s, 1 H), 7.53 (m, 2 H), 7.69 (m, 1 H) and 9.03 (m, 1 H); δ_F($CDCl_3$) 80.4 (s, 3 F), 115.4 (s, 2 F), 121.3 (s, 4 F) and 125.6 (s, 2 F); *m/z* 470 (M^+, 77.5%), 451 (M^+ − Cl, 10.3) and 223 (M^+ − CO − C_4F_9, 100) (Found: C, 38.0; H, 0.9; N, 6.0; F, 44.3. $C_{15}H_5F_{11}N_2OS$ requires C, 38.3; H, 1.1; N, 6.0; F, 44.4%).

Compound 8mi. Mp 176–177 °C; ν_{max}(KBr)/cm^{-1} 1690 (C=O) and 1100–1240 (CF); δ_H($CDCl_3$) 6.63 (s, 1 H), 7.49 (m, 2 H), 7.66 (m, 1 H) and 8.97 (m, 1 H); δ_F($CDCl_3$) 58.1 (s, 2 F); *m/z* 286 (M^+, 100%), 351 (M^+ − Cl, 26.5) and 223 (M^+ − CO − Cl, 98.9) (Found: C, 46.0; H, 1.5; N, 9.9; F, 13.3. $C_{11}H_5ClF_2N_2SO$ requires C, 46.1; H, 1.8; N, 9.8; F, 13.25%).

Compound 8aj. Mp 199–201 °C; ν_{max}(KBr)/cm^{-1} 1680 (C=O) and 1120–1200 (CF); δ_H($CDCl_3$) 2.44 (s, 3 H), 6.70 (s, 1 H), 7.30 (d, $^3J_{HH}$ 8.6, 1 H), 7.47 (s, 1 H) and 8.87 (d, $^3J_{HH}$ 8.6, 1 H); δ_F($CDCl_3$) 66.5 (s, 2 F), 114.5 (s, 2 F) and 119.4 (s, 2 F); *m/z* 400 (M^+, 68.9%), 365 (M^+ − Cl, 12.0) and 237 (M^+ − CO − C_2F_4Cl, 100) (Found: C, 41.9; H, 1.55; N, 7.0; F, 28.8. $C_{14}H_7ClF_6N_2OS$ requires C, 42.0; H, 1.8; N, 7.0; F, 28.45%).

Compound 8cj. Mp 166–168 °C; ν_{max}(KBr)/cm^{-1} 1680 (C=O) and 1100–1200 (CF); δ_H($CDCl_3$) 2.41 (s, 3 H), 6.68 (s, 1 H), 7.27 (d, $^3J_{HH}$ 8.7, 1 H), 7.44 (s, 1 H) and 8.82 (d, $^3J_{HH}$ 8.6, 1 H); δ_F($CDCl_3$) 67.3 (s, 2 F), 115.1 (s, 2 F) and 120.0 (m, 6 F); *m/z* 500 (M^+, 59.3%), 465 (M^+ − Cl, 11.6) and 237 (M^+ − CO − C_4F_8Cl, 100) (Found: C, 38.4; H, 1.2; N, 5.55; F, 38.5. $C_{16}H_7ClF_{10}N_2OS$ requires C, 38.4; H, 1.4; N, 5.6; F, 37.9%).

Compound 8mj. Mp 188–190 °C; ν_{max}(KBr)/cm^{-1} 1680 (C=O) and 1140–1240 (CF); δ_H($CDCl_3$) 2.49 (s, 3 H), 6.67 (s, 1 H), 7.31 (d, $^3J_{HH}$ 9.0, 1 H), 7.49 (s, 1 H) and 8.87 (d, $^3J_{HH}$ 8.6, 1 H); δ_F($CDCl_3$) 58.2 (s, 2 F); *m/z* 300 (M^+, 81.1%), 265 (M^+ − Cl, 22.2) and 237 (M^+ − CO − Cl, 100) (Found: C, 47.95; H, 2.0; N, 9.5; F, 12.8. $C_{12}H_7ClF_2N_2OS$ requires C, 47.9; H, 2.35; N, 9.3; F, 12.6%).

Preparation of compounds 8ak, 8dk

A mixture of 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), 2-amino-6-nitrobenzothiazole **7k** (1.5 mmol), triethylamine (5 mmol) and DMF (3 ml) was stirred at 90 °C for 12 h to give a black reaction mixture from which DMF was distilled under reduced pressure. The residue, dissolved in ethyl acetate, was adsorbed on silica (particle size 100–200 mesh; 5 g) and air dried at 50 °C. The whole mass was then purified by column chromatography using light petroleum–ethyl acetate (20 : 1, v/v) as eluent to give the products.

Compound 8ak. Mp 132–134 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1130–1180 (CF); δ_H($CDCl_3$) 6.74 (s, 1 H), 8.28 (d, $^3J_{HH}$ 8.7, 1 H), 8.53 (s, 1 H) and 9.14 (d, $^3J_{HH}$ 8.7, 1 H); δ_F($CDCl_3$) 66.6 (s, 2 F), 115.7 (s, 2 F) and 120.4 (s, 2 F); *m/z* 431 (M^+, 84.1%), 385 (M^+ − NO_2, 17.9) and 268 (M^+ − C_2F_4Cl − CO, 100) (Found: C, 36.2; H, 0.7; N, 9.9; F, 26.6. $C_{13}H_4ClF_6N_3O_3S$ requires C, 36.2; H, 0.9; N, 9.7; F, 26.4%).

Compound 8dk. Mp 150–152 °C; ν_{max}(KBr)/cm^{-1} 1690 (C=O) and 1140–1220 (CF); δ_H($CDCl_3$) 6.90 (s, 1 H), 8.46 (d, $^3J_{HH}$ 9.08, 1 H), 8.68 (s, 1 H) and 9.29 (d, $^3J_{HH}$ 9.0, 1 H); δ_F($CDCl_3$) 80.2 (s, 3 F), 115.2 (s, 2 F), 121.3 (m, 4 F) and 125.3 (s, 2 F); *m/z* 515 (M^+, 84.5%), 496 (M^+ − F, 13.0), 469 (M^+ − NO_2, 18.4) and 268 (M^+ − CO − C_4F_9, 100) (Found: C, 34.9; H, 0.6; N, 8.3; F, 40.8. $C_{15}H_4F_{11}N_3O_3S$ requires C, 34.9; H, 0.8; N, 8.2; F, 40.6%).

Synthesis of 7-polyfluoroalkyl-5*H*-thiazolo[3,2-*a*]pyrimidin-5-ones and 7-polyfluoroalkyl-7*H*-thiazolo[1,2-*a*]pyrimidin-7-ones

Typical procedure. A mixture of 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), 2-amino-1,3-thiazole **9** (1.5 mmol), triethylamine (5 mmol) and acetonitrile (5 ml) was stirred at 90 °C for 50 h to give a black reaction product, which was then adsorbed onto silica (particle size 100–200 mesh; 5 g) and air dried at 50 °C. The whole mass was then purified by column chromatography using light petroleum–ethyl acetate (8 : 1, v/v) as eluent to give 7-polyfluoroalkyl-5*H*-thiazolo-[3,2-*a*]pyrimidin-5-ones. After that, elution first with light petroleum–ethyl acetate (2 : 1, v/v) gave the excess of 2-amino-1,3,4-thiadiazole **9**, and then with light petroleum–ethyl acetate (1 : 1) gave 5-polyfluoroalkyl-7*H*-thiazolo[1,2-*a*]pyrimidin-7-ones.

Compound 10a. Mp 63–65 °C; ν_{max}(KBr)/cm^{-1} 1710 (C=O) and 1100–1200 (CF); δ_H($CDCl_3$) 6.62 (s, 1 H), 7.16 (d, $^3J_{HH}$ 4.9, 1 H) and 8.01 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 66.5 (s, 2 F), 114.0 (s, 2 F) and 119.3 (s, 2 F); *m/z* 336 (M^+, 75.1%), 301 (M^+ − Cl, 20.0) and 173 (M^+ − CO − C_2F_4Cl, 100) (Found: C, 32.4; H, 0.9; N, 8.3; F, 34.0. $C_9H_3ClF_6N_2OS$ requires C, 32.1; H, 0.9; N, 8.3; F, 33.9%).

Compound 11a. Mp 138–140 °C; ν_{max}(KBr)/cm^{-1} 1650 (C=O) and 1130–1190 (CF); δ_H($CDCl_3$) 6.63 (s, 1 H), 7.09 (d, $^3J_{HH}$ 4.9, 1 H) and 7.37 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 66.7 (s, 2 F), 110.9 (s, 2 F) and 118.3 (s, 2 F); *m/z* 336 (M^+, 45.7%), 301 (M^+ − Cl, 14.4) and 173 (M^+ − CO − C_2F_4Cl, 100) (Found: C, 32.0; H, 0.85; N, 8.4; F, 33.75. $C_9H_3ClF_6N_2OS$ requires C, 32.1; H, 0.9; N, 8.3; F, 33.9%).

Compound 10b. Mp 54–56 °C; ν_{max}(KBr)/cm^{-1} 1700 (C=O) and 1130–1240 (CF); δ_H($CDCl_3$) 6.63 (s, 1 H), 7.15 (d, $^3J_{HH}$ 4.9, 1 H) and 8.02 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 80.1 (s, 3 F), 116.1 (s, 2 F) and 125.6 (s, 2 F); *m/z* 320 (M^+, 100%), 301 (M^+ − F, 12.8) and 173 (M^+ − CO − C_2F_5, 82.5) (Found: C, 33.7; H, 0.95; N, 9.05; F, 42.4. $C_9H_3F_7N_2OS$ requires C, 33.8; H, 0.9; N, 8.75; F, 41.5%).

Compound 11b. Mp 181–183 °C; ν_{max}(KBr)/cm^{-1} 1650 (C=O) and 1130–1240 (CF); δ_H($CDCl_3$) 6.71 (s, 1 H), 6.96 (d, $^3J_{HH}$ 4.9, 1 H) and 7.38 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 79.4 (s, 3 F), 112.3 (s, 2 F) and 124.1 (s, 2 F); *m/z* 320 (M^+, 78.0%), 301 ($M^+ - F$, 8.8) and 173 ($M^+ - CO - C_2F_5$, 100) (Found: C, 33.8; H, 0.8; N, 8.9; F, 40.9. $C_9H_3F_7N_2OS$ requires C, 33.8; H, 0.9; N, 8.75; F, 41.5%).

Compound 10m. Mp 47–49 °C; ν_{max}(KBr)/cm^{-1} 1700 (C=O) and 1130–1230 (C−F); δ_H($CDCl_3$) 6.60 (s, 1 H), 7.20 (d, $^3J_{HH}$ 4.9, 1 H) and 8.03 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 58.0 (s, 2 F); *m/z* 236 (M^+, 82.4%), 201 ($M^+ - Cl$, 36.5) and 173 ($M^+ - CO - Cl$, 100) (Found: C, 35.2; H, 6.9; N, 12.2; F, 16.6. $C_7H_3ClF_2N_2OS$ requires C, 35.5; H, 1.3; N, 11.8; F, 16.1%).

Compound 11m. Mp 159–161 °C; ν_{max}(KBr)/cm^{-1} 1640 (C=O) and 1100–1200 (C−F); δ_H($CDCl_3$) 6.65 (s, 1 H), 7.23 (d, $^3J_{HH}$ 4.9, 1 H) and 7.54 (d, $^3J_{HH}$ 4.9, 1 H); δ_F($CDCl_3$) 56.3 (s, 2 F); *m/z* 236 (M^+, 64.7%) and 173 ($M^+ - CO - Cl$, 100) (Found: C, 35.9; H, 1.3; N, 11.8; F, 16.5. $C_7H_3ClF_2N_2OS$ requires C, 35.5; H, 1.3; N, 11.8; F, 16.1%).

Synthesis of 2-polyfluoroalkyl[1,3]thiazino[3,2-*a*]benzimidazol-4-ones

A mixture of 2-hydropolyfluoroalk-2-enoate **1** (1 mmol), 2-mercaptobenzimidazole **12** (1.5 mmol), $NaHCO_3$ (5 mmol) and acetonitrile (5 ml) was stirred at 50 °C for 6 h, and then at 90 °C for 10 h with continued stirring to give a brown reaction product. After cooling to room temperature, the reaction mixture was extracted with ethyl acetate. The extract was washed with saturated brine, dried (Na_2SO_4) and evaporated. The resulting residue was purified by column chromatography using light petroleum–ethyl acetate (10 : 1) as eluent to give 2-polyfluoroalkyl[1,3]thiazino[3,2-*a*]benzimidazol-4-one **14** (78%).

Compound 14c. Mp 148–150 °C; ν_{max}(KBr)/cm^{-1} 1690 (C=O) and 1120–1240 (C−F); δ_H($CDCl_3$) 7.06 (s, 1 H), 7.48 (m, 2 H), 7.81 (m, 1 H) and 8.52 (m, 1 H); δ_F($CDCl_3$) 67.6 (s, 2 F), 109.2 (s, 2 F) and 119.4 (m, 6 F); *m/z* 486 (M^+, 100%), 451 ($M^+ - Cl$, 14.5), 251 ($M^+ - C_4F_8Cl$, 6.6) and 223 ($M^+ - CO - C_4F_8Cl$, 55.6) (Found: C, 36.9; H, 0.9; N, 5.5; F, 38.2. $C_{15}H_5ClF_{10}N_2OS$ requires C, 37.0; H, 1.0; N, 5.8; F, 39.0%).

Acknowledgements

We thank Dr K. von Werner of Hoechst AG Werk Gendorf, Germany, for the gift of perfluoroalkyl iodide 612 and Professor H.-M. Wu and Dr Shao-Kai Jiang of our Institute for the measurement and interpretation of the 600 MHz ^{1}H NMR and ^{13}C NMR spectra of compound **5a′e**.

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Paper 6/03071H
Received 1*st January* 1996
Accepted 5*th November* 1996