

# Synthesis of polyfluorinated ketones *via* the ate-complexes

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Asymmetric polyfluorinated ketones  $R^F\text{COR}$  are formed by treating various derivatives of (polyfluoro)alkanoic acids (esters, anhydrides, acid chlorides) with lithium tetraalkylaluminates ("ate-complexes"). The highest yields of the ketones (65–78 %) were obtained from (polyfluoro)alkanoyl chlorides.

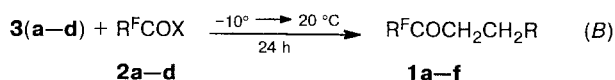
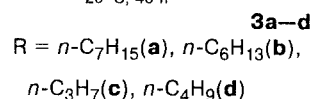
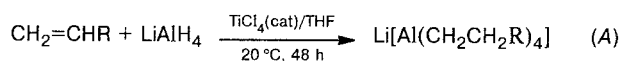
**Key words:** fluorinated ketones, synthesis; lithium tetraalkylaluminates, reaction with (polyfluoro)alkanoyl chlorides.

Fluorinated ketones are used as fire-resistant solvents for polymers as well as synthons for obtaining biologically active compounds and thermo-, light-, and chemically stable polymers. Traditionally, ketones of the  $R^F\text{COR}$  type are obtained by treating fluorocarboxylic acids or their derivatives (esters, nitriles, acid halides) with organomagnesium and organolithium compounds.<sup>1</sup> Surprisingly, the much more available organoaluminum compounds have not been utilized for this purpose. Moreover, the records of their use for the synthesis of organofluorine compounds are rather scarce.<sup>2,3</sup>

We have elaborated an efficient method for the synthesis of nonsymmetric ketones of the general formula  $R^F\text{COCH}_2\text{CH}_2\text{R}$  (**1a–f**) by treating the derivatives of (polyfluoro)alkanoic acids of the general formula  $R^F\text{COX}$  (**2a–d**, X = Cl, MeO or EtO, 4- $\text{NO}_2\text{C}_6\text{H}_4\text{O}$ ,  $\text{CF}_3\text{COO}$ ) with lithium tetraalkylaluminates ("ate-complexes") of general type **3**. The latter are readily formed from terminal alkenes and  $\text{LiAlH}_4$  in the presence of a  $\text{TiCl}_4$  catalyst (Scheme 1, A). The reaction is easy to perform and, unlike most reactions involving organoaluminum compounds, does not require that the synthesis be performed under a stream of argon.

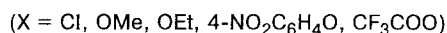
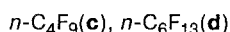
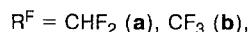
The reactions of fluorine-substituted substrates (**2a–d**) (X = Cl, OMe, OEt, 4- $\text{NO}_2\text{C}_6\text{H}_4\text{O}$ ,  $\text{CF}_3\text{COO}$ ) with ate-complexes **3a–d** result exclusively in asymmetric ketones **1a–f** (Scheme 1, B; Tables 1 and 2), the yield of which strongly depends on the reactivity of the carbonyl component, *i.e.*, on the nature of the ligand X in compounds **2a–d**. When X = OMe or OEt, the yields of compounds **1a–d** are as small as 7–10 %. If *p*-nitrophenyl fluorocarboxylates are used, the yields of compounds **1a–f** increase significantly, but these substrates tend to decompose on storage. The anhydrides (X =  $\text{CF}_3\text{COO}$ ) react satisfactorily, but a sixfold excess of these compounds with respect to **3** is required. The best yields of fluoroketones are attained using the

Scheme 1



**2a–d**

**1a–f**



acid chlorides, **2a–d** (X = Cl), at a molar ratio ate-complex : acid chloride = 1 : 3.

Tables 1 and 2 present the parameters of the hitherto unknown products synthesized in this work.

## Experimental

IR spectra were recorded on a Specord-75 IR spectrophotometer in a 5 mm-thick layer.  $^1\text{H}$  NMR spectra were recorded on a Tesla BS-567A spectrometer (100 MHz) using  $\text{Me}_4\text{Si}$  as the internal standard. Elemental analysis data are in accordance with the structures presented.

**Preparation of ate-complexes (general procedure).** 1-Nonene (56 g, 0.48 mol) and  $\text{TiCl}_4$  (0.5 g, 3.7 mmol) were added dropwise with stirring to a suspension of  $\text{LiAlH}_4$  (4.7 g, 0.12 mol) in THF (200 mL) in such a way that the temperature did not exceed 40 °C. The mixture was kept for one day at ~20 °C and then used in reactions with derivatives of fluorocarboxylic acids.

**Synthesis of fluoro-substituted ketones. Method 1.** The reaction of perfluorovaleroyl chloride with lithium tetraoctylaluminate (**3b**).

**Table 1.** Yields and characteristics of asymmetric polyfluorinated ketones **1**

Compound	R <sup>F</sup>	R	Method of synthesis	Yield (%)	B.p./°C (p/Torr)
1,1-Difluoro-2-undecanone ( <b>1a</b> )	HCF <sub>2</sub>	C <sub>7</sub> H <sub>15</sub>	1	73	94–95 (34)
1,1,1-Trifluoro-2-decanone ( <b>1b</b> )	HF <sub>3</sub>	C <sub>6</sub> H <sub>13</sub>	1	65	96–97 (41)
1,1,1,2,2,3,3,4,4-Nonafluoro-5-decanone ( <b>1c</b> )	C <sub>4</sub> F <sub>9</sub>	C <sub>3</sub> H <sub>7</sub>	1	68	81–82 (50)
1,1,1,2,2,3,3,4,4-Nonafluoro-5-undecanone ( <b>1d</b> )	C <sub>4</sub> F <sub>9</sub>	C <sub>4</sub> H <sub>9</sub>	1	76	92–93 (45)
1,1,1,2,2,3,3,4,4-Nonafluoro-5-tridecanone ( <b>1e</b> )	C <sub>4</sub> F <sub>9</sub>	C <sub>6</sub> H <sub>13</sub>	3	42	111–112 (23)
1,1,1,2,2,3,3,4,4,5,5,6,6-Tridecafluoro-7-pentadecanone ( <b>1f</b> )	C <sub>6</sub> F <sub>13</sub>	C <sub>6</sub> H <sub>13</sub>	1	72	110–111 (7)

**Table 2.** Spectroscopic characteristics of polyfluorinated ketones **1**

Ketone	IR, $\nu/\text{cm}^{-1}$	<sup>1</sup> H NMR, $\delta$ (J/Hz)
<b>1a</b>	1755	0.88 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 6.0$ ); 1.2–1.36 (m, 12 H, (CH <sub>2</sub> ) <sub>6</sub> ); 1.46–1.80 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.64 (t, 2 H, COCH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 7.0$ )
<b>1b</b>	1765	0.70 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 6.1$ ); 0.92–1.18 (m, 10 H, (CH <sub>2</sub> ) <sub>5</sub> ); 1.26–1.54 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.71 (t, 2 H, COCH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 6.8$ )
<b>1c</b>	1760	0.85 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 6.0$ ); 0.90–1.19 (m, 6 H, (CH <sub>2</sub> ) <sub>3</sub> ); 1.35–1.68 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.70 (t, 2 H, COCH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 6.8$ )
<b>1d</b>	1757	0.91 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 5.4$ ); 1.26–1.48 (m, 6 H, (CH <sub>2</sub> ) <sub>3</sub> ); 1.57–1.84 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.76 (t, 2 H, COCH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 6.8$ )
<b>1e</b>	1750	0.89 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 5.4$ ); 1.24–1.50 (m, 10 H, (CH <sub>2</sub> ) <sub>5</sub> ); 1.56–1.84 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.75 (t, 2 H, COCH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 6.8$ )
<b>1f</b>	1755	0.92 (t, 3 H, CH <sub>3</sub> , $J_{\text{CH}_3\text{CH}_2} = 5.4$ ); 1.76–1.44 (m, 10 H, (CH <sub>2</sub> ) <sub>5</sub> ); 1.56–1.86 (m, 2 H, COCH <sub>2</sub> CH <sub>2</sub> ); 2.75 (t, 2 H, CH <sub>2</sub> , $J_{\text{CH}_2\text{CH}_2} = 7.0$ )

Perfluorovaleroyl chloride (**2c**, X = Cl) (102 g, 0.36 mol) was added at –10 °C with stirring to the ate-complex **3b** (R =

C<sub>6</sub>H<sub>13</sub>) obtained by the above procedure. The mixture was kept for one day at ~20 °C, then cooled to 0 °C. Water and 20 % aqueous H<sub>2</sub>SO<sub>4</sub> were added dropwise until the inorganic salts dissolved. The mixture was extracted with ether and the extract was dried with MgSO<sub>4</sub> and concentrated, after which the product **1e** was isolated by distillation *in vacuo*.

**Method 2.** Reaction of trifluoroacetic anhydride with lithium tetraoctylaluminate. Trifluoroacetic anhydride (**2b**, X = OCOF<sub>3</sub>) (75.6 g, 0.36 mol) was added dropwise at –20 °C to a stirred solution of the ate-complex **3b** obtained from LiAlH<sub>4</sub> (2.28 g, 0.06 mol), 1-octene (28 g, 0.25 mol), and TiCl<sub>4</sub> (0.25 g, 1.85 mmol). The mixture was kept for one day at ~20 °C and worked up according to method 1 to give ketone **1b**.

**Method 3.** Reaction of *p*-nitrophenyl perfluorovalerate with Li[AlOct<sub>4</sub>]. *p*-Nitrophenyl ester **2c** (X = 4-NO<sub>2</sub>C<sub>6</sub>H<sub>4</sub>O) (69.3 g, 0.18 mol) was added dropwise at –5 °C with stirring to a solution of the ate-complex **3b** obtained as described above. The mixture was kept for one day at –20 °C and worked up as above. Ketone **1e** was isolated according to method 1.

**Method 4.** Reaction of **3b** with ethyl perfluorovalerate. Ester **2c** (X = OEt) (52.5 g, 0.18 mol) was added dropwise at ~20 °C to a stirred solution of the ate-complex **3b** obtained as described above. The mixture was refluxed for 3 h. Subsequent work-up and isolation of ketone **1e** were carried out according to method 1.

## References

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Received October 28, 1993