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# Evaluation of Zard trifluoromethylketone synthesis for the preparation of potential bifunctional fluorinated synthons

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**Abstract**

In the quest for potential bifunctional fluorinated synthons, we examined the behavior of chlorodifluoroacetic and hexafluoroglutaric anhydride in their reaction with acid chlorides in the presence of pyridine under the conditions of Zard trifluoromethylketone synthesis. Chlorodifluoroacetic anhydride led easily to the expected chlorodifluoromethyl ketones in the case of relatively non-encumbered primary acid chlorides. In the case of hexafluoroglutaric anhydride we observed the unexpected formation of α substituted hexafluorocyclohexane-1,3-dione derivatives among with the corresponding fluorinated 3-chloro-cyclohexenones.


*Keywords:* Chlorodifluoroacetic anhydride; Hexafluoroglutaric anhydride; Chlorodifluoromethyl ketones; Hexafluorocyclohexane-1,3-diones; 3-Chloro-hexafluorocyclohexenones

## 1. Introduction

Fluorinated bifunctional synthons of the type X-$(CF_2)_n$-Y are very useful intermediates in widely different areas like biochemistry, catalysis or material science. Their interest is dependent on their chain length. Thus, the first terms of this series ($n = 1$) have gained great importance for the introduction of the difluoromethylene unit into bioactive molecules as an isostere of the ethereal oxygen atom [1]. With the development of fluorous chemistry, there is a growing demand from non-fluorine specialized laboratories, for ready to use long chains compounds (typically $n = 3$–8), bearing fluorinated synthons [2]. In this area, after an extensive exploitation of simple perfluoroalkylated chains, the demand seems now to shift towards more elaborated synthons, and more specifically to easily functionalizable (in the sense of common organic chemistry) unsymmetrical ones. Fluorinated materials to achieve this goal may be derived from perfluoroalkyl compounds obtained by the telomerization of tetrafluoroethylene, either with diiodine (α,ω-diiodoperfluoroalkanes) [3] or with methanol (1H, 1H, ωH-perfluorinated alcohols) [4]. Attention was also given to the desymmetrization of α,ω-perfluorinated diacids or their derivatives [5].

Some years ago, Zard and co-workers described a very convenient synthesis of trifluoromethyl ketones by the reaction of nucleophilic ketene species, generated from acid chlorides, with trifluoroacetic anhydride [6]. This methodology enjoyed a great success for the trifluoromethylation of various acidic substrates [7]. To our knowledge, this reaction has seldom been used for the introduction of fluorinated groups differing from trifluoromethyl [8].

In this context, we examined the behavior of two readily and commercially available fluorinated anhydrides in this reaction. On one hand, chlorodifluoroacetic anhydride was expected to lead to chlorodifluoroketones as potential difluoromethylene synthons. On the other hand, hexafluoroglutaric anhydride was thought to be a convenient precursor for the preparation of unsymmetrical bifunctional hexafluorinated chains, amenable to further chemical elaborations. We present here our results concerning these two fluorinated anhydrides.

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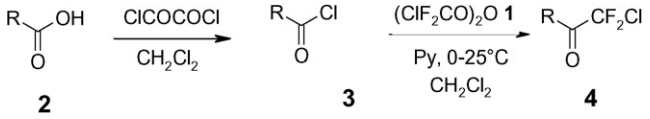
Table 1
The reaction of chlorodifluoroacetic anhydride **1** with acid chlorides in the presence of pyridine

| entry | | R | Yield[a] (%) of **4** |
|---|---|---|---|
| 1 | **4a** | $PhCH_2CH_2CH_2$ | 80 |
| 2 | **4b–c** | $CH_3(CH_2)_n$[b] | 60–79 |
| 3 | **4d** | $CH_3CHPhCH_2$ | <5 |
| 4 | **4e** | Cyclohexyl | 0 |
| 5 | **4f** | $PhCH_2$ | 0[c] |
| 6 | **4g** | $Menthylch_2$ | 0 |

[a] Isolated yields.
[b] $n = 8, 14$.
[c] Reaction performed at 20, 0 or −30 °C.




Scheme 1.

## 2. Results and discussion

### 2.1. Reactions of chlorodifluoroacetic anhydride

We are aware of only one report suggesting the use of chlorodifluoroacetic anhydride **1** for the synthesis of a chlorodifluoromethyl ketone in the arachidonic acid series [8a]. However, the scope of this reaction was not fully explored. In our hands, under the conditions described by Zard [6a], the reaction of chlorodifluoroacetic anhydride with simple primary aliphatic acids **2** (Table 1, entries 1 and 2) was straightforward and gave easy access to α-chlorodifluoromethyl ketones **4** in satisfactory isolated yields (Scheme 1). As was observed with trifluoroacetic anhydride, no reaction occurs with secondary aliphatic acids (Table 1, entry 4). Moreover, branching at the β-carbon of the acid function was deleterious to the outcome of the reaction (Table 1, entries 3, 5 and 6) [6a,b].

In a reappraisal of Zard's method, a Boehringer group recently showed that the reaction of trifluoroacetic anhydride with secondary acids was possible, provided that the reaction was run in toluene [9]. We also tried this modified protocol with chlorodifluoroacetic anhydride. In the present case, we observed considerable darkening of the reaction medium with apparent decomposition of the anhydride before any useful reaction occurs with the intermediate ketene. It seems thus that, to date, this methodology could be applied only for the preparation of primary and relatively unhindered chlorodifluoromethyl ketones. As pointed out very recently by Percy, the synthesis of this kind of aliphatic chlorodifluoromethyl ketones by the organometallic route is by no means a trivial task, stressing thus the interest of the present study [10].

Table 2
The reaction of hexafluoroglutaryl anhydride **4** with acid chlorides

| Entry | R in **5** | Ratio **8**:**9** | Isolated yield (%) |
|---|---|---|---|
| 1 | **a** $PhCH_2CH_2$ | 0:100 | 84 |
| 2 | **b** $CH_3(CH_2)_7$ | 50:50–20:80 | 30–55 |
| 3 | **c** $CH_3(CH_2)_9$ | 50:50–0:100 | 79 |

#### 2.1.1. Reactions of hexafluoroglutaric anhydride

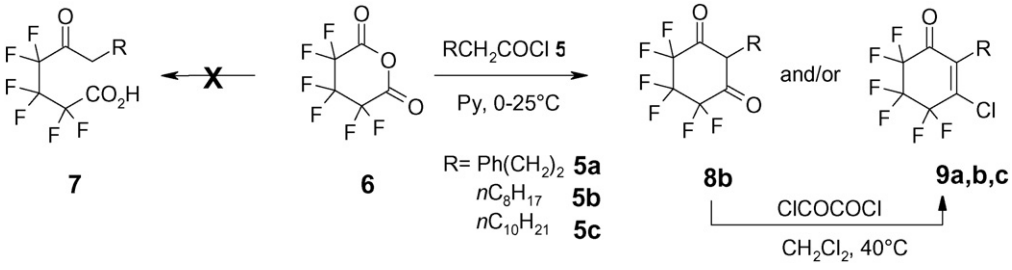
Based on the mechanism proposed for the formation of trifluoromethyl ketones [6a], we initially thought that the reaction of a hexafluoroglutaric anhydride **6** with acid chlorides under the conditions of Zard's reaction could lead to an open chain dissymmetric fluorinated acid **7** (Scheme 2).

Unexpectedly, instead of acid **7**, we observed either the exclusive formation of **9a** with 4-phenylpropanoic acid chloride, or the formation of the symmetrical fluorinated β-diketones **8b–c** accompanied by the 3-chlorocyclohexenones **9b–c** when we used a long alkyl chain acid chloride as the chosen starting material (Table 2).

Due to the similar polarities of **8** and **9**, we were not able to completely separate the two compounds by chromatography; only a small amount of pure chloroketone **9b** could be isolated by this technique. The formation of a precipitate in the reaction mixture in these particular cases explains perhaps the difference in reactivity observed between **5a** and **5b–c**. We did not obtain significant modification of the proportion of the two compounds in different solvents (dichloromethane, toluene) but it was possible to reduce the proportion of **8b** from 50% to 20% with a long reaction time (6–36 h for **9b**) and to complete conversion in 72 h (**9c**). However, the mixture of diketones **8b–c** with chloroketones **9b–c**, could be easily totally converted to chloroketones **9b–c** by oxalyl chloride [11] giving some evidence for the prior formation of **8** over **9** in the reaction medium.

#### 2.1.2. Structure determination

The determination of the structures assigned to compounds **8** and **9**, relied on the micro analytical analysis results as well as their mass spectrometric analysis, which confirm the presence




Scheme 2.

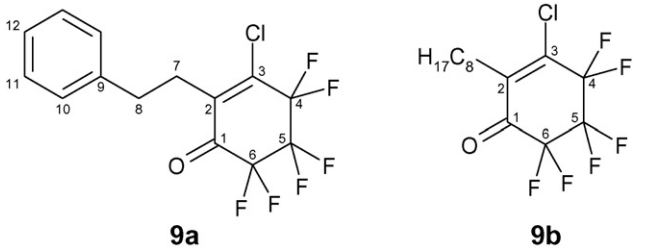



Fig. 1. NMR numbering for compounds **9a** and **9b**.

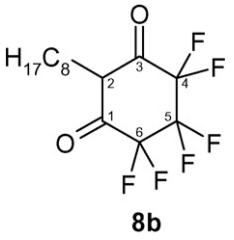
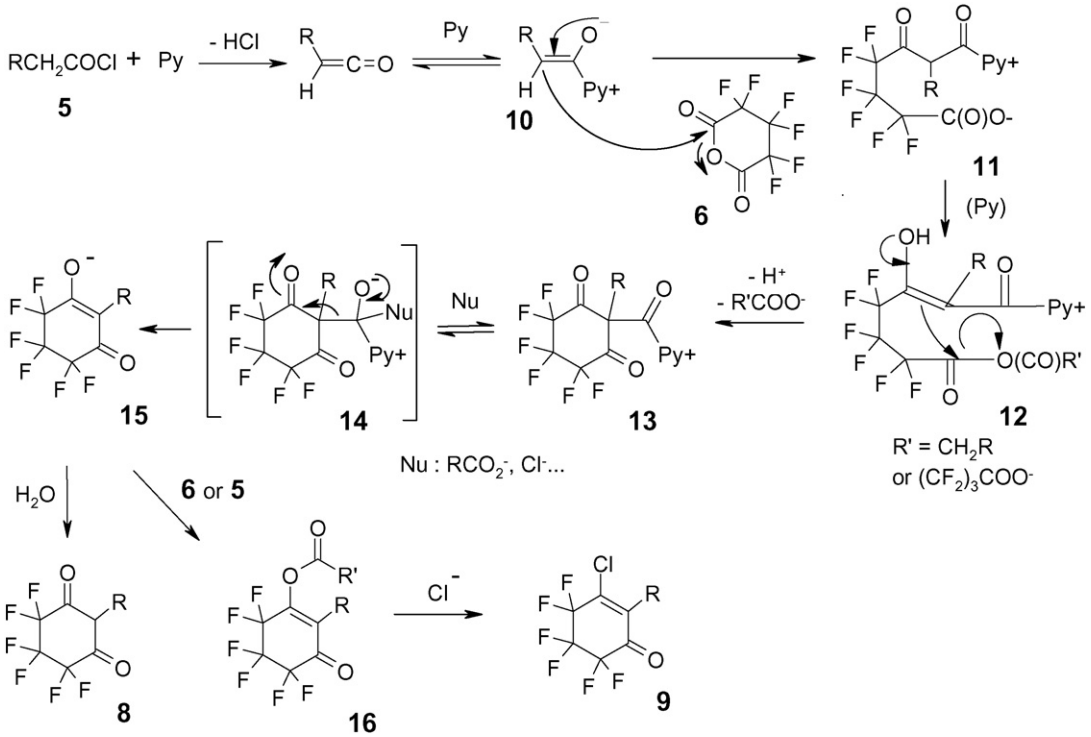



Fig. 2. NMR numbering for compound **8b**.

of a chlorine atom for **9**. All the structures proposed were also consistent with the observed spectral data.

*2.1.2.1. Structure of the chloroenones **9**.* For the molecule **9a**, we observed three signals in the $^{19}$F NMR spectrum, one for each $CF_2$, which suggests a non symmetrical structure as expected for **7** but the presence of a chlorine atom revealed by the mass spectrometry invalidates this structure. The $^{1}$H NMR spectra showed the signals for the phenyl group and only two triplets for two methylene groups. The third methylene group present in the starting materials had thus disappeared. The analysis of the $^{13}$C NMR spectra gave more information; the presence of a phenyl group and only two methylene groups was confirmed. Moreover, we observed one carbonyl signal at 178 ppm and two ethylenic carbons at 141 and 143 ppm. The loss of these signals in DEPT, as well as the 2D NMR HETCOR experiments demonstrated the absence of proton linked to these two carbon atoms. The same coupling pattern was found for the carbonyl and the second ethylenic signal: triplet of triplets for a $^{2}J_{CF}$ (27 Hz) and a $^{3}J_{CF}$ (3 Hz). The carbonyl atom $C_1$ and one of the ethylenic carbons $C_3$ at 143 ppm are vicinal to a difluoromethylene which (as shown by the presence of $^{2}J_{CF}$ and $^{3}J_{CF}$) suggests a cyclic structure like in **9** (Fig. 1). The first ethylenic signal at 141 ppm appears as a triplet with only one coupling constant $^{3}J_{C2F}$ (3 Hz). This ethylenic carbon $C_2$ three bonds away from the fluorine atoms is thus located between $C_1$ and $C_3$. The signal of one of the two methylene groups shows a very low coupling constant with the fluorine atoms ($< 1$ Hz) which can be tentatively attributed to a $^{4}J_{CF}$ and then to the $C_7$ methylene carbon. For the other compound **9b**, we obtained similar data for the new cycle formed with three signals for the three difluoromethylene groups and the disappearance of the proton of one methylene on the $C_2$ carbon atom.

*2.1.2.2. Structure of the diketone **8b**.* With a long alkyl chain in place of the 3-phenylpropyl group for the substrate **5**, we observe as well as **9b** the formation of another compound **8b**. In this case, a symmetrical structure is suggested by the presence of only two signals in the $^{19}$F NMR spectrum for the three difluoromethylene groups at 121 and 134 ppm. In the $^{1}$H NMR




Scheme 3.

spectrum we obtain the characteristic system for a long carbon chain with an additional triplet signal at 2.8 ppm integrating for only one proton and a multiplet for a methylene group at 2.4 ppm when compared to the $^{1}H$ NMR spectrum of **9b**. Connected with the mass spectral data, these results were compatible with the symmetrical diketone **8a** (Fig. 2). This compound was not isolated, but analyzed within the mixture with the chloroketone.

#### 2.1.3. Mechanism of the reaction

Based on current knowledge [6], the formation of the diketone **9** during this reaction may be tentatively explained by initial nucleophilic attack of the betaine species **10** (resulting from ketene formation induced by pyridine from the acid chloride **5**), on hexafluoroglutaric anhydride **6**. We initially expected that the reaction would stop at the stage of the carboxylate intermediate **11** so formed (Scheme 3). The following steps of this reaction are far from trivial. The observed transformation of **11** to a cyclohexanedione skeleton may be foreseen by further activation of the carboxylate group in **11** to **12** in the form of a mixed anhydride by reaction with either an excess of anhydride **6** or acid chloride **5** [12]. Ensuing intramolecular cyclisation occurring *via* the enol form of the remaining carbonyl group in **12** should lead to intermediate **13**. The addition of a nucleophilic species (such as chloride, carboxylate, etc.) on the carbonyl pyridinium function may lead to the intermediate **14** which can either evolve back to **13** or lead to **15**. Once enolate **15** is obtained, the introduction of the chlorine atom can be explained by a mechanism similar to the chlorination of β-diketones described by Heathcock et al. [11]: formation of an enol-ester **16** from the enolate with **5** or **6** which is displaced by a chloride ion to afford **9**. The low solubility of one of the intermediates **13** or **15** in the reaction medium as it was observed experimentally with the formation of a precipitate, should stop this last reaction and explain the presence of **8** after hydrolysis for some of our substrates.

Use of the conditions described by Reeves et al. (reflux of toluene with acid as starting materials) [9] to avoid the presence of chloride ions in the reaction mixture did not give the expected result. The direct transformation of the acid **5** into the β-diketone **8** was not observed. The anhydride **6** showed a total lack of reactivity under these particular conditions.

## 3. Conclusions

We have shown that the synthesis of relatively unhindered chlorodifluoromethyl ketones using the reaction of chlorodifluoroacetic anhydride with acid chlorides in the presence of pyridine is a viable alternative to the organometallic pathway. Under these reaction conditions hexafluoroglutaric anhydride leads to the unexpected formation of hexafluorocyclohexane-1, 3-dione and or fluorinated 3-chloro-cyclohex-2-enones. The chemistry of these new compounds is currently under investigation [15].

## 4. Experimental

### 4.1. General

Each reaction was carried out under an argon atmosphere in a freshly distilled solvent, unless otherwise noted. Dichloromethane was distilled from calcium hydride. Pyridine was distilled and stored under argon. Reactions were monitored by thin-layer chromatography on silica gel 60 $F_{254}$, or by $^{19}F$ NMR spectroscopy. Unless otherwise noted, yields refer to materials purified by column chromatography or distillation under reduced pressure.

NMR spectra were recorded on a Bruker AC-300 spectrometer. Reported coupling constants and chemicals shifts were based on a first order analysis. Internal reference was the residual peak of $CHCl_3$ (7.27 ppm) for $^{1}H$ (300 MHz), central peak of $CDCl_3$ (77 ppm) for $^{13}C$ (75 MHz) spectra and internal $CFCl_3$ (0 ppm) for $^{19}F$ (282 MHz) NMR spectra. Melting points were determined on a Mettler FP61 melting point apparatus. IR spectra were recorded on a Nicolet Impact 400D. Low-resolution mass spectra were recorded on a HP MS 5989B spectrometer. Elemental analyses were carried out at ICSN (Gif-sur-Yvette). Silica gel from Merck (Kieselgel 60 ACC, 35–70 or 70–200 mesh) was used for column chromatography.

### 4.2. General procedure

#### 4.2.1. General procedure for the synthesis of chlorodifluoroketone

To a solution of acid (1.15 mmol) in anhydrous dichloromethane was added oxalyl chloride (0.15 mL, 1.37 mmol) and the reaction mixture was stirred at room temperature for 2 h. Then solvent and an excess of oxalyl chloride were removed off under reduced pressure. The remaining oil was diluted in anhydrous dichloromethane (20 mL) with chlorodifluoroanhydride (1 mL, 5.7 mmol) and cooled at 0 °C. Pyridine was slowly added (0.6 mL, 6.8 mmol), the cooling bath was removed and the reaction was monitored by $^{19}F$ NMR. After 1–4 h, a solution of hydrochloric acid 1 M was cautiously added and the reaction mixture was extracted successively with dichloromethane (3 × 20 mL), the organic phase was washed with brine, dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude oil was purified by silica gel chromatography, (pentane to pentane/ether: 9/1 depending on the substrate).

#### 4.2.2. General procedure for the synthesis of chlorohexafluorocyclohex-2-enone

To a solution of acid (2.5 mmol) in anhydrous dichloromethane was added oxalyl chloride (0.25 mL, 2.9 mmol) and the reaction mixture was stirred at room temperature for 2 h. Then solvent and excess of oxalyl chloride were removed under vacuum. The remaining oil was diluted in dry dichloromethane (20 mL) and cooled at 0 °C with hexafluorochloroanhydride (1 mL, 7.44 mmol). Pyridine was slowly added (1.2 mL, 13.6 mmol), the cooling bath was removed and the reaction was monitored by $^{19}F$ NMR. A solution of hydrochloric acid 1 M was cautiously added and the reaction mixture was

extracted with dichloromethane (3 × 20 mL), washed by a solution of sodium chloride. The organic layer was dried over $MgSO_4$, filtered and concentrated *in vacuo*. The crude residue was purified by silica gel chromatography, (pentane/ether: 9/1).

When the substrate is an alkyl acid, the extracted reaction mixture was mixed with oxalyl chloride (0.5 mL, 5.8 mmol, 2 equiv) at 40 °C for 2 h and the cooled reaction mixture was hydrolyzed, extracted and purified with the usual work up.

### 4.3. Analytical description

#### 4.3.1. 1-Chloro-1,1-difluoro-5-phenylpentan-2-one (**4a**)[13]

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −68.7 (s, $-CF_2Cl$); $^1H$ RMN $\delta$ (ppm): 1.9 (quint., 2H,–$CH_2$–C$\underline{H_2}$–$CH_2$, $^3J_{H-H}$ = 6.9 Hz); 2.6 (t, 2H, –$CH_2$–$CH_2$–C$\underline{H_2}$, $^3J_{H-H}$ = 7.9 Hz); 2.7 (t, 2H, –C$\underline{H_2}$–$CH_2$–$CH_2$, $^3J_{H-H}$ = 7.5 Hz); 7.2 (m, 5H, Ph.); $^{13}C$ RMN $\delta$ (ppm): 24.4 ($C_4$); 34.3–34.6 ($C_3$, $C_5$); 119.8 (t,–$CF_2Cl$, $^1J_{CF}$ = 306.0 Hz); 126.3 ($C_9$); 128.5–128.6 (4C, $C_7$, $C_8$); 140.7 ($C_6$); 191.8 (t, $C_2$, $^2J_{C-F}$ = 29.0 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 3091 ($\nu_{CHsp2}$); 2934; 2858; 1757 ($\nu_{CO}$); 1444; 1152 ($\nu_{C-C}$); 1065; 912; 686; MS (GC/CI $CH_4$) *m/z* (%): 273/275 ($M^+ + C_2H_5$, 5); 233/235 ($MH^+$, 5); 215/217 ($MH^+-H_2O$, 100); 147 ($M^+-CF_2Cl$, 5); 104 (6); 91(4); Anal.: calc. for $C_{11}H_{11}OF_2Cl$ (232.65): C, 56.8; H, 4.8; found: C, 57.2; H, 5.1.

#### 4.3.2. 1-chloro-1,1-difluoro-undecan-2-one (**4b**)

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −68.8 (s, 2F); $^1H$ RMN $\delta$ (ppm): 0.89 (t, 3H, $CH_3$); 1.27 (s, 12H, $6CH_2$); 1.65 (m, 2H, H for $C_\beta$); 2.75 (t, 2H, H for $C_\alpha$); $^{13}C$ RMN $\delta$ (ppm): 14. ($C_{11}$); 22.6; 28.7; 29.1; 29.2; 29.6; 31.7 ($C_5$–$C_{10}$); 22.8 ($C_4$); 35.12 ($C_3$); 119.9 (t, $C_1$, $^1J_{C-F}$ = 306.0 Hz); 192 (t, $C_2$ = O, $^2J_{C-F}$ = 29.5 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 2929 ($\nu_{CHsp3}$); 2847; 1787 ($\nu_{CO}$); 1178 ($\nu_{C-C}$); MS (GC/CI $CH_4$) *m/z* (%): 155 ($M^+-CF_2Cl$, 50); 185–187 ($M^+-C_4H_7$, 35); 199 ($M^+-C_3H_6$, 29); 221–223 ($MH^+-HF$, 15); 241 ($MH^+$, 100); 243 ($MH^+$, 30); 269 ($M^+-C_2H_5$, 13); Anal.: calc. for $C_{11}H_{19}OF_2Cl$ (240.71): C, 54.9; H, 7.95; found: C, 54.3; H, 7.6.

#### 4.3.3. 1-Chloro-1,1-difluoro-heptadecan-2-one (**4c**)[14]

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −68.8 (s, 2F); $^1H$ RMN $\delta$ (ppm): 0.89 (t, 3H, $CH_3$); 1.27 (m, 24H, $12CH_2$); 1.69 (m, 2H, H for $C_\beta$); 2.75 (t, 2H, H for $C_\alpha$); $^{13}C$ RMN (ppm): 14.1; 22.7; 22.9: 28.7; 29.2; 29.3; 29.5; 29.6; 29.65; 29.7; 31.9; 35.1; 119.8 (t, $C_1$, $^1J_{C-F}$ = 306.0 Hz); 191.9 (t, $C_2$ = O, $^2J_{C-F}$ = 29.0 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 2934; 2847; 1762; 1465; 1142; 901; 717; MS (GC/CI $CH_4$) *m/z* (%): 239 ($M^+-CF_2Cl$, 20); 325/327 ($MH^+$, 100); 353/355 ($M + C_2H_5^+$, 5); Anal.: calc. for $C_{17}H_{31}OF_2Cl$ (324.88): C, 62.85; H, 9.6; found: C, 62.7; H, 9.6.

#### 4.3.4. 3-Chloro-4,4,5,5,6,6-hexafluoro-2-(2-phenyl)ethyl-cyclohex-2-enone (**9a**)

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −111.7 (m, 2F, $C_4$); −126.6 (m, 2F, $C_6$); −133.8 (m, 2F, $C_5$); $^1H$ RMN $\delta$ (ppm): 2.76 (t, 2H, *J* = 7.9 Hz); 2.96 (t, 2H, *J* = 7.9 Hz); 7.1–7.3 (m, 5H); $^{13}C$ RMN $\delta$ (ppm): 29.6 ($C_7$); 32.7 ($C_8$); 105.5; 108.3 (t, $C_4$, $C_6$, $^1J_{C-F}$ = 260.0 Hz, $^2J_{C-F}$ = 26.0 Hz); 108.4 (qt, $C_5$, $^1J_{C-F}$ = 260.0 Hz, $^2J_{C-F}$ = 26.0 Hz); 126.8 ($C_{12}$); 128.5–128.7 ($C_{10}$, $C_{11}$); 138.8 ($C_9$); 141.2 (t, $C_2$, $^3J_{C-F}$ = 3.0 Hz);143.0 (tt, $C_3$, $^2J_{C-F}$ = 27.0 Hz, $^3J_{C-F}$ = 3.0 Hz); 178.0 (t t, $C_1$ = O, $^2J_{C-F}$ = 27.0 Hz, $^3J_{C-F}$ = 3.0 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 3436 ($\nu_{CHsp2}$); 2934 ($\nu_{CHsp3}$); 1721 ($\nu_{CO}$); MS (IE) *m/z* (%): 91 (100); 342 ($M^+$, 7); MS (GC/CI $CH_4$) *m/z* (%): 91(16); 307 ($MH^+-HCl$, 100); 325 ($MH^+-H_2O$, 99); 343 ($MH^+$, 51); Anal.: calc. for $C_{14}H_9OF_6Cl$ (342.66): C, 49.1; H, 2.65; found: C, 49.1; H, 2.7.

#### 4.3.5. 3-chloro-4,4,5,5,6,6-hexafluoro-2-octylcyclohex-2-enone (**9b**)

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −111.6 (m, 2F, $C_4$); −126.8 (m, 2F, $C_6$); −133.8 (m, 2F, $C_5$); $^1H$ RMN $\delta$ (ppm): 0.86 (t, 3H); 1.25 (m, 12H); 2.43 (t, 2H $C_7$); $^{13}C$ RMN $\delta$ (ppm): 14.0; 22.6; 26.8 (t, $C_7$, $^4J_{CF} < 1$ Hz); 27.6; 29.0; 29.1; 29.3; 31.8; 105.3 (ttt, $C_5$, $^1J_{C-F}$ = 261.0 Hz; $^2J_{C-F}$ = 27.0 Hz, $^3J_{C-F}$ = 2.0 Hz,); 108.4; 108.5 (ttq, $C_4$, $C_6$, $^1J_{C-F}$ = 261.0 Hz; $^2J_{C-F}$ = 25.5 Hz, $^3J_{C-F}$ = 2.0 Hz); 142.0 ($C_3$, tt $^2J_{C-F}$ = 27.0 Hz $^3J_{C-F}$ = 2.0 Hz); 142.5 ($C_2$ t, $^3J_{C-F}$ = 5.0 Hz); 178.3 (CO, tt, $^2J_{C-F}$ = 24.0 Hz, $^3J_{C-F}$ = 3.0 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 3050 ($\nu_{CHsp2}$); 2929 ($\nu_{CHsp3}$); 2863; 1726 ($\nu_{CO}$); 1178; 691; MS (GC/CI $CH_4$) *m/z* (%): 173 (30); 315 ($MH^+$-HCl, 20); 351/353 ($MH^+$, 100); 379/381 ($M + C_2H_5^+$, 20).

#### 4.3.6. 3-chloro-4,4,5,5,6,6-hexafluoro-decanylcyclohex-2-enone (**9c**)

Colorless oil; $^{19}F$ NMR $\delta$ (ppm): −111.7 (m, 2F, $CF_2$ $C_4$); −126.8 (m, 2F, $CF_2$ $C_6$); −133.9 (m, 2F, $CF_2$ $C_5$); $^1H$ RMN $\delta$ (ppm): 0.87 (t, 3H); 1.25 (m, 16H); 2.63 (t, 2H $C_7$); $^{13}C$ RMN $\delta$ (ppm): 14.1; 22.7; 26.8 (t, $C_7$, $^4J_{CF} < 1$ Hz); 27.6; 29.1; 29.2; 29.3 (2C); 31.5; 31.8; 105.3 (ttt, $C_5$, $^1J_{C-F}$ = 261.0 Hz; $^2J_{C-F}$ = 27.0 Hz, $^3J_{C-F}$ = 2.0 Hz); 108.4–108.5 (ttq, $C_4$, $C_6$, $^1J_{C-F}$ = 261.0 Hz; $^2J_{C-F}$ = 25.5 Hz, $^3J_{C-F}$ = 2.0 Hz); 142.0 ($C_3$, tt $^2J_{C-F}$ = 27.0 Hz $^3J_{C-F}$ = 2.0 Hz); 142.5 ($C_2$ t, $^3J_{C-F}$ = 5.0 Hz); 178.2 (CO, tt, $^2J_{C-F}$ = 24 Hz, $^3J_{C-F}$ = 3.0 Hz); IR (film, $\upsilon_{max}$, $cm^{-1}$): 2960; 2852; 1726; 1593; 1450; 1219; 1147; 860; 574. MS (GC/CI $CH_4$) *m/z* (%): 83(100); 343 ($MH^+-HCl$, 40); 379/381 ($MH^+$, 100); 407/409 ($M + C_2H_5^+$, 10); Anal.: calc. for $C_{16}H_{21}OF_6Cl$ (378.78): C, 50.7; H, 5.6; found: C, 50.7; H, 5.9.

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