

# Selective reductive dehalogenation at position 8 in 8-chloro-1,2,3,4,8-pentafluorobicyclo[2.2.2]octa-2,5-dienones

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## Abstract

The reduction of 8-chloro-1,2,3,4,8-pentafluorobicyclo-[2.2.2]octa-2,5-dienones **I** having aryl and alkyl substituents at the double bond with zinc in acetic acid leads to successive displacement of chlorine and fluorine atoms in position 8 by hydrogen. © 1998 Published by Elsevier Science S.A.

**Keywords:** Fluorinated bicyclo[2.2.2]octadienones; Reduction; Zinc; Dehalogenation

## 1. Introduction

We have earlier reported [1] that Diels-Alder reaction of 6-chloro-2,3,4,5,6-pentafluoro-2,4-cyclohexadienone with substituted acetylenes affords cycloadducts, 8-chloro-1,2,3,4,8-pentafluoro-bicyclo[2.2.2]octa-2,5-dienones **I**, in good yield. The structures of these compounds, which were established on the basis of  $^{13}\text{C}$  NMR spectroscopy and X-ray data [2] have shown that the cycloadditions proceed with high selectivity to give only one isomer. Bicyclodienones **I** undergo aromatization by the action of sodium hydroxide under mild conditions to afford arylacetic acids **II** containing chlorine and fluorine atoms in  $\alpha$ -positions [1]. In the present article we report the results of the reduction of 8-chloro-1,2,3,4,8-pentafluoro-bicyclo[2.2.2]octa-2,5-dienones **Ia–d** with zinc in acetic acid.

## 2. Results

We have found that treatment of compounds **Ia–d** with zinc dust in boiling acetic acid results in the substitution of hydrogen for chlorine to give bicyclic ketones (**IIIa–d**). The increase of the zinc amount resulted in the substitution of hydrogen for both geminal chlorine and fluorine atoms (**IVa–d**); fluorine atoms in other positions remains un-

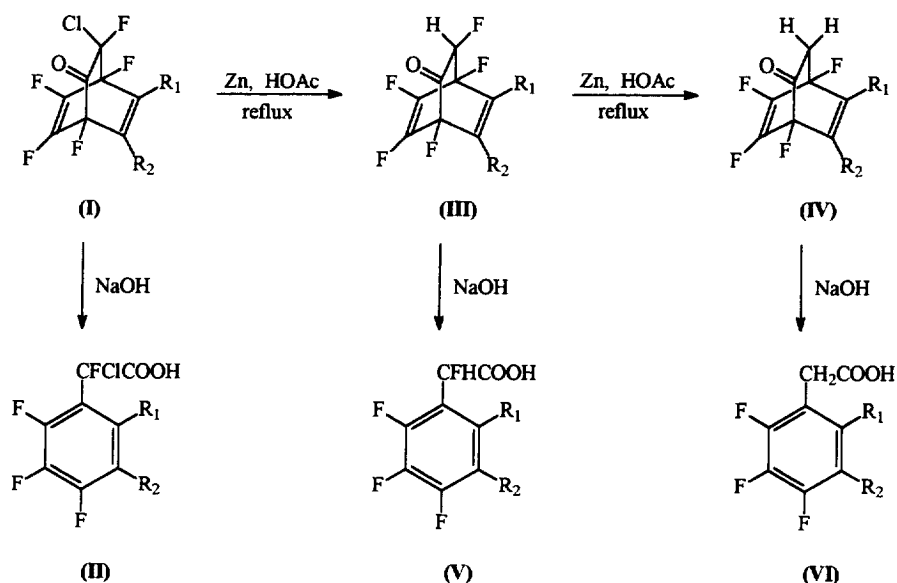
affected (Scheme 1). The reaction conditions and yield are given in Table 1.

Structure of compounds **IIIa–d** and **IVa–d** have been confirmed by comparing their spectral characteristics with those of cycloadducts (**Ia–d**) [1]. Thus, two signals were found in  $^{19}\text{F}$  NMR spectra of compounds **III** and **IV**, as well as in those of bicyclooctadienones (**I**), in the field range characteristic for vinylic fluorine atoms (from 2 to 12 ppm, relative to  $\text{C}_6\text{F}_6$ ) and two upfield signals ( $-27$  to  $-46$  ppm) of fluorine atoms at bridgehead positions. In the  $^{19}\text{F}$  NMR spectra of bicyclodienones **III** appears the upfield signal ( $-19$  to  $-22$  ppm) with a high coupling constant (53 Hz) relating to the fluorine atom of the CHF-group. In  $^1\text{H}$  NMR spectra of bicyclodienones **III** exists the signal with the same coupling constant at 5 ppm.  $^{19}\text{F}$  NMR spectra of compounds **IV** contain only four signals and their  $^1\text{H}$  NMR spectra are characterized by the appearance of two  $\text{CH}_2$ -group doublet signals at 2.7 to 2.9 ppm as AB-systems. The presence of two absorption bands in the IR spectra of bicyclodienones **III** and **IV** in the range of 1750 to 1785  $\text{cm}^{-1}$  indicates that the double bonds and carbonyl group in these compounds remained unaffected.

It should be noted the substitution of hydrogen for chlorine at  $\alpha$ -position to the carbonyl group, particularly in cyclic ketones, is well known [3], but similar substitution for fluorine atoms have not been found in the literature [4].

Bicyclooctadienones **III** and **IV** similarly to bicyclooctadienones **I** [1] readily undergo aromatization when acted upon by alkali yielding 85–95% of the respective aryl

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Scheme 1.

Table 1  
Reduction of bicyclocyclohexadienones **Ia–d** with Zn/AcOH

	Mole ratio Zn/compound I	Time (h)	Yield(%) of <b>III</b> and <b>IV</b>
<b>Ia</b>	3	2	<b>IIIa</b> , 77
	6	8	<b>IVa</b> , 73
<b>Ib</b>	2.5	4	<b>IIIb</b> , 86
	6	12	<b>IVb</b> , 81
<b>Ic</b>	6	6	<b>IIIc</b> , 72
	12	16	<b>IVc</b> , 65
<b>Id</b>	6	8	<b>IIId</b> , 70
	15	10	<b>IVd</b> , 68

acetic acids **Va–d** and **VIa–d**. The structure of the compounds **Va–d** and **VIa–d** are confirmed by their spectral and analytical data.

### 3. Experimental details

The reactants **Ia–d** were prepared from 6-chloro-2,3,4,5,6-pentafluoro-2,4-cyclohexadienone and the acetylenes  $R_1C\equiv CR_2$  using the literature method [1]. IR spectra were obtained using a Specord M-80 spectrometer from KBr cells. Mass spectra were measured on a Finnigan MAT-8200 instrument operated at 70 eV. NMR spectra were recorded on a Bruker WP-200SY spectrometer operating at 200.00 MHz for  $^1H$  and 188.28 MHz for  $^{19}F$  with TMS and  $C_6F_6$  as internal standards, respectively, in  $CDCl_3$  solution.

#### 3.1. General procedure for bicyclic dienones **IIIa–d** and **IVa–d**

A solution of bicyclic dienone **I** (5 mmol) in 20 ml of glacial acetic acid with corresponding amounts of zinc dust was stirred vigorously under reflux (Table 1). Then the solution was filtered, poured into water (100 ml), and extracted with carbon tetrachloride. The extract was dried over  $CaCl_2$  and evaporated. The residue was recrystallized. The analytical and spectral data for compounds **IIIa–d** and **IVa–d** are given in Tables 2 and 3.

#### 3.2. General procedure for arylacetic acids **Va–d** and **VIa–d**

A solution consisting of a 2.5-fold molar excess of NaOH in water (10 ml) was added dropwise (during 10–15 min) to a stirred solution of the bicyclic adduct **III** or **IV** (2 mmol) in dioxan at room temperature. The reaction mixture was stirred for a further 15 min, poured into 5% HCl solution (50 ml) and extracted with dichloromethane. The extract was dried over  $CaCl_2$  and evaporated. The residue was purified by crystallization. Tables 4 and 5 present experimental results and spectral data for the arylacetic acids **Va–d** and **VIa–d**.

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Table 2  
Analytical and spectral data for bicyclooctadienones IIIa–IIIc.

	Melting point (°C)	Molecular weight Found (Calcd.)	Empirical formula	<sup>19</sup> F NMR spectra; chemical shifts (ppm) and <i>J</i> values (Hz)			<sup>1</sup> H NMR spectra; chemical shifts (ppm) and <i>J</i> values (Hz)		IR spectra (cm <sup>-1</sup> )		
				F <sup>1</sup>	F <sup>2</sup> and F <sup>3</sup>	F <sup>4</sup>	F <sup>7</sup>	CFH	miscellaneous	CF=CF	C=O
R <sub>1</sub> =H, R <sub>2</sub> =Ph <b>(IIIa)</b>	62–64	286.0404 (286.0404)	C <sub>14</sub> H <sub>7</sub> F <sub>5</sub> O	-38.0 dd 16; 8	7.7 s 10.7 s	-40.3 s	-19.7 ddd 53; 8; 6	4.75 dd 53; 7	6.35 m (CH); 7.24 m (Ph)	1750	1780
R <sub>1</sub> = R <sub>2</sub> = Ph <b>(IIIb)</b>	158–161	362.0726 (362.0730)	C <sub>20</sub> H <sub>11</sub> F <sub>5</sub> O	-35.7 m 5	9.1 t 10.9 d 4	-39.5 d 4	-21.1 ddd 53; 10; 5	5.08 ddd 53; 7; 2	7.05–7.24 m (2 Ph)	1760	1785
R <sub>1</sub> =H, R <sub>2</sub> =Bu <sup>n</sup> <b>(IIIc)</b>	viscous liquid	266.0730 (266.0730)	C <sub>12</sub> H <sub>11</sub> F <sub>5</sub> O	-38.0 s	6.8 s 9.6 s	-45.2 s	-19.6 d 53	4.66 dm 53	0.93 t (CH <sub>3</sub> ); 1.40 m (2CH <sub>2</sub> ); 2.31m (CH <sub>2</sub> ); 6.05 m (CH)	1750	1780
R <sub>1</sub> = R <sub>2</sub> = Et <b>(IIIc)</b>	viscous liquid	266.0730 (266.0730)	C <sub>12</sub> H <sub>11</sub> F <sub>5</sub> O	-42.5 t 8	6.8 t 8.7 s 4	-45.8 s	-21.3 ddd 53; 4; 3	4.75 ddd 53; 7; 2	1.00 t (CH <sub>3</sub> ); 1.05 t (CH <sub>3</sub> ); 2.76 m (2CH <sub>2</sub> )	1750	1780

Table 3  
Analytical and spectral data for bicyclooctadienones IVa–IVd.

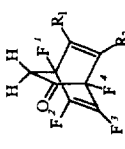
	Melting point (°C)	Molecular weight Found (Calcd.)	Empirical formula	<sup>19</sup> F NMR spectra; chemical shifts (ppm) and <i>J</i> values (Hz)			<sup>1</sup> H NMR spectra; chemical shifts (ppm) and <i>J</i> values (Hz)		IR spectra (cm <sup>-1</sup> )
				F <sup>1</sup>	F <sup>2</sup> and F <sup>3</sup>	F <sup>4</sup>	CH <sub>2</sub> (AB-system)	miscellaneous	
R <sub>1</sub> =H, R <sub>2</sub> =Ph <b>(IVa)</b>	viscous liquid	268.0514 (268.0511)	C <sub>14</sub> H <sub>8</sub> F <sub>4</sub> O	-29.5 s	2.4 s 11.8 s	-38.6 s	2.66 d 16	2.74 d 16	1750 1765
R <sub>1</sub> = R <sub>2</sub> = Ph <b>(IVb)</b>	136–137	344.0793 (344.0824)	C <sub>20</sub> H <sub>12</sub> F <sub>4</sub> O	-27.6 s	3.6 d 11.8 s	-36.9 d	2.77 dm 16	2.88 dd 16; 4	1760 1765
R <sub>1</sub> =H, R <sub>2</sub> =Bu <sup>n</sup> <b>(IVc)</b>	viscous liquid	248.0818 (248.0824)	C <sub>17</sub> H <sub>12</sub> F <sub>4</sub> O	-29.1 s	2.1 s 10.7 s	-37.9 s	2.73 d 16	2.82 d 16	1750 1760
R <sub>1</sub> = R <sub>2</sub> = Et <b>(IVd)</b>	viscous liquid	248.0818 (248.0824)	C <sub>15</sub> H <sub>12</sub> F <sub>4</sub> O	-31.2 s	2.2 s 10.3 s	-37.1 s	2.75 d 16	2.83 d 16	1755 1765

Table 4  
Analytical and spectral data for arylacetic acids Va–Vd.

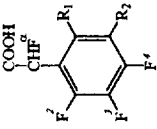
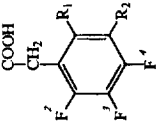
	Melting point (°C)	Molecular weight Found (Calcd.)	Empirical formula	<sup>19</sup> F NMR spectra, chemical shifts (ppm) and <i>J</i> values (Hz)			<sup>1</sup> H NMR spectra, chemical shifts (ppm) and <i>J</i> values (Hz)		IR spectra (cm <sup>-1</sup> )
				F <sup>2</sup> and F <sup>3</sup>	F <sup>4</sup>	F <sup>α</sup>	CFH	miscellaneous	
R <sub>1</sub> =H, R <sub>2</sub> =Ph (Va)	130–133	284.0460 (284.0460)	C <sub>14</sub> H <sub>8</sub> F <sub>4</sub> O <sub>2</sub>	26.6 m 24.5 m	3.6 t 20	-15.4 d 46	6.19 d 46	7.44 m (Ph and CH); 7.88 (COOH)	1745
R <sub>1</sub> =R <sub>2</sub> =Ph (Vb)	190–195 (decomp)	360.0770 (360.0773)	C <sub>20</sub> H <sub>12</sub> F <sub>4</sub> O <sub>2</sub>	31.4 m 27.3 m	2.1 td 21; 1.5	-11.4 dt 44.5; 5	5.65 dd 44.5; 1.5	7.27–8.16 m (2Ph); 6.84 s (COOH)	1750
R <sub>1</sub> =H, R <sub>2</sub> =Bu <sup>n</sup> (Vc)	glassy substance	264.0779 (264.0773)	C <sub>12</sub> H <sub>12</sub> F <sub>4</sub> O	24.1 m 22.2 m	0.8 t 20	-14.8 d 45	5.95 d 45	0.95 t (CH <sub>3</sub> ); 1.42 m (2CH <sub>2</sub> ); 2.96 t (CH <sub>2</sub> ); 7.33 m (CH); 7.95 s (COOH)	1750
R <sub>1</sub> =R <sub>2</sub> =Et (Vd)	glassy substance	264.0779 (264.0773)	C <sub>12</sub> H <sub>12</sub> F <sub>4</sub> O	28.5 m 24.7 m	1.1 t 20	-13.6 d 45	5.62 d 45	1.07 t (CH <sub>3</sub> ); 1.12 t (CH <sub>3</sub> ); 2.65–2.80 m (2CH <sub>2</sub> ); 8.23 (COOH)	1750

Table 5  
Analytical and spectral data for arylacetic acids **VIa–VIId**.

 $R_1=H, R_2=Ph$ <b>(VIa)</b>	Melting point (°C)	Molecular weight Found (Calcd.)	Empirical formula	<sup>19</sup> F NMR spectra; chemical shifts (ppm) and <i>J</i> values (Hz)			<sup>1</sup> H NMR spectra; chemical shifts (ppm)	IR spectra (cm <sup>-1</sup> )
				F <sup>2</sup> and F <sup>4</sup>	F <sup>3</sup>	F <sup>3</sup>		
$R_1=H, R_2=Ph$ <b>(VIa)</b>	141–143	266.0547 (266.0555)	C <sub>14</sub> H <sub>9</sub> F <sub>3</sub> O <sub>2</sub>	24.5 dt 20; 7	22.1 dt 20; 7	1.9 t 20	3.80 s (CH <sub>2</sub> ); 7.33 m (CH); 7.47 m (Ph); 8.45 s (COOH)	1710
$R_1=R_2=Ph$ <b>(VIb)</b>	173–176	342.0770 (342.0773)	C <sub>20</sub> H <sub>13</sub> F <sub>3</sub> O <sub>2</sub>	26.0 m	25.6 m	0.4 t 21	3.51 d (CH <sub>2</sub> ); 7.06–7.18 m (2Ph); 7.69 s (COOH)	1715
$R_1=H, R_2=Et^a$ <b>(VIc)</b>	glassy substance	246.0871 (246.0867)	C <sub>12</sub> H <sub>13</sub> F <sub>3</sub> O <sub>2</sub>	23.3 m	22.2 m	0.6 t 20	0.94 t (CH <sub>3</sub> ); 1.40 m (2CH <sub>2</sub> ); 2.35 t (CH <sub>2</sub> ); 3.46 s (CH <sub>2</sub> ); 7.27 m (CH); 8.33 s (COOH)	1710
$R_1=R_2=Et$ <b>(VIId)</b>	glassy substance	246.0871 (246.0867)	C <sub>12</sub> H <sub>13</sub> F <sub>3</sub> O <sub>2</sub>	24.7 m	22.6 m	0.2 t 20	1.08 t (CH <sub>3</sub> ); 1.12 t (CH <sub>3</sub> ); 2.62–2.78 m (2CH <sub>2</sub> ); 8.20 (COOH)	1710

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