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Ferrocene Compounds. XXVIII.* Synthesis of 2-(Ferrocenylalkyl)- and 2-[Ferrocenyl(phenyl)alkyl]-1,3-propanediols and Their Acetates

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Reaction of the appropriate reagent $Fc(CH_2)_nCHRX$ (**1–3**, **6**, and **9**) with sodium salt of diethyl malonate in dry xylene gave 81–91% of the corresponding diethyl (ferrocenylalkyl)malonate or diethyl ferrocenyl(phenyl)alkylmalonate (**11**). Using $Fc(CH_2)_nCHRX$ (**4**, **7**, **8** and **10**) under similar reaction conditions, transesterification products – ethyl ferrocenylalkyl malonates or ethyl ferrocenyl(phenyl)-alkyl malonates (**12**) were obtained. Reduction of condensation products **11** with lithium aluminium hydride in diethyl ether gave the corresponding diols **13** (45–66%), which will be in further studies subjected to lipase-mediated transformations with vinyl acetate to chiral monoacetates. By the action of acetic anhydride on diols **13** in a benzene solution, the corresponding mono- **14** (25–52%) and diacetates **15** (36–51%) were obtained.

Key words: ferrocene compounds; diethyl (ferrocenylalkyl)malonates; ethyl ferrocenylalkyl malonates; 2-ferrocenylalkyl-1,3-propanediols and their acetates.

INTRODUCTION

Selective catalysis by hydrolytic enzimes can be exploited most efficiently for transformation of enantiotopic groups. In contrast to enantiomer selectivity, in a completely enantiotope selective transformation the total

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* For Part XXVII, see Ref. 1.

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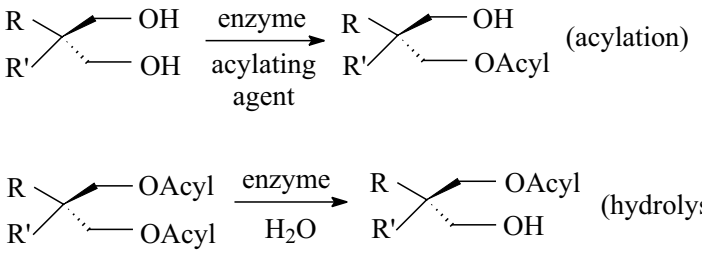
amount of the achiral substrate can be transformed to an enantiomerically pure chiral product. In this process, enantiotopic groups are converted to constitutionally different groups. Enantiotopic groups can be found either in achiral compounds containing a single prochiral centre or in *meso*-compounds.[2,3]

Lipase-catalyzed asymmetric transformations of 2-substituted 1,3-propanediols to chiral 1,3-propanediol monoacetates can be performed in an inert solvent (toluene, diisopropyl ether, *etc.*) by the action of acetic acid esters as acetyl donors. The best results were obtained with vinyl acetate as solvent, which at the same time served as irreversible donor of acetyl group. In these reactions, catalyzed by lipases isolated from *Pseudomonas fluorescens, Pseudomans fragi* or *porcine pancreas,* several 2-alkyl-, 2-alkenyl-, 2-alkoxymethyl-, 2-arylmethoxy-, 2-arylthio- and 2-arylmethyl-1,3-propanediols were converted to 13–97% of the corresponding monoacetates with optical yields e.e. 60–90%.[4,5,6]

On the other hand, some *meso*-diacetates can be desymmetrized by partial hydrolyzis in the presence of *Pseudomonas fluorescens* lipase, porcine liver esteraze or acetylcholin esteraze to the corresponding chiral monoacetates (e.e. 33–86%).[6,7]



Scheme 1.

In the field of ferrocene diols, acetylation of *meso,*dl-1,1'-bis(α-hydroxyethyl)ferrocenes in dry acetone, using vinyl acetate as acetyl donor and *Pseudomonas cepacia* lipase as catalyst, allowed for the diacetate of the (*R*,*R*)-enantiomer and the free (*S*,*S*)-diol to be obtained.[8] Another example of lipase-mediated acetylation is the desymmetrization of the prochiral 1,2-bis(hydroxymethyl)ferrocene by production of both enantiomers of 2-acetoxymethyl-1-hydroxymethylferrocene.[9]

The aim of this work was to synthesize several 2-(ferrocenylalkyl)- and 2-[ferrocenyl(phenyl)alkyl]-1,3-propanediols as substrates for investigation of their lipase-catalyzed stereoselective acetylation. These diols were designed with ferrocenyl group in α-, β-, and γ-position of the alkane chain

relative to the propanediol methine group. Some of them contain a chiral centre in various positions of the alkane chain. We have planned to prepare their mono- and diacetates for comparison with the products of biocatalyzed acetylations.

RESULTS AND DISCUSSION

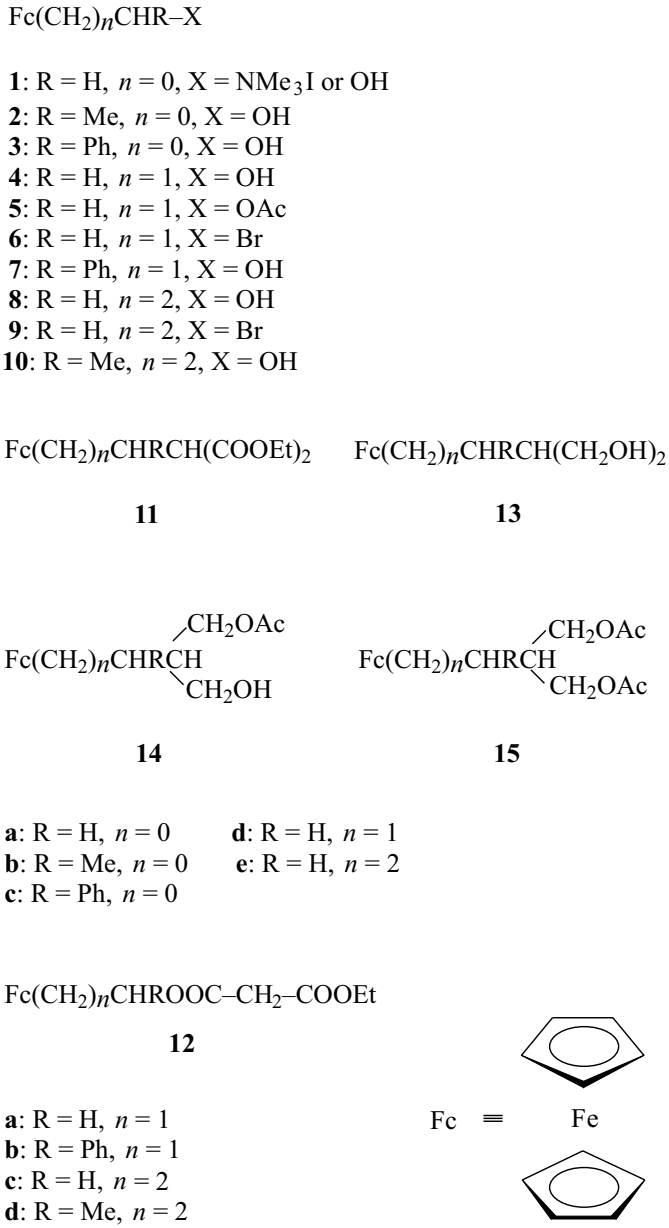
As the starting materials for preparation of the desired derivatives of 2-ferrocenylalkyl-1,3-propenediols we have used $Fc(CH_2)_nCHRX$ (n = 0–2; R = H, Me, Ph; X = OH, OAc, NMe_3I, Br), most of which has have been described previously. We have already published condensation reactions of the mentioned reagents (n = 0; R = H, p-ClC_6H_4, p-MeC_6H_4, p-$MeOC_6H_4$; R = OH) with diethyl malonate.[10] They were performed under similar conditions to those described in Ref. 11 for malonic ester synthesis with 2-ferrocenylethanol and ferrocenyl(phenyl)methanol, *i.e.* by refluxing the xylene solutions of ferrocene reagents with 3.5 molar excess of sodium salt of diethyl malonate.

Starting from carbinols $Fc(CH_2)_nCHROH$ (**1**–**3**) in condensations with diethyl malonate, we have prepared 81–93% of the previously described malonates **11a–c**.[10] However under the same circumstances in the case of the alcohols **4**, **7**, **8** and **10,** we have isolated 79–97% of the transesterification products – ethyl ferrocenylalkyl (or ferrocenyl(phenyl)alkyl) malonates (**12a–d**). To perform the desired malonic ester syntheses with the mentioned carbinols, we converted them into the corresponding acetates; however under the same reaction conditions they gave the mentioned transesterification products again. By the action of phosphorus tribromide in benzene, compounds **4** and **8** were transformed into bromides **6** and **9**, which underwent the »classical« malonic ester condensation, giving the desired esters **11d** and **11e** (91 and 81%). Malonates **11a–e** were reduced with lithium aluminium hydride in diethyl ether, giving 45–66% of 2-(ferrocenylalkyl)- or 2-[ferrocenyl(phenyl)alkyl]-1,3-propanediols (**13**). Refluxing the benzene solutions of these diols with a little molar excess of acetic anhydride gave 25–52% of the corresponding monoacetates **14** and 36–50% of diacetates **15**.

The preliminary results indicated that diols **13a** and **13d** were stereoselectively acylated by vinyl acetate in the presence of *Mucor miehei* lipase as catalyst.

The French paper[11] dealing with condesations of α-ferrocenylethanol and α-phenylferrocenylmethanol with sodium salt of diethyl malonate is one of the rare publications dealing with malonic ester syntheses in which carbinols have been used, instead of the usually applied halogenides or tosylates. For these reactions, the authors assumed the S_N1 mechanism (with

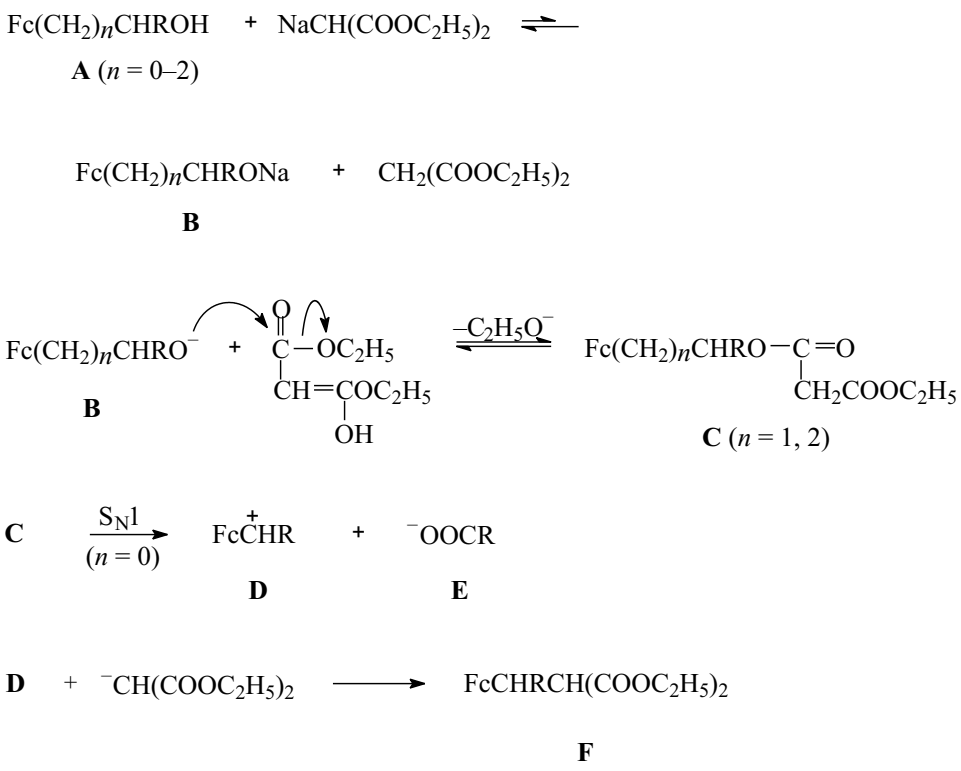
hydroxylic groups leaving the carbinols) because of the high stability of α-ferrocenylcarbonium ions, but they stressed that this explanation is not satisfactory. It is well-known that the hydroxyl group does not leave from



Scheme 2.

ordinary alcohols and its substitution can be performed when it is protonated or converted to a (reactive) ester, because water and acylates are good leaving groups.[12] In this connection, we assumed conversion of carbinols to malonates as intermediates in the reactions performed.

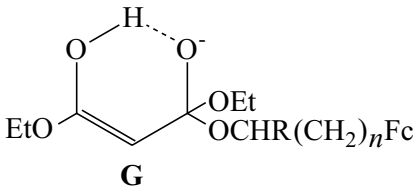
In Ref. 13, base-catalyzed transesterification of lower malonates (dimethyl, diethyl) with higher alcohols (hexyl, heptyl, benzyl) have been described (*e.g.* transesterification of diethyl malonate with benzyl alkohol in the presence of sodium hydroxide was completed in 2 hours of refluxing with 83% yield). For these conversions, the authors suggested an S_N2 process facilitated by enolization of malonic ester (*i.e.*, conversion **B** → **C** in Scheme 3). The relative ease of transesterification of diethyl malonate is also notable from its conversion to dimethyl ester by shaking it in a methanolic solution of potassium methoxide under anhydrous conditions.[14] Keeping in mind these facts, we supposed conversion of carbinols **A** and sodiomalonic ester (enolate) to the corresponding ethyl ferrocenylalkyl malonates **C** in the first and second reaction steps. The alkoxide **B** needed for this reaction is formed



Scheme 3.

in an (unfavourable) equilibrium between carbinols **A** ($pK_a \approx 16$) and sodiomalonic ester ($pK_a = 13.5$). In the case of alcohols **4**, **7**, **8** and **10,** the corresponding **C** (*i.e.* esters **12a–d**) is the final reaction product. However, in the reactions of ferrocyl carbinols* (**1–3**), one could suppose the S_N1 transformation of esters **C** into malonates **F** (**11a–c**) because of the extraordinary stability of the intermediate carbocations **D** and the relatively good leaving group **E**.

One could propose an alternative pathway for transesterification of diethyl malonate by $Fc(CH_2)_nCHROH$ involving cyclic enolic form **G**[15] (Scheme 4) which may contribute to the »internal catalysis«.



G

Scheme 4.

It is interesting to mention that similar problems have been encountered in our investigations of the reactions of $Fc(CH_2)_nX$ (n = 1, 2; X = AcO, NMe_3I, Br) with alkoxide derived from methyl glycolate (or methyl lactate). Instead of the desired oxaaliphatic esters $Fc(CH_2)_nOCH_2COOMe$, $FcCH_2OMe$ (for n = 1)[16] and $HOCH_2COOCH_2CH_2Fc$ (for n = 2)[17] were obtained as the main products. We have supposed that these transformations occurred *via* oxonium species $HOCH_2C\overset{+}{O}O(Me)(CH_2)_nFc$: in the case of n = 1 this intermediate cleaved by BAC1 mechanism giving ferrocyl methyl ether, and for n = 2 BAL2, the cleavage occurred during the formation of the equilibrium controled transesterification product. The similar ester $HOCH_2COOCH_2Fc$ is obviously unstable under the reaction conditions and it dissociates to $FcCH_2^+$ giving $FcCH_2OMe$, according to the above discussion.

EXPERIMENTAL

Melting points were determined with a Buechi apparatus. The IR spectra were recorded for KBr pellets or CCl_4 solutions with a Bomem MB100 Mid FT IR spectrophotometer. The ^1H NMR spectra of $CDCl_3$ solutions were recorded on a Varian EM 360 or Varian Gemini 300 spectrometer with tetramethylsilane as internal standard.

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* ferrocyl = ferrocenylmethyl.

Products were purified by preparative thin layer chromatography on silica gel (Merck, Kieselgel 60 HF_{254}) and by recrystallization from benzene.

N,N,N-trimethylferrocylammonium iodide (**1**) was prepared by quaternization of *N,N*-dimethylferrocylamine with methyl iodide in acetone.[16] Carbinols **2** and **3** were prepared by reduction of the corresponding acylferrocenes with sodium boron hydride in isopropyl alcohol.[18] Reduction of ferroceneacetic acid[19] with lithium aluminium hydride in diethyl ether gave 94% of 2-ferrocenylethanol (**4**).[20] Reaction of carbinol **4** with acetic anhydride in benzene abs. gave acetate **5**[1] (85%) and bromination of **4** with phosphorus tribromide gave 76% of 2-ferrocenylethyl bromide (**6**).[21] Carbinol **7** was prepared by hydroboration-oxidation of styrylferrocene.[22] Reduction of ferrocenepropanoic acid with lithium aluminium hydride in diethyl ether gave 83% of 3-ferrocenyl-1-propanol (**8**).

IR spectrum (CH_2Cl_2) υ_{max}/cm^{-1}: 3617 s (OH), 3092 w (C–H) arom., 2935 m, 2872 m (C–H) aliph.; ^1H NMR spectrum ($CDCl_3$) δ/ppm: 4.09 s and 4.05 m (9H, Fc), 3.62 (t, 2H, CH_2O), 2.39 (m, 2H, Fc*CH*$_2$), 1.75 (m, 2H, CH_2*CH*$_2CH_2$), 2.03 (s, 1H, OH).

*3-Ferrocenylpropyl Bromide (**9**)*

Phosphorus tibromide (333 mg, 1.23 mmol) was added dropwise to a solution of 3-ferrocenyl-3-propanol (900 mg, 3.68 mmol) in dry benzene (5 mL). The solution was stirred at room temperature overnight. The reaction mixture was washed with a saturated aqueous solution of $NaHCO_3$ and again with water and then dried over Na_2SO_4. The benzene was evaporated in *vacuo* and purifed by TLC.

IR spectrum (CH_2Cl_2) υ_{max}/cm^{-1}: 3097 w (C–H) arom., 2932 m, 2851 m (C–H) aliph., 559 s (C–Br); ^1H NMR spectrum ($CDCl_3$) δ/ppm: 4.11 s and 4.06 m (9H, Fc), 2.47 (m, 2H, Fc*CH*$_2$), 2.01 (t, 2H, CH_2*CH*$_2CH_2$), 3.39 (t, 2H, CH_2Br).

*4-Ferrocenylbutan-2-ol (**10**)*

N,N,N-trimethylferrocenylammonium iodide (**1**, 1 g, 2.6 mmol) and monosodium salt of butane-2,4-dione (500 mg, 4 mmol) were dissolved in dry acetonitrile, and the solution was heated under reflux for 15 hours. After addition of water (10 mL) to the reaction mixture, it was extracted with dichloromethane. The organic layer was washed with saturated aqueous solution of sodium chloride, dried over sodium magnesium sulphate and evaporated to dryness. The residue was purified by thin layer chromatography giving 724 mg (80%) of 4-ferrocenylbutane-2-one. The physical properties of the compound obtained and of the previonsly prepared authentic specimen are identical.[23]

To the ethereal solution of the ketone obtained (433 mg, 1.69 mmol), 1 M solution of $LiAlH_4$ in the same solvent (5 mL) was added. After refluxing for 2 hours, water (10 mL) and a few drops of aqueous hydrochloric acid (1:1) were added. After extraction of the aqueous layer with several portions of diethyl ether, the combined organic phases were washed with saturated aqueous solution of sodium chloride, dried over sodium sulphate, and evaporated to dryness; 386 mg (88.5%) of carbinol **10** was obtained. The physical properties of the compound obtained are identical with the properties of the carbinol prepared by Bouveault-Blanc reduction of 2-ferrocenylethyl acetate.[24]

IR spectrum (CH_2Cl_2) υ_{max}/cm^{-1}: 3367 b (OH), 3096 w (C–H) arom., 2966 m, 2927 m (C–H) aliph.; ^1H NMR spectrum ($CDCl_3$) δ/ppm: 4.09 s and 4.05 m (9H, Fc), 3.79 (m, 1H, methine), 2.4 (m, 2H, Fc*CH*$_2$), 1.69 (m, 2H, *CH*$_2$CH), 1.64 (s, 1H, OH), 1.19 (d, 3H, CH_3).

*Diethyl (Ferrocenylalkyl)malonates, Diethyl [Ferrocenyl(phenyl)alkyl]malonates (**11**), Ethyl Ferrocenylalkyl Malonates and Ethyl Ferrocenyl(phenyl)alkyl Malonates (**12**)*

General Procedure

82 mg (4 mmol) of molten sodium in dry xylene (10 mL) was converted by shaking into fine dispersion and diethyl malonate (1.06 g, 6.6 mmol) was added dropwise. The mixture was stirred for ½ hour at 140 °C until sodium disappeared. A solution of the appropiate Fc$(CH_2)_n$CHRX in the same solvent (5 mL) was added. After reflux for 3 hours, the reaction mixture was poured into crushed ice and water, extracted with diethyl ether, washed with saturated aqueous solution of sodium chloride, dried over sodium sulphate, and evaporated to dryness giving resinous yellow, orange, or brown products, which partially crystallized after standing in refrigerator. Esters **11a**–**11c** have been prepared previously starting from reagents **1**–**3.**[10] Condensation reactions of bromides **6** and **9** gave malonates **11d** and **11e**. By reactions of carbinols **4**, **7**, **8**, and **10** with dietyl malonate, transesterification products **12** were obtained (Tables I–IV).

*2-(Ferrocenylalkyl)-1,3-propanediols and 2-[Ferrocenyl(phenyl)alkyl]-1,3-propanediols (**13**)*

General Procedure

To a solution of malonate **11** (3 mmol) in diethyl ether abs. (5 mL), 1 M solution of lithium aluminium hydride in the same solvent (3 mL) was added. The reaction mixture was refluxed for 3 hours and worked up in the usual manner (Tables I, II and IV).

*Ferrocene 1,3-Propanediol Monoacetates **14** and Diacetates **15***

General Procedure

Acetic anhydride (43.4 mg, 0.40 mmol) was added to a solution of diol **13** (0.36 mmol) in benzene abs. (3 mL). After refluxing for 3 hours and standing overnight, the reaction mixture was evaporated to dryness and separated by means of preparative thin layer chromatography to the corresponding mono- (**14**) and diacetates **15** (Tables V–VII).

TABLE I

Physical constants and IR spectral data for $Fc(CH_2)_nCHRCH(COOEt)_2$ (**11**), $Fc(CH_2)_nCHROOC–CH_2–COOEt$ (**12**) and $Fc(CH_2)_nCHRCH(CH_2OH)_2$ (**13**)[a]

Compd.	R	Formula	Yield	M.p.	Anal. calcd. (found) / %		IR / cm^{-1}	
no.	n	(M_r)	%	°C	C	H	ν(OH)	ν(C=O)
11d	H	$C_{19}H_{24}FeO_4$	91	44.5–45.5	61.32	6.46	–	1752 s
	1	(371.8)			(61.15)	(6.58)		1735 s
11e	H	$C_{20}H_{26}FeO_4$	81	39–40	62.21	6.74	–	1746 s
	2	(385.8)			(61.99)	(6.49)		1728 s
12a	H	$C_{17}H_{20}FeO_4$	76	resin	59.34	5.82	–	1741 b
	1	(343.8)			(59.50)	(6.08)		
12b	Ph	$C_{23}H_{24}FeO_4$	97	resin	65.75	5.71	–	1754 s
	1	(419.8)			(65.49)	(5.90)		1737 s
12c	H	$C_{18}H_{22}FeO_4$	70	resin	60.37	6.15	–	1758 s
	2	(357.8)			(60.01)	(5.97)		1731 s
12d	Me	$C_{19}H_{24}FeO_4$	84	resin	61.32	6.46	–	1754 s
	2	(371.8)			(61.52)	(6.60)		1741 s
13b	Me	$C_{15}H_{20}FeO_2$	61	resin	62.52	6.99	3448 b	–
	0	(287.8)			(62.51)	(7.13)		
13c	Ph	$C_{20}H_{22}FeO_2$	60	resin	68.61	6.29	3413 b	–
	0	(349.8)			(68.54)	(6.06)		
13d	H	$C_{15}H_{20}FeO_2$	66	68–69	62.52	6.99	3372 bs	–
	1	(287.8)			(62.50)	(6.83)		
13e	H	$C_{16}H_{22}FeO_2$	45	55–56	63.59	7.34	3293 bs	–
	2	(301.8)			(63.53)	(7.16)		

[a] The structure of the compound **13a** (R = H, n = 0) is described in Ref. 1: spectral analysis and a single crystal X-ray study showed the hydroxyl groups of this compound are involved in the intermolecular OH····O hydrogen bond; the crystal structure is additionally stabilized

TABLE II

^{1}H NMR spectra of $Fc(CH_2)_nCHRCH(COOEt)_2$ (**11**) and $Fc(CH_2)_nCHRCH(CH_aH_bOH)_2$ (**13**)

Compd.	Ferrocene protons		Methine protons[a]		Methylene protons[a]						CH_3	OH[b]
no.			α	ω	CH_2CH_3	H_a	H_b	α	β	γ		
11d	4.11 s (9)	4.06 m	–	3.36 (1, t)	4.21 (4, q)		–	2.37 (2, t)	2.11 (2, m)	–	1.28 (6, t)	–
11e	4.08 s (9)	4.04 m	–	3.33 (1, m)	4.18 (4, m)		–	2.36 (2, t)	1.54 (2, m)	1.92 (2, m)	1.26 (6, t)	–
13b	4.14 s (9)	4.04 s	2.67 s (1, m)	1.65 (1, m)	–	3.70 (2, dd)	3.57 (2, dd)	–	–	–	1.31 (3, d)	2.57 (2, b)
13c[c]	4.19 m	3.85 s (10)	4.03 s	2.04 (1, m)	–	3.74 (2, m)	3.58 (2, m)	–	–	–	–	2.55 (2, b)
13d	4.10 s (9)	4.05 s	–	1.78 (1, m)	–	3.82 (2, dd)	3.66 (2,dd)	2.37 (2, t)	1.46 (2, m)	–	–	2.62 (2, b)
13e	4.15 s (9)	4.12 s	–	1.74 (1, m)	–	3.81 (2, dd)	3.64 (2, dd)	2.32 (2, t)	1.26 (2, m)	1.51 (2, m)	–	2.82 (2, b)

[a] α, β,...ω denote position of CH_2/CH of the aliphatic chain relative to the ferrocene nucleus.

[b] The signals corresponding to the hydroxylic protons dissapeared after addition of D_2O to the solutions.

[c] Benzene protons were registered at δ 7.32 m and 7.27 m ppm (5H).

TABLE III

^{1}H NMR spectra of $Fc(CH_2)_nCHROOC–CH_2–COOCH_2CH_3$ (**12**)

Compd. no.	Ferrocene protons		Methine protons	Methylene protons[a]					CH_3
				α	β	γ	CH_3CH_2	$COCH_2CO$	
12a	4.12 s	4.08 m	–	2.68	4.28 q	–	4.20 q	3.38	1.28
	(9)			(2, t)	(4)			(2,s)	(3, t)
12b	4.11 s	4.09 m	5.57	2.92 m 2.85 m	–	–	4.21	3.35	1.25
	(9)		(1, t)	(2)			(2, q)	(2, s)	(3, t)
12c	4.09 s	4.05 m	–	2.40	1.86	–	4.22 –	3.39	1.27
	(9)			(2, t)	(2, m)		(4, m)	(2, s)	(3, t)
12d	4.09 s	4.04 m	4.98	2.35	1.83 m 1.73 m	–	–	3.57	1.27
	(9)		(1, m)	(2, m)	(2, m)			(2, s)	(6, m)

[a] See footnote (a) of Table II.

[b] Benzene protons were registered at δ 7.27 m ppm (5H).

TABLE IV

^{13}C NMR spectra of $Fc(CH_2)_nCHRCH(COOEt)_2$ (**11**) and $Fc(CH_2)_nCHRCH(CH_2OH)_2$ (**13**)

Compd. no.	Ferrocene C-atoms			Methine C-atoms		Methylene C-atoms					Methyl C-atoms	Benzene C-atoms		COO
	unsubst. ring	subst. ring												
		CH	C	α	ω	α	β	γ	CH_2OH	CH_2CH_3	CH_2CH_3	C	CH	
11d	67.14	67.89 68.35	87.22	–	51.31	29.57	26.86	–	–	61.17	13.84	–	–	169.43
11e	66.95	67.09 67.81 68.28	88.30	–	51.68	28.91	28.38	28.48	–	61.12	13.82	–	–	169.47
13b	65.72	67.06 67.09 68.24 68.53	92.92	31.81	48.59	–	–	–	64.24 64.41	–	–	–	–	–
13c	66.47	68.15 68.50 69.52	91.45	43.91	48.23	–	–	–	64.51 64.69	–	–	143.83	126.53 128.25 128.37	
13d	66.99	67.73 68.32	88.58	–	41.42	26.86	26.86	–	65.54	–	–	–		–
13e	67.30	68.27 68.75	89.33	–	41.68	27.32	27.32	28.58	66.21	–	–	–		–

TABLE V

Physical constants and IR spectral data for $Fc(CH_2)_nCHRCH(CH_2OH)CH_2OAc$ (**14**) and $Fc(CH_2)_nCHRCH(CH_2OAc)_2$ (**15**)

Compd.	R	Formula	Yield	Anal. calcd. (found) / %		IR / cm^{-1}	
no.	*n*	(M_r)	%	C	H	υ(OH)	υ(C=O)
14a	H	$C_{16}H_{20}FeO_3$	52	60.80	6.33	3440 b	1740 s
	0	(315.8)		(61.02)	(6.50)		
14b	Me	$C_{17}H_{22}FeO_3$	44	61.86	6.67	3460 b	1741 s
	0	(329.8)		(61.76)	(6.71)		
14c	Ph	$C_{22}H_{24}FeO_3$	36	67.38	6.31	3470 b	1730 s
	0	(391.8)		(67.49)	(6.32)		
14d	H	$C_{17}H_{22}FeO_3$	46	61.86	6.67	3536 b	1741 s
	1	(329.8)		(62.00)	(6.69)		
14e	H	$C_{18}H_{24}FeO_3$	25	62.83	6.98	3522 b	1732 s
	2	(343.8)		(62.71)	(7.17)		
15a	H	$C_{18}H_{22}FeO_4$	51	60.37	6.15	–	1742 s
	0	(356.8)		(61.44)	(6.30)		
15b	Me	$C_{19}H_{24}FeO_4$	46	61.32	6.46	–	1738 s
	0	(371.8)		(61.61)	(6.52)		
15c	Ph	$C_{24}H_{26}FeO_4$	44	66.39	5.99	–	1744 s
	0	(433.8)		(66.02)	(6.17)		
15d	H	$C_{19}H_{24}FeO_4$	50	61.32	6.46	–	1744 s
	1	(371.8)		(60.88)	(6.18)		
15e	H	$C_{20}H_{26}FeO_4$	36	62.21	6.74	–	1734 s
	2	(385.8)		(62.43)	(6.75)		

[a] All the compounds prepared are yellow-orange resins.

TABLE VI

^{1}H NMR spectra of $Fc(CH_2)_nCHRCH(CH_aH_bOH)CH_cH_dOAc$ (**14**) and $Fc(CH_2)_nCHRCH(CH_cH_dOAc)_2$ (**15**)

Compd. no.	Ferrocene protons		Methine protons[a]		Methylene protons[a]					Methyl protons		OH
			α	ω	H_cH_d	H_aH_b	α	β	γ	CH_3COO	CH_3CH	
14a	4.10 s (9)	4.07 m	–	1.88 (1, m)	4.17 (2, m)	3.53 (2, m)	2.44 (2, d)			2.08 (3, s)	–	2.05 (1, b)
14b	4.14 m (10)		2.73 m	1.77 (1, m)	4.08 m 3.93 dd (2)	3.53 (2, m)	–	–	–	2.04 (3, s)	1.36 (3, d)	2.73 (1, b)
14c[b]	4.12 m (10)	3.76 s	4.21 m	1.92 (1, m)	3.97 (2, m)	3.57 m 3.46 m (2)	–	–	–	2.09 s 2.01 s (3)	–	2.05 (1, b)
14d	4.12 s (9)	4.08 s	–	1.85 (1, m)	4.21 (2, dd)	3.62 m 3.54 m (2)	2.39 (2, t)	1.54 (2, m)	–	2.08 (3, s)	–	2.01 (1, b)
14e	4.12 s (9)	4.06 s	–	1.80 (1, m)	4.18 (2, dd)	3.59 dd 3.49 dd (2)	2.31 (2, t)	1.35 (2, m)	1.54 (2, m)	2.07 (3, s)	–	2.12 (1, b)
15a	4.10 s (9)	4.05m	–	1.96 (1, m)	4.21 m 3.96 m (4)	–	2.46 (2, d)	–	–	2.06 (6, s)	–	–
15b	4.12 m (10)		2.77 m	1.90 (1, m)	4.06 m 3.85 dd (4)	–	–	–	–	2.03 (6, s)	1.36 (3, d)	–
15c[b]	4.08 m (10)	3.78 s	4.10 m	2.43 (1, m)	3.95 m 3.65 m (4)	–	–	–	–	2.06 s 1.98 s (6)	–	–
15d	4.08 m (9)	4.06 m	–	2.01 (1, m)	4.15 (4, m)	–	2.35 (2, t)	1.59 (2, m)	–	2.06 (6, s)	–	–
15e	4.12 s (9)	4.06 m	–	2.01 (1, m)	4.01 (4, m)	–	2.30 (2, t)	1.38 (2, m)	1.52 (2, m)	2.05 (6, s)	–	–

[a] See footnote at Table II. H_c and H_d were registered under the same integral line as ferrocene protons (*e.g.*, in the case of **14a**, signals of 9 Fc protons and 2 H_cH_d were not well resolved and were registered together as 11 protons).

[b] Benzene protons were registered as folows: **14c**, δ 7.27 m and 7.34 m; **15c** 7.30 m and 7.36 m ppm (5H). Two singlets corresponding to the acetate protons indicate the presence of two diastereomeric pairs of enantiomers.

TABLE VII

^{13}C HNM spectra of $Fc(CH_2)_nCHRCH(CH_2OH)CH_2OOCCH_3$ (**14**) and $Fc(CH_2)_nCHRCH(CH_2OOCCH_3)_2$ (**15**)

Compd. no.	Ferrocene C-atoms			Methine C-atoms		Methylene C-atoms					Methyl C-atoms		Benzene C-atoms		COO
	unsubst. ring	substit. ring													
		CH	C	α	ω	α	β	γ	CH_2OH	CH_2OAc	$CHCH_3$	$OCCH_3$	C	CH	
14a	67.78	68.84 69.07	85.83	–	42.57	28.51		–	64.08	62.23	–	20.76	–	–	171.74
14b	65.66	67.12 68.18 68.43	92.38	31.85	46.91	–	–	–	63.54	61.53	17.13	20.74	–	–	170.26
14c	66.82	68.63 68.89 69.16 69.89	91.40	44.35	46.76	–	–	–	63.43	60.92	–	20.74	143.32	126.67 126.72 128.31	171.59
14d	67.14	67.81 68.42	88.54	–	40.01	26.67	28.86	–	64.27	62.45	–	20.71	–	–	171.72
14e	67.19	68.15 68.61	89.02	–	40.07	29.52	27.39	28.29	64.41	62.39	–	20.69	–	–	171.68
15a	67.58	68.51 68.81	84.78	–	39.09	28.68	–	–	–	63.73	–	20.65	–	–	171.01
15b	66.09	67.30 68.21 68.61	91.92	31.97	43.27	–	–	–	–	62.96 62.78	16.91	20.75 20.60	–	–	171.01
15c	66.75	68.52 68.74 69.46	90.80	43.18	44.59	–	–	–	–	62.87 62.67	–	20.74 20.60	142.73	–	170.94
15d	67.97	68.63 69.37	89.01	–	36.78	26.48	29.15	–	–	63.95	–	20.71	–	–	171.12
15e	67.32	68.24 68.72	88.96	–	36.83	29.44	27.72	28.29	–	64.04	–	20.66	–	–	171.09

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SAŽETAK

Priprava 2-(ferocenilalkil)- i 2-[fenil(ferocenil)alkil]-1,3-propandiola i njihovih acetata

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Reakcijom pogodno odabranih reagensâ $Fc(CH_2)_nCHRX$ (**1**–**3**, **6** i **9**) s natrijevim dietil-malonatom u suhom ksilenu pripravljeni su odgovarajući dietil-(ferocenilalkil)malonati i dietil-[fenil(ferocenil)alkil)malonati (**11**) u 81–91%-tnom iskorištenju. Uporabom $Fc(CH_2)_nCHRX$ (**4**, **7**, **8** i **10**) pri sličnim okolnostima nastaju transesterifikacijski produkti – etil-ferocenilalkil-malonati, odnosno etil-fenil(ferocenil)alkil-malonati (**12**). Redukcijom kondenzacijskih produkata **11** s litijevim aluminijevim hidridom u dietil-eteru dobiveni su odgovarajući dioli **13** (45–66%), koji će se u daljnim istraživanjima upotrijebiti kao supstrati za lipazama katalizirane pretvorbe s vinil-acetatom u kiralne monoacetate. Djelovanjem acetanhidrida na benzenske otopine diolâ **13** pripravljeni su odgovarajući mono- **14** (25–52%) i diacetati **15** (36–51%).