Synthesis and surfactant properties of symmetric and unsymmetric sulfosuccinic diesters, Aerosol-OT homologues

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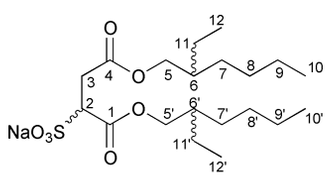
The synthesis and surfactant behaviour of two series of sulfosuccinic diesters, AOT-related compounds, are described [Aerosol-OT **1**: sodium bis(2-ethylhexyl) sulfosuccinate]. The first family contains unsaturated, racemic or enantiopure, 2-ethylhex(en)yl chains with various positions of the double bond. These compounds are readily prepared from the corresponding unsaturated alcohol by the standard two-step procedure; their critical micelle concentrations are higher than those of normal AOT and depend on the position of the double bond. The second series consists of nonsymmetric homologues with two different substituents: various unsymmetrical sulfosuccinic diesters with two enantiopure saturated or unsaturated chains of opposite configuration, or with two different substituents like methyl and 2-ethylhexyl, hydrogenated and deuterated chains as well as saturated and unsaturated chains are described. These unsymmetrical sulfosuccinic diesters are readily obtained in a three-step synthetic procedure involving the regiospecific sulfonation of maleic monoester in aqueous medium. The structure of the sodium 4-alkyl-2-sulfosuccinic acid key intermediate is unambiguously resolved by NMR comparative analysis of the hydrogenated and deuterated derivatives. The surfactant behaviour of some unsymmetrical compounds is studied.

Introduction

During the last decade there has been a growing interest in separation techniques using chiral surfactants like capillary electrophoresis (MEKC)[1,2] or membrane-based separation[3] that afford attractive means for racemate resolution. Moreover, it has long been recognized that supramolecular assemblies of surfactant molecules can enhance chemical rates and influence the selectivity by the microenvironment provided by the aggregates.[4] Some enantioselective reactions have been described which occur in the presence of chiral functional surfactants.[5,6] Nevertheless, unless there are specific interactions between the surfactant molecules and the reactants or the solutes, the enantioselectivity is most often limited by the dynamic features of the surfactant aggregates. Improvements can be obtained by using macromolecular amphiphiles[2,7] or by designing new chiral surfactants that self-aggregate in more rigid supramolecular assemblies.[8,9]

In this context we are involved in the development of chiral, optically active, dialkyl sulfosuccinate surfactant relatives of the well-known Aerosol-OT® **1** (AOT, sodium bis(2-ethylhexyl) sulfosuccinate, Fig. 1). Indeed AOT has been extensively investigated due to its exceptional efficiency in forming reverse micellar aggregates in organic solvents and in entrapping large amounts of water.[10,11] Various hydrophilic molecules can be solubilised within the water core so that a great number of chemical reactions have been successfully performed in AOT reverse microemulsions.[11,12] Some optically active AOT-related compounds with enantiopure (*S*)-2-octyl, (*R*)- or (*S*)-2-ethyl-1-hexyl chains have been synthesized but, unfortunately, their enantioselectivities in chemical reactions and liquid membrane separation have been found to be very weak.[13,14] In order to improve the enantioselectivity in such reverse micelle or microemulsion processes and to delineate structure–performance relationships, we have chosen to develop new AOT-related compounds.



1 (AOT)

Fig. 1 Structure of Aerosol OT **1**.

In this paper, we report the synthesis of two series of new sodium sulfosuccinates with the AOT-atomic framework. The first homologous series contains unsaturated, racemic or enantiopure tails with various positions of the double bond that may afford a means of modulating surfactant–surfactant or surfactant–solute interactions. Furthermore, these compounds can be used as precursors for the preparation of macromolecular amphiphiles.[15]

The second series consists of nonsymmetric homologues with two different substituents, either two saturated or unsaturated chains of opposite configurations (*unlike* stereoisomers) or two different chains. For this purpose, a new and efficient synthetic pathway to unsymmetrical sulfosuccinic diesters has been developed. The solution behaviour and surfactant properties of these new compounds are then compared with those of AOT.

Results and discussion

Preparation of symmetric bis(2-ethylhexenyl) sulfosuccinic diesters

The synthesis of the unsaturated sulfosuccinic diesters **5a**–**c** was achieved in two steps from the corresponding alcohols (Scheme 1). The unsaturated alcohols **2a** and **2b** were prepared by alkylation of the corresponding hexenoic acid with iodoethane

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followed by the reduction of the α-ethylated acid with $LiAlH_4$ with about 60% overall yields.[16] The alcohol **2b** was obtained as a mixture of two isomers with a relative *E* : *Z* ratio of 77 : 22 from commercial hex-4-enoic acid. The β-unsaturated alcohol **2c** was prepared in one step by reduction of 2-ethylhex-2-enoic acid with good yield (90%, *E* : *Z* = 96 : 4). (*R*) and (*S*) enantiomers of 2-ethylhex-5-en-1-ol, (***R***)-(−)-**2a** (ee ~ 96%) and (***S***)-(+)-**2a** (ee ~ 82%), were readily obtained in good yields by lipase PS-catalysed transesterification of the racemic alcohol **2a** according to the recently described procedure.[16]

The sulfosuccinic diesters ***rac***, (***R,R***)-, (***S,S***)-**5a** and **5b** were prepared with acceptable overall yields (35 to 40%) by esterification of maleic acid followed by sulfonation of the maleic diesters with sodium bisulfite.[13] For the thermosensitive β-unsaturated alcohol **2c**, the esterification yield is very poor (only 33%) so that it is highly preferable to use fumaroyl chloride as starting material.[17] The fumaric diester **4c** was thus obtained in 62% yield by reacting the alcohol with fumaroyl chloride in dichloromethane at room temperature in the presence of potassium carbonate. Subsequent sulfonation readily afforded the sulfosuccinic diester **5c** in 76% yield.

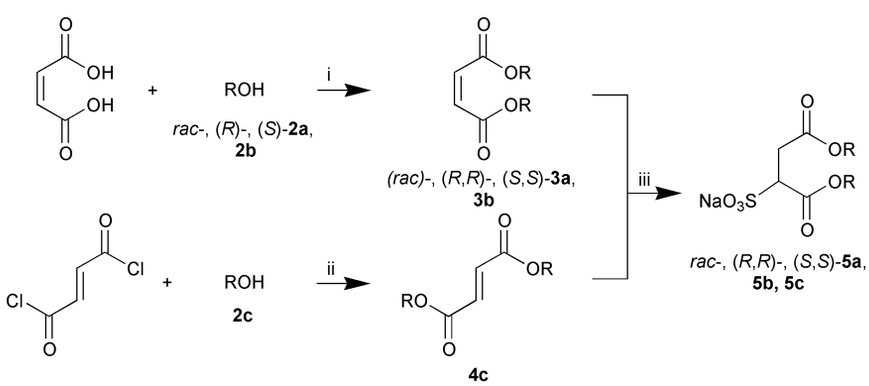
In every case, the nucleophilic addition of bisulfite selectively takes place on the activated double bond of maleic esters provided that sodium bisulfite is progressively added. Nevertheless, when a terminal double bond is present, the sulfonation of the alkenyl chains becomes competitive and the sulfosuccinic diesters ***rac***, (***R,R***)- and (***S,S***)-**5a** are isolated with slightly lower yields (50 to 70%). The sulfosuccinic unsaturated diesters **5a**–**c** were fully characterised by NMR spectroscopy, mass spectrometry and elemental analysis. Complete assignment of the ^1H and ^{13}C NMR signals was achieved from the HCOR spectra. As already observed, the addition of bisulfite is not stereoselective and leads to an equimolar mixture of epimers at the chiral carbon atom C_2 linked to the sulfonate group.[13] For example, the presence of equimolar amounts of both diastereomers has been unambiguously demonstrated for the diester (***R,R***)-**5a** by the ^1H and ^{13}C NMR study of its (*R*)-(+)-α-methylbenzylammonium salt **6a**, prepared by cation exchange in biphasic water–cyclohexane medium. In the ^{13}C NMR spectrum, the diastereomeric discrimination was mainly observed for the sp^3 carbons of the sulfosuccinic part C_2 and C_3 (respectively 61.57, 61.53 and 33.21, 33.10 ppm), the two carbonyl nuclei C_1 and C_4 (170.92, 170.86 and 169.19, 168.97 ppm) and extended as far as the ester substituent C_7 and $C_{7'}$. It is worth noticing that the chirality effect is also observed to a lower extent in the ^{13}C NMR spectra of the sodium salts where the signals of some sp^3 carbons of the ester substituents are split.[18]

Preparation of unsymmetrical sulfosuccinic diester

Sulfosuccinic diesters with two different substituents cannot be prepared as described above since the addition of bisulfite to nonsymmetric maleic diesters leads to a mixture of two regioisomers.[15] Similar behaviours have been observed for other nucleophilic additions to maleate and unsymmetrical α-substituted succinic diesters have been obtained by multistep procedures.[19]

We found that unsymmetrical sulfosuccinic diesters are readily obtained from maleic anhydride in a three-step synthetic procedure, depicted in Scheme 2, involving (1) preparation of maleate monoester, (2) addition of bisulfite and (3) esterification of the sulfosuccinic monoester with a second alcohol in the presence of DCC as coupling reagent. Various unsymmetrical diesters with two enantiopure saturated or unsaturated 2-ethylhex(en)yl chains of opposite configuration **11**, **12** or with two different substituents like methyl and 2-ethylhexyl **13**, hydrogenated and deuterated chains **14** as well as saturated and unsaturated chains **15** have thus been obtained.

The usefulness of this synthetic pathway arises from the regiospecific addition of bisulfite to maleate monoesters **7**, **8** in aqueous medium that affords a unique isomer. The position of the sulfonate, α to the carboxylic acid and β to the ester, has been deduced from ^1H and ^{13}C NMR spectra of hydrogenated and deuterated sulfosuccinic monoesters **9**, $\mathbf{D_2}$-**9**. The ^1H NMR spectra show that the methyne proton H_2 α to the sulfonate is deshielded in the acidic CO_2H form (4.21 ppm in D_2O + 1



	R
2a, 3a, 5a	—CH_2-CH(Et)-CH_2-CH_2-CH=CH_2 *rac*, (*R*) or (*S*)
2b, 3b, 5b	—CH_2-CH(Et)-CH_2-CH=CH-CH_3 *Z*/*E* = 22/77
2c, 4c, 5c	—CH_2-C(Et)=CH-CH_2-CH_2-CH_3

Scheme 1 Synthesis of unsaturated sulfosuccinic diesters **5**: (i) PTSA, toluene–dioxane, reflux; (ii) K_2CO_3–$MgSO_4$, CH_2Cl_2, RT; (iii) $NaHSO_3$, H_2O–Pr^iOH, 60 °C.

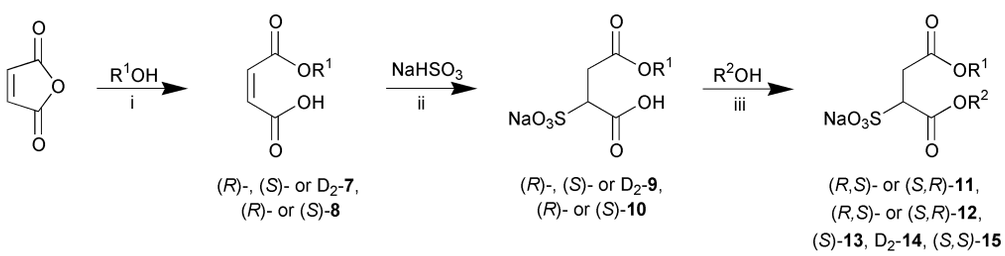
equiv. DCl, pD ~ 5 and 3.99 ppm in D_2O; 3.62 ppm in DMSO and 3.46 ppm in DMSO + 1 equiv. Na_2CO_3) while the chemical shifts of the methylene protons H_3 are not significantly modified by the deprotonation of the carboxylic acid (2.99 and 2.96 ppm in D_2O or D_2O + DCl; 2.83 and 2.72 ppm in DMSO and 2.83 and 2.60 ppm in DMSO + 1 equiv. Na_2CO_3). The carbonyl nuclei C_1 and C_4 have been unambiguously assigned from the comparison of the ^{13}C NMR spectra of hydrogenated and deuterated compounds: as illustrated in Fig. 2, upon selective irradiation of both methylene protons H_3, the carbonyl ester nucleus C_4, at 171.3 ppm, exhibits a $^3J_{C-H}$ coupling constant of 2.2 Hz with the methyne protons H_5 of the ester substituent that disappears for the deuterated product while, in both hydrogenated and deuterated compounds, the carbonyl acid nucleus C_1 gives a doublet at 169.7 ppm with a $^3J_{C-H}$ coupling constant of 6 Hz with the proton H_2. In the non-decoupled spectra, the ester nucleus C_4 appears as a multiplet ($^2J_{C4-H3}$ 7.3 Hz; $^3J_{C4-H2}$ 2.8 Hz; $^3J_{C4-H5}$ 2.2 Hz) that simplifies into a double triplet in the deuterated product ($^2J_{C4-H3}$ 7.3 Hz; $^3J_{C4-H2}$ 2.8 Hz) while the acid nucleus C_1 gives a well defined triple doublet with three different coupling constants ($^2J_{C1-H2}$ 6 Hz; $^3J_{C1-H3}$ 8.6 Hz; $^3J_{C1-H3'}$ 3.4 Hz) for both hydrogenated and deuterated compounds. The clearly distinct ^3J coupling constants arise from distinct dihedral angles with the two diastereotopic protons H_3 and $H_{3'}$, thus demonstrating that the unsubstituted methylene CH_2 is β to the carboxylic acid function in agreement with previously reported NMR data for similar atomic frameworks.[20,21]

The regiospecificity of the nucleophilic addition may be explained by the decrease of the carboxylic acid electron-withdrawing effect upon deprotonation in neutral aqueous medium that induces a shift of the double bond electron-density toward the ester and favours the addition on the most electrophilic carbon centre β to the ester group. The polarization of the double bond induced by deprotonation is confirmed by the ^1H NMR analysis of maleate half ester **7**: in neutral aqueous medium (D_2O or D_2O–CD_3OD) the ethylenic protons are nonequivalent and give well separated signals (6.58 and 5.76 ppm) while in nonaqueous medium or in acidic water (DMSO, D_2O + DCl) their chemical shifts are very close (6.39 and 6.36 ppm). The following previously reported results further illustrate and confirm the regioselectivity enhancement resulting from the acid dissociation in water and shed light on the interest of performing these reactions in aqueous media: Aerhard *et al.* found that the addition of bromide to maleic monoester in acidic organic medium leads to a mixture of two regioisomers[20] while Neumann *et al.* obtained a unique product from the addition of cysteine or homocysteine in water.[22]

The unsymmetrical sulfosuccinic diesters **11**–**15** are then readily obtained by esterification in the presence of DCC–DMAP with acceptable yields (55–75%). NMR spectroscopy and thin layer chromatography of the highly unsymmetrical methyl/2-ethylhexyl diester **13** unambiguously demonstrate that a single product is obtained, thus illustrating the regiospecificity of the whole synthetic pathway. It is worth noticing that acid-catalysed esterification, either in the presence of PTSA or BF_3, has been found unsuccessful because it leads to significant amounts of transesterification side-products.[17] On the other hand, the unsymmetrical methyl/2-ethylhexyl diester **13** can alternatively be prepared with fairly good yields from the silver salt of 2-ethylhexyl sulfosuccinate **9** using the procedure depicted in Scheme 3: the reaction of iodomethane with the silver salt in toluene affords the methyl sulfonate methyl carboxylate diester **16**. Subsequent nucleophilic substitution of the methyl sulfonate with sodium bromide quantitatively liberates the sodium sulfosuccinic diester **13** with more than 90% overall yield.[17,23] Nevertheless, when larger alkyl halides like 2-iodoethylhexane are used, the reaction yields are much lower (only 45%).[17]

Surfactant properties

The surfactant behaviour of unsaturated and saturated sodium sulfosuccinates **5a**–**c**, **11**, **12** and **15** has been studied by surface tension measurements of aqueous solutions at 25 °C (Fig. 3).



	R^1	R^2
7, 9, 11	—CH_2-CH(Et)-CH_2-CH_2-CH_2-CH_3 (*R*) or (*S*)	—CH_2-CH(Et)-CH_2-CH_2-CH_2-CH_3 (*S*) or (*R*)
8, 10, 12	—CH_2-CH(Et)-CH_2-CH_2-CH=CH_2 (*R*) or (*S*)	—CH_2-CH(Et)-CH_2-CH_2-CH=CH_2 (*S*) or (*R*)
D_2-**7**, D_2-**9**, D_2-**14**	—CD_2-CH(Et)-CH_2-CH_2-CH_3 *rac*	—CH_2-CH(Et)-CH_2-CH_2-CH_3 *rac*
13, 15	—CH_2-CH(Et)-CH_2-CH_2-CH_3 (*S*)	CH_3 **13** or —CH_2-CH(Et)-CH_2-CH_2-CH=CH_2 (*S,S*)-**15**

Scheme 2 Synthesis of dissymmetric diesters **11**–**15**: (i) 90 °C; (ii) $NaHSO_3$, H_2O–Pr^iOH, 60 °C; (iii) DCC, DMAP, DMAP–HCl, DMF, RT.

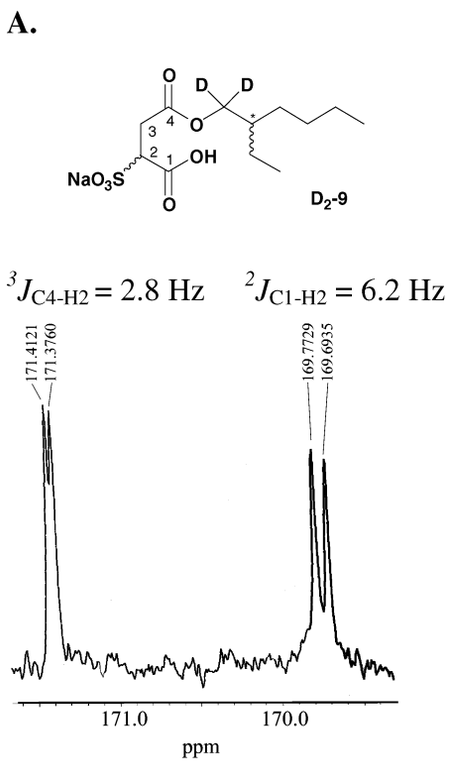


Fig. 2 ^{1}H-coupled ^{13}C partial spectrum of carbonyl nuclei C_1, C_4 in DMSO-d_6 after irradiation of H_3: A. **D_2-9**; B. (***S***)**-9**.

The parameters derived from these measurements are given in Table 1 and compared with those of normal AOT **1**.

The cmc of unsaturated surfactants **5a**, **5b** and **5c**, which range from 1.7 to 3.6 mM, are higher than those of saturated ones (1 mM), in agreement with a hydrophilic contribution of the electron rich polarisable double bond.[24] It is worth noticing that the cmc value depends on the position of the unsaturation: the longer the distance between the double bond and the sulfosuccinic polar head group, the higher the cmc value. Interestingly, the cmc value of the unsymmetrical saturated–

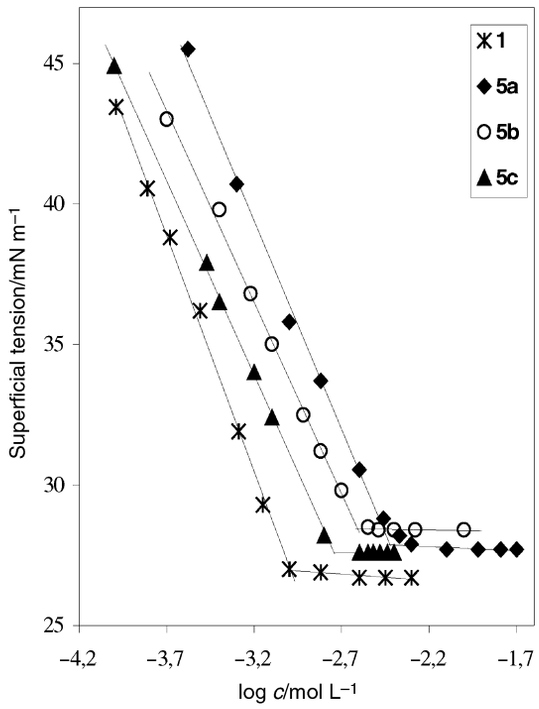
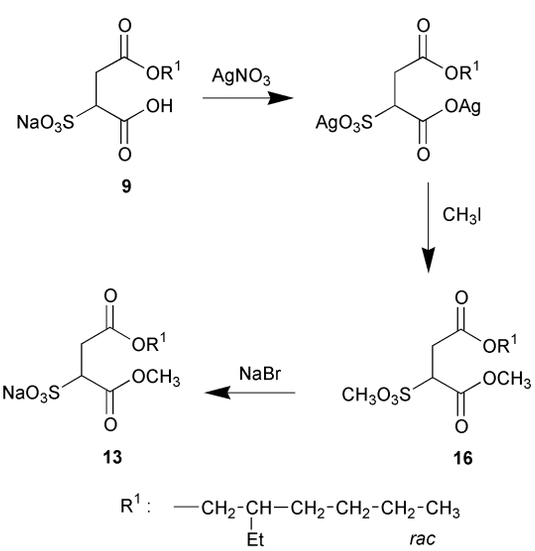


Fig. 3 Surface tension γ *vs.* log concentration for surfactants **5a**–**c** and Aerosol OT **1** at 25 °C.



Scheme 3 Alternative synthesis of the dissymmetric diester **13**.

unsaturated sulfosuccinate **15** lies between the cmc values of its saturated and unsaturated homologues. The presence of a double bond does not significantly influence the interfacial packing since the minimum surface tensions reached above the cmc (27.5 to 28.5 mN m^{-1}) as well as the areas per head group a_s at the air–water interface (120 to 140 Å^2), evaluated using the Gibbs adsorption isotherm, are only slightly higher than those of saturated derivatives.

Furthermore, the parameters obtained for optically active sulfosuccinates with enantiopure unsaturated or saturated tails (***R,R***)-, (***S,S***)-, (***S,R***)-, (***R,S***)**-12** and (***S,R***)-, (***R,S***)**-11** indicate that the configuration of the lipophilic chains weakly affects the surfactant properties.

Conclusion

The synthetic pathways to a series of new sodium sulfosuccinate surfactants with racemic or enantiomerically pure saturated or unsaturated branched tails have been established.

Table 1 Surfactant properties of sulfosuccinates. Values obtained from surface tension measurements

Compound	cmc/mM	Γ/μmol m^{-2}	a_s/Å^2	γ_{min}/mN m^{-1}
Unsaturated sodium sulfosuccinates				
5a	3.7 ± 0.2[a]	1.35 ± 0.05	125 ± 4	27.7
5b	2.4 ± 0.2[a]	1.30 ± 0.05	129 ± 5	28.4
5c	1.7 ± 0.2[a]	1.30 ± 0.05	126 ± 5	27.6
(***R*,*R***)-**5a**	2.9 ± 0.2	1.30 ± 0.04	127 ± 5	27.8
(***S*,*S***)-**5a**	3.6 ± 0.2	1.35 ± 0.02	124 ± 2	27.7
(***S*,*R***)-**12**	2.6 ± 0.1	1.20 ± 0.05	140 ± 5	27.3
(***R*,*S***)-**12**	3.1 ± 0.2	1.35 ± 0.05	123 ± 3	27.7
Unsaturated–saturated sodium sulfosuccinates				
15	1.9 ± 0.1	1.35 ± 0.04	123 ± 3	26
Saturated sodium sulfosuccinates				
(***R*,*S***)-**11**	1.1 ± 0.1	1.50 ± 0.08	112 ± 6	26.9
(***S*,*R***)-**11**	1.0 ± 0.1	1.20 ± 0.02	138 ± 3	27
(***R*,*R***)-**1**[b]	0.9	1.1	160	26.5
(***S*,*S***)-**1**[c]	1.4	1.3	130	26.5
AOT-1[d]	1.0 ± 0.1	1.40 ± 0.05	120 ± 5	26.7

[a] In good agreement with the cmc values deduced from conductivity measurements, respectively: 3.1, 2.5 and 1.7 mM for **5a**, **5b** and **5c**. [b] From ref. 13*a*. [c] From ref. 13*b*. [d] Commercial AOT purified by column chromatography on silica gel.

The synthetic approach to unsymmetrical sulfosuccinates described in this paper is hoped to be quite general and offers the opportunity to produce various sulfosuccinic derivatives simply by changing the reacting alcohols. Moreover, the regiospecificity of the addition arising from deprotonation in aqueous medium, depicted here in the case of bisulfite, is expected to be attainable with other nucleophiles in neutral aqueous medium, thus giving access to other substituted succinic derivatives.

The preliminary studies of the surfactant behaviour of these AOT-related compounds show that the introduction of a double bond in the 2-ethylhexyl atomic framework results in the expected increase of the cmc values. Moreover, the interfacial packing is not significantly influenced by the presence of a double bond or by the absolute configuration of the chains so that the unsaturated and optically active sodium sulfosuccinates developed in this work are hoped to exhibit microemulsifier efficiencies similar to that of normal AOT. The use of these new chiral surfactants as well as of macromolecular amphiphiles resulting from their polymerisation for asymmetric induction in chemical reactions and chiral discrimination in separation processes is currently being studied.

Experimental

Unless otherwise mentioned, all starting materials were purchased from Acros Organics. Solvents were distilled by conventional methods. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker AC 300 (respectively 300 and 75 MHz). IR spectra were obtained on a Magna-IR Spectrometer 550 (KBr pellets or films). Mass spectra were determined using an electrospray ion-source (ES) on a Platform II Mass Spectrometer. Chemical ionisation (CI) was carried out using CH_4 or NH_3 as the reactant gas and electronic impact (EI) was performed at 70 eV on a GC/MS Engine HP-5989 Spectrometer. GC analyses were obtained with an Erba Science GC 6000 gas chromatograph using nitrogen as carrier and an Alltech RSL150 capillary column (25 m × 0.25 mm id); temperature program isotherm at 40 °C for 3 min, then increased at a rate 10 °C min^{-1} to 200 °C, isotherm at 200 °C for 5 min. Optical rotations were measured on a Perkin-Elmer Model 241 polarimeter at 25 °C and are given in 10^{-1} deg cm^2 g^{-1}. Melting points and boiling points are uncorrected. Surface tension measurements were obtained by the Du Noüy method with a platinum-ring with a Krüss K10T tensiometer, thermostatted at 25 °C. Elemental analyses were obtained from the Service Central d'Analyses (CNRS, Vernaison).

Synthesis of unsaturated alcohols 2a–c

2-Ethylhex-5-en-1-ol 2a, (*R*)-(−)- and (*S*)-(+)-2-ethylhex-5-en-1-ol (*R*)-2a and (*S*)-2a. These were prepared according to the previously described procedure.[16] Their enantiomeric excesses are respectively: (***R*)-2a** ee ~ 96%, (***S*)-2a** ee ~ 82%.

Synthesis of 2-ethylhex-4-enoic acid. To a cooled solution (0 °C) of LDA (27.4 mL of a 2 M solution in THF–*n*-heptane, 55 mmol) was added under nitrogen hex-4-enoic acid (2.5 g, 21 mmol, *Z* : *E* mixture purchased from Lancaster) in anhydrous THF (25 mL). After stirring at room temperature for 30 min and subsequent cooling to 0 °C, iodoethane (5.1 g, 32 mmol) was added. The mixture was stirred for 3 h at room temperature and the reaction was then quenched with 3 M HCl (90 mL). After removal of THF, the reaction mixture was extracted with Et_2O and the combined organic phases were washed with 1 M NaOH. The aqueous basic layer was acidified to pH ~ 1 with conc. HCl and then extracted with Et_2O. The crude 2-ethylhex-4-enoic acid was isolated after drying over Na_2SO_4 and removal of the solvent and was used in the next step without further purification (2.4 g, 77%, colourless oil); R_f (Et_2O–*n*-hexane 1 : 1, I_2) 0.48; t_r (GC, min) 11.6 (88%); δ_H ($CDCl_3$) 0.94 (6 H, t, *J* 7, CH_3), 1.63 (5 H, m, CH_2 and CH_3-CH=CH), 2.27 (3 H, m, CH and CH_2-CH=CH), 5.46 (2 H, m, =CH).

Synthesis of 2-ethylhex-4-en-1-ol 2b. To a solution of crude 2-ethylhex-4-enoic acid (2.4 g, 16 mmol) in dry Et_2O (50 mL) at 0 °C was slowly added $LiAlH_4$ (1.6 g, 42 mmol). After stirring at room temperature for 2 h, the mixture was poured into H_2O (200 mL) and conc. HCl was added until the solution became clear. The resulting mixture was extracted with Et_2O. The combined organic phases were washed with brine, dried over Na_2SO_4, and purified by silica gel column chromatography with Et_2O–*n*-hexane 1 : 1 as eluent to provide **2b** (1.2 g, 68%); R_f (Et_2O–*n*-hexane 1 : 1, H_2SO_4) 0.59; t_r(GC, min) 8.9 (*Z*), 9.2 (*E*), (ratio *Z* : *E* 22 : 77); ν_{max}(film)/cm^{-1} 3400 (OH), 1500 (C=C), 1000 (C–O); δ_H ($CDCl_3$) 0.90 (3 H, t, *J* 7.8, CH_3), 0.99 (3 H, t, *J* 7.5, CH_3), 1.32 (2 H, m, CH_2), 1.66 (4 H, m, CH, CH_3-CH=CH), 2.03 (2 H, m, CH_2-CH=CH), 3.54 (2 H, d, *J* 5.3, OCH_2), 5.34 (2 H, m, =CH); δ_C ($CDCl_3$) 11.25 (CH_3), 17.88 (CH_3-CH=CH), 23.25, 33.57 (CH_2), 42.38 (CH), 65.18 (OCH_2), 125.07 (CH= *Z*), 126.46 (CH= *E*), 128.75 (CH= *Z*), 129.43 (CH= *E*); *m*/*z* (EI) 128 (M^+), 110 ($M^+ - H_2O$).

Synthesis of 2-ethylhex-2-en-1-ol 2c. Prepared as described above for **2b**, starting from commercially available (Lancaster) 2-ethylhex-2-enoic acid (3.0 g, 21 mmol) and $LiAlH_4$ (2.4 g, 63 mmol) to provide **2c** (2.3 g, 90%); bp = 56 °C (8 mbar); R_f (Et_2O–*n*-hexane 1 : 1, H_2SO_4) 0.50; t_r (GC, min) 7.9 (*Z*), 8.05 (*E*), (ratio *Z* : *E* 4 : 96); ν_{max}(film)/cm^{-1} 3300 (OH), 1640 (C=C), 1020 (C–O); δ_H ($CDCl_3$) 0.91 (3 H, t, *J* 7.5, CH_3), 0.99 (3 H, t, *J* 7.5, CH_3), 1.36 (2 H, m, CH_2), 1.39 (H, s, OH), 2.07 (4 H, m, CH_2-CH=CH), 4.03 (1.8 H, s, OCH_2 *E*), 4.14 (0.2 H, s, OCH_2 *Z*), 5.37 (H, t, *J* 7.5, CH=); δ_C ($CDCl_3$) 13.28, 13.74 (CH_3), 21.02, 22.87, 29.34 (CH_2), 59.90 (OCH_2 *Z*), 66.92 (OCH_2 *E*), 126.37 (CH *E*), 127.44 (CH *Z*), 140.65 (C=C); *m*/*z* (EI) 128 (M^+, 39%), 110 ($M^+ - H_2O$, 14), 57 (100).

Synthesis of saturated alcohols 2d

Deuterated 2-ethylhexanol-d_2 D_2-2d. Prepared as described above for **2b**, starting from 2-ethylhexanoic acid (0.6 g, 4.1 mmol) and $LiAlD_4$ (0.4 g, 9.5 mmol) to provide alcohol **D_2-2d** (0.53 g, 99%); R_f (Et_2O–*n*-hexane 1 : 8, H_2SO_4) 0.33; t_r (GC,

min) 6.2; δ_H ($CDCl_3$) 0.90 (6 H, t, *J* 7, CH_3), 1.23–1.45 (9 H, m, CH, CH_2); *m*/*z* (CI, CH_4) 131 (MH^+, 27%), 115 ($MH^+ - H_2O$, 100%).

(*R*)-(−)- and (*S*)-(+)-2-ethylhexan-1-ol (*R*)-2d and (*S*)-2d. Prepared by lipase catalysed transesterification according to the previously described procedure.[16] Their enantiomeric excesses are respectively: (***R***)-**2d** ee ~ 94% and (***S***)-**2d** ee ~ 90%.

Synthesis of symmetric sulfosuccinic diesters 5

Preparation of maleic diesters: 3a, (*R,R*)-3a, (*S,S*)-3a and 3b. *(Z)-But-2-ene-1,4-dioic acid bis(2-ethylhex-5-enyl) ester **3a**.* The diester **3a** was prepared according to the previously described procedure.[13] Starting from maleic acid (230 mg, 2.0 mmol), alcohol **2a** (500 mg, 3.9 mmol), PTSA (10 mg, 0.1 mmol) in toluene (4 mL), crude product **3a** was isolated (420 mg, 64%) (Found: C, 70.33; H, 9.64. Calc. for $C_{20}H_{32}O_4 \cdot 0.25H_2O$: C, 70.44; H, 9.61%); R_f (Et_2O–petroleum ether 1 : 5, H_2SO_4) 0.79; ν_{max}(film)/cm^{-1} 1730 (C=O), 1650 (C=C); δ_H ($CDCl_3$) 0.91 (6 H, t, *J* 7.5, CH_3), 1.37–1.46 (8 H, m, CH_2), 1.67 (2 H, m, CH), 2.08 (4 H, m, CH_2-CH=CH_2), 4.12 (4 H, d, *J* 5.9, OCH_2), 4.96 (2 H, dm, *J* 10.3, =C*H*H), 5.03 (2 H, dm, *J* 16.9, =CH*H*), 5.69 (2 H, ddt, *J* 16.9, *J* 10.3, *J* 6.6, C*H*=CH_2), 6.25 (2 H, s, CH=CH); δ_C ($CDCl_3$) 10.82 (C12′, C12), 23.58 (C11′, C11), 29.89 (C7′, C7), 31.10 (C8′, C8), 41.39 (C6′, C6), 65.02 (C5′, C5), 114.36 (C10′, C10), 129.70 (C2, C3), 138.51 (C9′, C9), 165.24 (C1, C4).

*(Z)-But-2-ene-1,4-dioic acid bis[(R)-2-ethylhex-5-enyl] ester (**R,R**)-3a and (Z)-but-2-ene-1,4-dioic acid bis[(S)-2-ethylhex-5-enyl] ester (**S,S**)-3a.* Prepared as described above for **3a** starting from enantiomers (***R***)-**2a** (570 mg, 86%) and (***S***)-**2a** (550 mg, 84%) respectively. The IR, MS, NMR spectra are identical with those of **3a**.

*(Z)-But-2-ene-1,4-dioic acid bis(2-ethylhex-4-enyl) ester **3b**.* Prepared as described above for **3a** starting from maleic acid (280 mg, 2.3 mmol) in dioxane (2 mL) and 2-ethylhex-4-en-1-ol **2b** (600 mg, 4.6 mmol). **3b** was isolated after extraction and purification by column chromatography with Et_2O–petroleum ether 1 : 5 as eluent (460 mg, 56%); R_f (Et_2O–petroleum ether 1 : 5, H_2SO_4) 0.80; t_r (GC, min) 26.05, 26.55 (isomers *Z*, *E*); ν_{max}(film)/cm^{-1} 1730 (C=O), 1640 (C=C); δ_H ($CDCl_3$) 0.90 (6 H, t, *J* 7.6, CH_3), 1.35 (4 H, m, CH_2), 1.64 (8 H, m, CH_3-CH=CH, CH), 2.03 (4 H, m, CH_2-CH=CH_2), 4.09 (4 H, d, *J* 5.7, OCH_2), 5.39 (4 H, m, =CH), 6.23 (2 H, s, COCH=CHCO); δ_C ($CDCl_3$) 10.93 (C12′, C12), 17.81 (C10′, C10), 23.28 (C11′, C11), 33.63 (C7′, C7), 39.00 (C6′, C6), 67.24 (C5′, C5), 125.48 (C9′, C9 *Z*), 126.97 (C9′, C9 *E*), 127.62 (C8′, C8 *Z*), 128.27 (C8′, C8 *E*), 129.62 (C2, C3), 165.16 (C1, C4); *m*/*z* (CI, NH_3) 337.2 (MH^+), 354.3 ($MH^+ + NH_3$).

Preparation of (*E*)-but-2-ene-1,4-dioic acid bis(2-ethylhex-2-enyl) ester 4c. To K_2CO_3 (4.3 g, 31 mmol) and $MgSO_4$ (3.75 g, 31 mmol), previously dried at 230 °C under nitrogen, was added a solution of 2-ethylhex-2-en-1-ol **2c** (4.0 g, 31 mmol) in CH_2Cl_2 (70 mL). After cooling to 0 °C, fumaroyl dichloride (2.4 g, 15.5 mmol) was added dropwise. The reaction mixture was stirred for 2 h at 0 °C and then brought to room temperature and allowed to stir for 48 h. The solution was filtered and the mixture was extracted with 0.1 M NaOH. After purification by column chromatography with Et_2O–*n*-hexane 1 : 5 as eluent, ester **4c** (3.27 g, 62%) was obtained as colourless oil; R_f (Et_2O–*n*-hexane 1 : 5, H_2SO_4) 0.84; t_r (GC, min) 29; δ_H ($CDCl_3$) 0.91 (6 H, t, *J* 7, CH_3), 1.0 (6 H, t, *J* 7, CH_3), 1.35 (4 H, m, CH_2), 2.07 (8 H, m, CH_2-CH=CH_2), 4.62 (4 H, s, OCH_2), 5.48 (H, t, *J* 7, CH=C), 6.87 (2 H, s, COCH=CHCO); δ_C ($CDCl_3$) 12.90 (C12′, C12), 13.72 (C10′, C10), 21.26 (C11′, C11), 22.60 (C9′, C9), 29.40 (C8′, C8), 69.19 (C5′, C5), 130.62 (C2, C3), 133.64 (C7′, C7), 135.34 (C6′, C6), 164.80 (C1, C4); *m*/*z* (EI) 336.2 (M^+).

Preparation of unsaturated sulfosuccinic diesters: 5a–c, (*R,R*)-5a, (*S,S*)-5a. *Sodium 1,2-bis(2-ethylhex-5-enyloxycarbonyl)-ethanesulfonate **5a**.* To a solution of diester **3a** (420 mg, 1.3 mmol) in Pr^iOH (10 mL) containing a tip of a spatula of 1,3-di-*tert*-butylphenol was added sodium bisulfite (170 mg, 1.6 mmol) in H_2O (4 mL), previously degassed with nitrogen for 15 min. The reaction mixture was then refluxed for 20 h. A second crop of $NaHSO_3$ (60 mg, 0.6 mmol) was added and the reflux was maintained for the next 20 h. After evaporation of the solvent, the residue was dissolved in Et_2O and the filtrate was concentrated to dryness. Purification by column chromatography with EtOAc followed by EtOAc–MeOH 9 : 1 elution gradient gave **5a** (300 mg, 55%) as a paste (Found: C, 54.54; H, 7.65. Calc. for $C_{20}H_{33}NaO_7S$: C, 54.54; H, 7.55%); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.28; ν_{max}(KBr)/cm^{-1} 1736 (C=O), 1646 (C=C), 1053 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.5, CH_3), 1.25–1.40 (8 H, m, CH_2), 1.53 (2 H, m, CH), 2.02 (4 H, m, CH_2-CH=CH_2), 2.79 (H, dd, $J_{2,3}$ 4.1, $J_{3,3'}$ 17, C*H*HCO), 2.92 (H, dd, $J_{2,3}$ 11.4, $J_{3,3'}$ 17, CH*H*CO), 3.64 (H, dd, $J_{2,3}$ 4.1, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.91 (4 H, m, OCH_2), 4.94 (2 H, dm, *J* 10.3, =C*H*H), 5.01 (2 H, dm, *J* 17, =CH*H*), 5.79 (2 H, ddt, *J* 17, *J* 10.3, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.74, 10.76 (C12′, C12), 22.82, 22.86 (C11′), 23.02 (C11), 29.13, 29.20 (C7′), 29.30 (C7), 30.37 (C8′, C8), 34.08 (C3), 37.58, 37.60 (C6′), 37.65, 37.67 (C6), 61.37 (C2), 65.83, 65.86 (C5), 65.90, 65.92 (C5′), 114.63 (C10′), 114.75 (C10), 138.66 (C9′), 138.85 (C9), 168.35 (C1), 171.04 (C4); *m*/*z* (ES−) 440 (M^-, 5%), 417 [$(M - Na)^-$, 100].

*Sodium 1,2-bis[(R)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**R,R**)-5a.* Prepared as described above for **5a** starting from diester (***R,R***)-**3a** (600 mg, 1.8 mmol) to provide (***R,R***)-**5a** (350 mg, 45%) as a paste (Found: C, 54.07; H, 8.04. Calc. for $C_{20}H_{33}NaO_7S$: C, 54.54; H, 7.55%); $[\alpha]_D$ −2.6, $[\alpha]_{546}$ −5.4, $[\alpha]_{436}$ −13.5, $[\alpha]_{365}$ −21.1 (*c* 0.5 in cyclohexane); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.28; ν_{max}(KBr)/cm^{-1} 1736 (C=O), 1646 (C=C), 1053 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 1.27–1.36 (8 H, m, CH_2), 1.54 (2 H, m, CH), 2.02 (4 H, m, CH_2-CH=CH_2), 2.80 (H, dd, $J_{2,3}$ 4, $J_{3,3'}$ 17.3, C*H*HCO), 2.92 (H, dd, $J_{2,3}$ 11.4, $J_{3,3'}$ 17.3, CH*H*CO), 3.63 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.91 (4 H, m, OCH_2), 4.93 (2 H, dm, *J* 10.3, =C*H*H), 5.01 (2 H, dm, *J* 16.9, =CH*H*), 5.79 (2 H, ddt, *J* 16.9, *J* 10.3, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.73, 10.74 (C12′, C12), 22.82, 22.86 (C11′), 23.02 (C11), 29.13, 29.20 (C7′), 29.30 (C7), 30.37 (C8′, C8), 34.06 (C3), 37.59, 37.65 (C6′), 37.67 (C6), 61.38 (C2), 65.84, 65.87 (C5), 65.92 (C5′), 114.62 (C10′), 114.74 (C10), 138.65 (C9′), 138.83 (C9), 168.30 (C1), 171.02 (C4); *m*/*z* (ES−) 417 [$(M - Na)^-$, 100%], 418 [$(MH - Na)^-$, 20]; *m*/*z* (ES+) 463 [$(M + Na)^+$, 100%], 479 [$(M + K)^+$, 71].

*Sodium 1,2-bis[(S)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**S,S**)-5a.* Prepared as described above starting from diester (***S,S***)-**3a** (800 mg, 2.4 mmol) to provide (***S,S***)-**5a** (460 mg, 48%) as a paste (Found: C, 52.67; H, 7.67. Calc. for‡ $C_{20}H_{33}NaO_7S \cdot H_2O$: C, 52.39; H, 7.69%); $[\alpha]_D$ +2.1, $[\alpha]_{546}$ +5.3, $[\alpha]_{436}$ +12.6, $[\alpha]_{365}$ +20.6 (*c* 0.5 in cyclohexane); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.28; ν_{max}(KBr)/cm^{-1} 1736 (C=O), 1646 (C=C), 1058 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 1.27–1.36 (8 H, m, CH_2), 1.53 (2 H, m, CH), 2.02 (4 H, m, CH_2-CH=CH_2), 2.79 (H, dd, $J_{2,3}$ 3.7, $J_{3,3'}$ 17, C*H*HCO), 2.92 (H, dd, $J_{2,3}$ 11.4, $J_{3,3'}$ 17, CH*H*CO), 3.65 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.91 (4 H, m, OCH_2), 4.93 (2 H, dm, *J* 10.1, =C*H*H), 5.01 (2 H, dm, *J* 17.3, =CH*H*), 5.78 (2 H, ddt, *J* 17.3, *J* 10.1, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.75, 10.77 (C12′, C12), 22.85, 22.89 (C11′), 23.05 (C11), 29.16, 29.23 (C7′), 29.32 (C7), 30.39 (C8′, C8), 34.08 (C3), 37.62, 37.68 (C6′), 37.70 (C6), 61.41 (C2), 65.88, 65.91 (C5), 65.96, 65.97 (C5′), 114.65 (C10′), 114.77 (C10), 138.67 (C9′), 138.86 (C9), 168.32 (C1), 171.04 (C4); *m*/*z* (ES−) 417 [$(M - Na)^-$, 100%].

*Sodium 1,2-bis(2-ethylhex-4-enyloxycarbonyl)ethanesulfonate **5b**.* Prepared as described above starting from diester **3b**

‡ Confirmed with Karl Fisher method.

(1.28 g, 3.8 mmol) to provide **5b** (1.2 g, 72%) as a paste; R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.28; δ_H ($CDCl_3$) 0.86 (6 H, t, CH_3), 1.25 (4 H, m, CH_2), 1.61 (8 H, m, *C*H_3-CH=CH, CH), 2.05 (4 H, m, *C*H_2-CH=CH), 3.17 (2 H, d, *J* 6.8, CH_2CO), 4.03 (2 H, d, *J* 6.3, OCH_2), 4.12 (2 H, d, *J* 7, OCH_2), 4.38 (H, t, *J* 6.8, OCH_2), 5.37 (4 H, m, CH=C); δ_C ($CDCl_3$) 11.06, 12.91 (C12′, C12), 18.00 (C10′, C10), 22.92, 23.19 (C11′, C11), 32.70 (C3), 33.65 (C7′, C7), 38.99 (C6′, C6), 61.25 (C2), 67.59, 69.25 (C5′, C5), 125.53, 127.86 (C9′, C9, C8′, C8 *E*), 127.70, 128.51 (C9′, C9, C8′, C8 *Z*), 170.06, 171.47 (C1, C4).

Sodium 1,2-bis(2-ethylhex-2-enyloxycarbonyl)ethanesulfonate ***5c***. Prepared as described above starting from fumaric diester **4c** (1.5 g, 4.5 mmol) to provide **5c** (1.49 g, 76%) as a paste; R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.28; δ_H ($CDCl_3$) 0.94 (12 H, m, CH_3), 1.32 (4 H, m, CH_2), 1.99 (8 H, m, *C*H_2-CH=CH_2), 3.23 (2 H, m, CH_2CO), 4.53 (5 H, m, OCH_2, $CHSO_3Na$), 5.4 (2 H, m, CH=C); δ_C ($CDCl_3$) 12.91, 12.99 (C12′, C12), 13.88 (C10′, C10), 21.19 (C11′, C11), 22.71 (C9′, C9), 29.56 (C8′, C8), 33.03 (C3), 61.23 (C2), 69.00, 70.63 (C5′, C5), 129.84, 130.57 (C7′, C7), 135.39, 135.77 (C6′, C6), 169.68 (C1), 171.39 (C4).

Preparation of ammonium salt 6a. *(R)-(+)-1-Phenylethylammonium 1,2-bis[(R)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate* ***6a***. A solution of (*R*)-1-phenylethylamine (14 mg, 0.11 mmol) in 110 μL 1 M HCl and 160 μL water and a solution of (***R***)**-5a** (50 mg, 0.11 mmol) in 8 mL cyclohexane were vigorously stirred for 24 h. After addition of water, the organic phase was separated, washed with water and dried over Na_2SO_4. The diastereomeric ammonium salt **6** was isolated by removal of solvent (53 mg, 84%) as an oil; δ_H ($CDCl_3$) 0.85 (3 H, t, *J* 7.8, CH_3), 0.89 (3 H, t, *J* 7.2, CH_3), 1.27–1.43 (8 H, m, CH_2), 1.54 (2 H, m, CH), 1.59 (3 H, d, *J* 6.9, *C*H_3-CH-N), 2.07 (4 H, m, *C*H_2-CH=CH_2), 2.85 (H, m, C*H*HCO), 3.09 (H, m, CH*H*CO), 3.97 (5 H, m, $CHSO_3Na$, OCH_2), 4.42 (H, q, *J* 6.6, CH-N), 4.93 (2 H, m, =C*H*H), 5.0 (2 H, m, =CH*H*), 5.75 (2 H, m, CH=), 6.40 (3 H, s, NH_3^+), 7.35 (5 H, m, H_{Ar}); δ_C (CD_3Cl) 10.75, 10.77, 10.84, 10.85 (C12′, C12), 21.01 (*C*H_3-CH-NH_3^+), 23.23, 23.28, 23.45 (C11′, C11), 29.55, 29.64, 29.74, 23.79 (C7′, C7), 30.77, 30.86, 30.88 (C8′, C8), 33.10, 33.21 (C3), 37.88, 37.92, 38.05, 38.08 (C6′, C6), 51.46 (CH-NH_3^+), 61.53, 61.57 (C2), 67.02, 67.06, 68.11, 68.19 (C5′, C5), 114.55, 114.64 (C10′, C10), 126.63, 128.43, 128.85 (C_{Ar}), 138.48, 138.49, 138.62 (C9′, C9), 139.06 (C_{ipso}), 168.97, 169.19 (C1), 170.86, 170.92 (C4).

Synthesis of unsymmetrical sulfosuccinic diesters 11–15

Preparation of (*Z*)-but-2-enedioic monoesters (*R*)-7, (*S*)-7 and D_2-7. *(Z)-But-2-enedioic acid mono-[(R)-2-ethylhexyl] ester* ***(R)-7***. A mixture of maleic anhydride (2.8 g, 28.8 mmol) and alcohol (***R***)**-2d** (ee ~ 94%, 2.5 g, 19.2 mmol) was heated at 90 °C for 3 h. After cooling to room temperature, the reaction mixture was partitioned between Et_2O and 1 M NaOH. The aqueous basic layer was acidified with conc. HCl (pH ~ 1) and extracted with CH_2Cl_2. The combined organic layers were dried over Na_2SO_4 and the solvent was evaporated to provide (***R***)**-7** (4.0 g, 91%, oil); R_f (EtOAc–MeOH 4 : 1, H_2SO_4) 0.19; ν_{max}(film)/cm^{-1} 3440 (OH), 1733 (CO_2R), 1640 (CO_2H), 1465 and 1383 (C=C); δ_H ($CDCl_3$) 0.91 (3 H, t, *J* 6.9, CH_3), 0.92 (3 H, t, *J* 7.4, CH_3), 1.32 (8 H, m, CH_2), 1.68 (H, m, CH), 4.22 (2 H, dd, *J* 1.8, *J* 6.5, OCH_2), 6.40 (H, d, *J* 12.9, C*H*=CH), 6.51 (H, d, *J* 12.9, CH=C*H*), 10.17 (H, s, CO_2H); δ_C ($CDCl_3$) 10.82 (C12), 13.94 (C10), 22.84 (C9), 23.63 (C11), 28.52 (C8), 30.23 (C7), 38.58 (C6), 60.03 (C5), 130.03 (C3), 133.92 (C2), 166.08 (C4), 167.22 (C1).

(Z)-But-2-enedioic acid mono-[(S)-2-ethylhexyl] ester ***(S)-7***. Prepared as described above for (***R***)**-7**, starting from maleic anhydride (2.8 g, 28.8 mmol) and alcohol (***S***)**-2d** (ee 90%, 2.5 g, 19.2 mmol) to provide (***S***)**-8** (3.5 g, 79%). The IR, MS, NMR spectra are identical with those of the monoester (***R***)**-7**.

(Z)-But-2-enedioic acid mono-2-ethylhexyl ester-5-d_2 $\boldsymbol{D_2}$***-7***. Prepared as described above for (***R***)**-7**, starting from maleic anhydride (0.4 g, 4.1 mmol) and alcohol $\mathbf{D_2}$**-2d** (0.5 g, 3.8 mmol) to provide $\mathbf{D_2}$**-7** (0.7 g, 91%, oil); R_f (EtOAc–MeOH 4 : 1, H_2SO_4) 0.19; δ_H ($CDCl_3$) 0.91 (3 H, t, *J* 7, CH_3), 0.92 (3 H, t, *J* 7.7, CH_3), 1.31–1.47 (8 H, m, CH_2), 1.66 (H, m, CH), 6.39 (H, d, *J* 12.9, C*H*=CH), 6.50 (H, d, *J* 12.9, CH=C*H*); δ_C ($CDCl_3$) 10.84 (C12), 13.95 (C10), 22.84 (C9), 23.50 (C11), 28.77 (C8), 30.11 (C7), 38.31 (C6), 129.36 (C3), 136.28 (C2), 164.67 (C4), 167.91 (C1).

Preparation of 2-ethylhexyl sulfosuccinic monoesters (*R*)-9, (*S*)-9, D_2-9. *Sodium 1-carboxy-2-[(R)-2-ethylhexyloxycarbonyl]ethanesulfonate* ***(R)-9***. A solution of sodium bisulfite (2.7 g, 26.1 mmol) in water (60 mL) was purged with nitrogen for 30 min and then added to a solution of (***R***)**-7** (3.0 g, 13.1 mmol) in Pr^iOH (75 mL). The mixture was heated at 60 °C for 48 h. After removal of the solvent, the crude reaction mixture was extensively extracted in MeOH–H_2O 4 : 1 until the product was no longer detected. The combined filtrates were concentrated to dryness, washed with Et_2O and then purified by silica gel column chromatography with EtOAc–MeOH 4 : 1 containing 0.5% trifluoroacetic acid (3.5 g, 81%), mp 248–251 °C (Found: C, 38.70; H, 5.54; Na, 6.93. Calc. for $C_{12}H_{21}NaO_7S·H_2O$:‡ C, 38.70; H, 5.41; Na, 6.58%); $[\alpha]_D$ −1.7, $[\alpha]_{436}$ −3.4, $[\alpha]_{365}$ −4.8 (*c* 4.4 in MeOH + 2% 6 M HCl); R_f (EtOAc–MeOH–TFA 80 : 20 : 0.5, H_2SO_4) 0.52; ν_{max}(KBr)/cm^{-1} 1737 (CO_2R), 1718 (CO_2H), 1054 (S=O); δ_H (DMSO-d_6) 0.84 (3 H, t, *J* 7.6, CH_3), 0.87 (3 H, t, *J* 6.3, CH_3), 1.29 (8 H, m, CH_2), 1.50 (H, m, CH), 2.73 (H, dd, $J_{2,3}$ 3.7, $J_{3,3}$ 17, C*H*HCO), 2.86 (H, dd, $J_{2,3}$ 10.9, $J_{3,3}$ 17, CH*H*CO), 3.62 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 10.9, $CHSO_3Na$), 3.91 (2 H, d, *J* 4.2, OCH_2), 12.10 (H, s, CO_2H); δ_C (DMSO-d_6) 10.80, 10.83 (C12), 13.91 (C10), 22.37 (C9), 23.16 (C11), 28.33 (C8), 29.73 (C7), 33.98 (C3), 38.11 (C6), 61.31 (C2), 65.39 (C5), 169.51 (C1), 171.27 (C4); *m*/*z* (ES−) 309 [(M − H − Na)$^-$, 100%], 310 [(M − Na)$^-$, 15], 311 [(MH − Na)$^-$, 7].

Sodium 1-carboxy-2-[(S)-2-ethylhexyloxycarbonyl]ethanesulfonate ***(S)-9***. Prepared as described above for (***R***)**-9**, starting from (***S***)**-7** (3.0 g, 13.1 mmol), product (***S***)**-9** was isolated (3.3 g, 77%); mp 228–236 °C (Found: C, 39.23; H, 5.53. Calc. for‡ $C_{12}H_{21}NaO_7S·0.75H_2O$:‡ C, 39.18; H, 5.48%); $[\alpha]_D$ +1.8, $[\alpha]_{436}$ +3.5 (*c* 4.4 in MeOH + 2% 6 M HCl); R_f (EtOAc–MeOH–TFA 80 : 20 : 0.5, H_2SO_4) 0.52; *ν*(KBr)/cm^{-1} 1745 (CO_2R), 1716 (CO_2H), 1052 (S=O); δ_H (DMSO-d_6) 0.84 (3 H, t, *J* 7.7, CH_3), 0.87 (3 H, t, *J* 6.3, CH_3), 1.24–1.31 (8 H, m, CH_2), 1.50 (H, m, CH), 2.73 (H, dd, $J_{2,3}$ 3.7, $J_{3,3}$ 16.9, C*H*HCO), 2.87 (H, dd, $J_{2,3}$ 11, $J_{3,3}$ 16.9, CH*H*CO), 3.64 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 11, $CHSO_3Na$), 3.90 (2 H, d, *J* 4.4, OCH_2), 12.10 (H, s, CO_2H); δ_C (DMSO-d_6) 10.81 (q, $^1J_{C–H}$ 124, C12), 13.93 (q, $^1J_{C–H}$ 124, C10), 22.42 (t, $^1J_{C–H}$ 125, C9), 23.17 (t, $^1J_{C–H}$ 125, C11), 28.33 (t, $^1J_{C–H}$ 125, C8), 29.74 (t, $^1J_{C–H}$ 125, C7), 33.98 (td, $^1J_{C–H}$ 131, $^2J_{C3–H2}$ 3.4, C3), 38.11 (d, $^1J_{C–H}$ 112, C6), 61.40 (dt, $^1J_{C–H}$ 138, $^2J_{C2–H3}$ 5.1, C2), 66.06 (t, $^1J_{C–H}$ 148, C5), 169.74 (ddd, $^2J_{C1–H2}$ 6.2, $^3J_{C1–H3}$ 8.6, $^3J_{C1–H3'}$ 3.4, C1), 171.30 (m, $^2J_{C4–H3}$ 7.3, $^3J_{C4–H2}$ 2.8, $^3J_{C4–H5}$ 2.2, C4); *m*/*z* (ES+) 304 [(M − 6H − Na)$^+$, 73%], 306 [(M − 4H − Na)$^+$, 100], 308 [(M − 2H − Na)$^+$, 89], 310 [(M − Na)$^+$, 33], 333 (M$^+$, 7), 349 [(M − 2H + H_2O)$^+$, 29].

Sodium 1-carboxy-2-[2-ethylhexyloxycarbonyl]ethanesulfonate-5-d_2 $\boldsymbol{D_2}$***-9***. Prepared as described above for (***R***)**-9** starting from sodium bisulfite (0.6 g, 5.6 mmol) and monoester $\mathbf{D_2}$**-7** (0.66 g, 2.8 mmol) to provide $\mathbf{D_2}$**-9** (0.6 g, 63%); R_f (EtOAc–MeOH–TFA 80 : 20 : 0.5, H_2SO_4) 0.52; δ_H (DMSO-d_6) 0.83 (3 H, t, *J* 7.4, CH_3), 0.86 (3 H, t, *J* 6.2, CH_3), 1.24–1.31 (8 H, m, CH_2), 1.48 (H, m, CH), 2.72 (H, dd, $J_{2,3}$ 3.7, $J_{3,3}$ 16.9, C*H*HCO), 2.86 (H, dd, $J_{2,3}$ 11, $J_{3,3}$ 16.9, CH*H*CO), 3.64 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 11, $CHSO_3Na$), 12.10 (H, s, CO_2H); δ_C (DMSO-d_6) 10.80 (q, $^1J_{C–H}$ 124, C12), 13.92 (q, $^1J_{C–H}$ 124, C10), 22.37 (t, $^1J_{C–H}$ 125, C9), 23.14 (t, $^1J_{C–H}$ 125, C11), 28.33 (t, $^1J_{C–H}$ 125, C8), 29.68 (t, $^1J_{C–H}$ 125, C7), 33.96 (td, $^1J_{C–H}$ 132, $^2J_{C3–H2}$ 4, C3), 37.83 (d, $^1J_{C–H}$ 112, C6), 61.40 (dt, $^1J_{C–H}$ 138, $^2J_{C2–H3}$ 5.1, C2), 169.66 (ddd, $^2J_{C1–H2}$ 6.2, $^3J_{C1–H3}$ 8.6, $^3J_{C4–H3'}$ 3.4, C1), 171.34 (td, $^2J_{C4–H3}$ 7.3, $^3J_{C4–H2}$ 2.8, C4); *m*/*z* (ES−) 311 [(M − H − Na)$^-$, 100%].

Preparation of 2-ethylhex-5-enyl sulfosuccinate monoesters (*R*)-10 and (*S*)-10. *Sodium 1-carboxy-2-[(R)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**R**)-**10**.* A mixture of maleic anhydride (0.74 g, 7.5 mmol) and alcohol (***R***)-**2a** (ee ~ 98%, 0.8 g, 6.3 mmol) was heated at 90 °C for 4 h. After cooling to room temperature, the crude product (***R***)-**8** was dissolved in Pr^iOH (30 mL) and added to a solution of sodium bisulfite (1.3 g, 12.5 mmol) in water (23 mL) which was previously purged with nitrogen for 30 min. The mixture was heated at 60 °C for 48 h. After workup described above for **9** and purification by silica gel column chromatography with EtOAc–MeOH 4 : 1 containing 0.5% trifluoroacetic acid, monoester (***R***)-**10** was obtained as a paste (1.7 g, 82%); $[\alpha]_D$ −1.9, $[\alpha]_{546}$ −3.1, $[\alpha]_{436}$ −5.6, $[\alpha]_{365}$ −7.5 (*c* 0.5 in MeOH); R_f (EtOAc–MeOH–TFA 80 : 20 : 0.5, H_2SO_4) 0.37; ν_{max}(KBr)/cm^{-1} 1725 (CO_2R), 1688 (CO_2H), 1597 (C=C), 1050 (S=O); δ_H (DMSO-d_6) 0.84 (3 H, t, *J* 7.4, CH_3), 1.26–1.37 (4 H, m, CH_2), 1.55 (H, m, CH), 2.04 (2 H, m, *C**H*$_2$-CH=CH_2), 2.63 (H, dd, $J_{2,3}$ 3.7, $J_{3,3}$ 16.9, C*H*HCO), 2.87 (H, dd, $J_{2,3}$ 9.9, $J_{3,3}$ 16.9, CH*H*CO), 3.68 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 9.9, $CHSO_3Na$), 3.90 (2 H, m, OCH_2), 4.94 (H, dm, *J* 10.1, =*CH*H), 5.03 (H, dm, *J* 16.9, =CH*H*), 5.80 (H, ddt, *J* 16.9, *J* 10.1, *J* 6.6, CH=), 12.19 (H, s, CO_2H); δ_C (DMSO-d_6) 10.88 (C12), 23.21 (C11), 29.50 (C7), 30.58 (C8), 34.15 (C3), 37.83 (C6), 61.59 (C2), 65.97 (C5), 114.89 (C10), 138.90 (C9), 169.68 (C1), 171.42 (C4); *m*/*z* (ES−) 307 [(M − Na)$^-$, 100%].

*Sodium 1-carboxy-2-[(S)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**S**)-**10**.* Prepared as described above for (***R***)-**10**, starting from maleic anhydride (0.27 g, 2.8 mmol) and alcohol (***S***)-**2a** (ee ~ 99%, 0.3 g, 2.3 mmol) to provide (***S***)-**10** (0.6 g, 78%) as a paste; $[\alpha]_D$ +1.8, $[\alpha]_{546}$ +2.9, $[\alpha]_{436}$ +5.3, $[\alpha]_{365}$ +7.0 (*c* 0.5 in MeOH); R_f (EtOAc–MeOH–TFA 80 : 20 : 0.5, H_2SO_4) 0.36; ν(KBr)/cm^{-1} 1725 (CO_2R), 1688 (CO_2H), 1597 (C=C), 1050 (S=O); δ_H (DMSO-d_6) 0.84 (3 H, t, *J* 7.4, CH_3), 1.29–1.34 (4 H, m, CH_2), 1.55 (H, m, CH), 2.04 (2 H, m, *C**H*$_2$-CH=CH_2), 2.68 (H, dd, $J_{2,3}$ 3.7, $J_{3,3}$ 16.9, C*H*HCO), 2.87 (H, dd, $J_{2,3}$ 9.9, $J_{3,3}$ 16.9, CH*H*CO), 3.68 (H, dd, $J_{2,3}$ 3.7, $J_{2,3}$ 9.9, $CHSO_3Na$), 3.92 (2 H, m, OCH_2), 4.94 (H, dm, *J* 10.1, =C*H*H), 5.02 (H, dm, *J* 16.8, =CH*H*), 5.80 (H, ddt, *J* 16.8, *J* 10.1, *J* 6.6, CH=), 12.19 (H, s, CO_2H); δ_C (DMSO-d_6) 10.76, 10.79 (C12), 23.03 (C11), 29.32 (C7), 30.39 (C8), 33.97 (C3), 37.60, 37.62 (C6), 61.30 (C2), 65.73 (C5), 114.77 (C10), 138.74 (C9), 169.50 (C1), 171.24 (C4); *m*/*z* (ES−) 307 [(M − Na)$^-$, 100%].

Preparation of unsymmetrical sulfosuccinic diesters 11–15. *Sodium 1-[(S)-2-ethylhexyloxycarbonyl]-2-[(R)-2-ethylhexyloxycarbonyl]ethanesulfonate (**S,R**)-**11**.* A mixture of monoester (***R***)-**9** (1.32 g, 4 mmol), alcohol (***S***)-**2d** (ee ~ 90%, 520 mg, 4 mmol), DCC (1.5 g, 7.3 mmol), DMAP (730 mg, 6.0 mmol) and DMAP HCl (630 mg, 4.0 mmol) was stirred in dimethylformamide (55 mL) for 96 h at room temperature. The DMF was evaporated, the residue was dissolved in EtOAc and the precipitated dicyclohexylurea (DCU) was removed by filtration. The filtrate was washed with 1 M HCl, brine and dried over Na_2SO_4. The reaction mixture was purified by silica gel column chromatography with EtOAc–MeOH (20 : 1, then 9 : 1) to provide the diester (***R,S***)-**11** (0.50 g, 59%) as a paste (Found: C, 53.68; H, 8.75. Calc. for $C_{20}H_{37}NaO_7S$: C, 54.03; H, 8.39%); $[\alpha]_D$ +7.6, $[\alpha]_{546}$ +4.9, $[\alpha]_{436}$ −2.2, $[\alpha]_{365}$ −6.1 (*c* 0.5 in cyclohexane); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.29; ν_{max}(KBr)/cm^{-1} 1733 (CO_2R), 1054 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.5, CH_3), 0.86 (6 H, t, *J* 6.5, CH_3), 1.24 (16 H, m, CH_2), 1.49 (2 H, m, CH), 2.78 (H, dd, $J_{2,3}$ 3.6, $J_{3,3}$ 17, C*H*HCO), 2.91 (H, dd, $J_{2,3}$ 11.5, $J_{3,3}$ 17, CH*H*CO), 3.62 (H, dd, $J_{2,3}$ 3.6, $J_{2,3}$ 11.5, $CHSO_3Na$), 3.91 (4 H, m, OCH_2); δ_C (DMSO-d_6) 10.74, 10.77, 10.81 (C12′, C12), 13.89 (C10′), 13.92 (C10), 22.38 (C9′), 22.41 (C9), 22.97, 23.00 (C11′), 23.15, 23.18 (C11), 28.33 (C8′, C8), 29.54, 29.60, 29.73 (C7′, C7), 34.09 (C3), 38.08, 38.12, 38.16 (C6′, C6), 61.40 (C2), 66.03, 66.08 (C5), 66.10, 66.17 (C5′), 168.34 (C1), 171.03 (C4); *m*/*z* (ES−) 421.1 [(M − H − Na)$^-$, 100%], 422.2 [(M − Na)$^-$, 16].

*Sodium 1-[(R)-2-ethylhexyloxycarbonyl]-2-[(S)-2-ethylhexyloxycarbonyl]ethanesulfonate (**R,S**)-**11**.* Prepared as described above for (***S,R***)-**11**, starting from monoester (***S***)-**9** (1.0 g, 3 mmol) and alcohol (***R***)-**2d** (ee ~ 99%, 400 mg, 3 mmol), DCC (1.15 g, 5.6 mmol), DMAP (500 mg, 4.5 mmol) and DMAP HCl (480 mg, 3.0 mmol) in DMF (45 mL) to provide the diester (***S,R***)-**11** (0.87 g, 65%) as a paste (Found: C, 53.87; H, 8.73. Calc. for $C_{20}H_{37}NaO_7S$: C, 54.03; H, 8.39%); $[\alpha]_D$ +3.1, $[\alpha]_{546}$ +1.7, $[\alpha]_{436}$ −0.4, $[\alpha]_{365}$ −2.0 (*c* 0.5 in cyclohexane); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.29; ν(KBr)/cm^{-1} 1735 (C=O), 1054 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 0.86 (6 H, t, *J* 7, CH_3), 1.24–1.35 (16 H, m, CH_2), 1.49 (2 H, m, CH), 2.78 (H, dd, $J_{2,3}$ 4.1, $J_{3,3}$ 17.3, C*H*HCO), 2.91 (H, dd, $J_{2,3}$ 11.4, $J_{3,3}$ 17.3, CH*H*CO), 3.62 (H, dd, $J_{2,3}$ 4.1, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.91 (4 H, m, OCH_2); δ_C (DMSO-d_6) 10.70, 10.73, 10.76 (C12′, C12), 13.82 (C10′), 13.86 (C10), 22.33 (C9′), 22.35 (C9), 22.95, 22.97 (C11′), 23.12, 23.15 (C11), 28.29 (C8′, C8), 29.52, 29.57, 29.70 (C7′, C7), 34.07 (C3), 38.06, 38.09, 38.14 (C6′, C6), 61.39 (C2), 66.01, 66.06, 66.14 (C5′, C5), 168.26 (C1), 170.99 (C4).

*Sodium 1-[(S)-2-ethylhex-5-enyloxycarbonyl]-2-[(R)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**S,R**)-**12**.* Prepared as described above for (***S,R***)-**11**, starting from monoester (***R***)-**10** (1.0 g, 3 mmol) and alcohol (***S***)-**2a** (ee ~ 99%, 420 mg, 3.3 mmol), DCC (1.15 g, 5.6 mmol), DMAP (500 mg, 4.5 mmol) and DMAP HCl (480 mg, 3 mmol) in DMF (45 mL) to provide the diester (***R,S***)-**12** (0.7 g, 53%) as a paste (Found: C, 52.46; H, 7.85. Calc. for $C_{20}H_{33}NaO_7S{\cdot}H_2O$:‡ C, 52.39; H, 7.67%); $[\alpha]_D$ +4.0, $[\alpha]_{436}$ −5.6, $[\alpha]_{365}$ −7.2 (*c* 0.5 in cyclohexane); R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.29; ν_{max}(KBr)/cm^{-1} 1738 (CO_2R), 1643 (C=C), 1047 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 1.27–1.36 (8 H, m, CH_2), 1.54 (2 H, m, CH), 2.02 (4 H, m, *C**H*$_2$-CH=CH_2), 2.79 (H, dd, $J_{2,3}$ 4, $J_{3,3}$ 17.3, C*H*HCO), 2.91 (H, dd, $J_{2,3}$ 11, $J_{3,3}$ 17.3, CH*H*CO), 3.63 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 11, $CHSO_3Na$), 3.90 (4 H, m, OCH_2), 4.93 (2 H, dm, *J* 10.1, =C*H*H), 5.01 (2 H, dm, *J* 17, =CH*H*), 5.79 (2 H, ddt, *J* 17, *J* 10.1, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.73 (C12′, C12), 22.82, 22.87 (C11′), 23.03 (C11), 29.14, 29.20, 29.31 (C7′, C7), 30.36 (C8′, C8), 34.07 (C3), 37.59, 37.61 (C6′), 37.66, 37.68 (C6), 61.39 (C2), 65.84, 65.87, 65.91, 65.93 (C5′, C5), 114.61 (C10′), 114.73 (C10), 138.65, 138.83 (C9′, C9), 168.33 (C1), 171.03 (C4); *m*/*z* (ES−) 417 [(M − Na)$^-$, 100%].

*Sodium 1-[(R)-2-ethylhex-5-enyloxycarbonyl]-2-[(S)-2-ethylhex-5-enyloxycarbonyl]ethanesulfonate (**R,S**)-**12**.* Prepared as described above for (***R,S***)-**11**, starting from monoester (***S***)-**10** (300 mg, 0.9 mmol) and alcohol (***R***)-**2a** (ee ~ 99%, 130 mg, 1.0 mmol), DCC (340 mg, 1.6 mmol), DMAP (170 mg, 1.4 mmol) and DMAP HCl (150 mg, 0.9 mmol) in DMF (45 mL) to provide the diester (***S,R***)-**12** (0.25 g, 63%) as a paste; R_f (EtOAc–MeOH 9 : 1, H_2SO_4) 0.33; $[\alpha]_D$ +6.0, $[\alpha]_{546}$ +0.2, $[\alpha]_{436}$ −6.4, $[\alpha]_{365}$ −12.8 (*c* 0.5 in cyclohexane); ν_{max}(KBr)/cm^{-1} 1742 (CO_2R), 1644 (C=C), 1055 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 1.25–1.28 (8 H, m, CH_2), 1.44 (2 H, m, CH), 2.00 (4 H, m, *C**H*$_2$-CH=CH_2), 2.80 (H, dd, $J_{2,3}$ 4, $J_{3,3}$ 17.3, C*H*HCO), 2.93 (H, dd, $J_{2,3}$ 11, $J_{3,3}$ 17.3, CH*H*CO), 3.63 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 11, $CHSO_3Na$), 3.90 (4 H, m, OCH_2), 4.94 (2 H, dm, *J* 10.1, =C*H*H), 5.02 (2 H, dm, *J* 17, =CH*H*), 5.79 (2 H, ddt, *J* 17, *J* 10.1, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.73 (C12′, C12), 22.82, 22.87 (C11′), 23.03 (C11), 29.14, 29.20 (C7′), 29.31 (C7), 30.36 (C8′, C8), 34.07 (C3), 37.59 (C6), 37.68 (C6′), 61.39 (C2), 65.84, 65.87, 65.91, 65.93 (C5′, C5), 114.61 (C6), 114.73 (C10), 138.65, 138.83 (C9′, C9), 168.33 (C1), 171.03 (C4); *m*/*z* (ES−) 417 [(M − Na)$^-$, 100%].

*Sodium 1-(methyloxycarbonyl)-2-[(S)-2-ethylhexyloxycarbonyl]ethanesulfonate (**S**)-**13**.* Prepared as described above for (***S,R***)-**11**, starting from monoester (***S***)-**9** (100 mg, 0.3 mmol) and MeOH (120 μL, 3 mmol), DCC (115 mg, 0.56 mmol), DMAP (55 mg, 0.45 mmol) and DMAP HCl (50 mg, 0.3 mmol) in DMF (5 mL) to provide the diester (***S***)-**13** (78 mg, 58%) as a paste; ν_{max}(KBr)/cm^{-1} 1737 (CO_2R), 1059 (S=O); δ_H (DMSO-d_6) 0.83 (3 H, t, *J* 7.5, CH_3), 0.86 (3 H, t, *J* 6.8, CH_3), 1.23–1.33

(8 H, m, CH_2), 1.49 (H, m, CH), 2.79 (H, dd, $J_{2,3}$ 4.1, $J_{3,3}$ 17.3, C*H*HCO), 2.91 (H, dd, $J_{2,3}$ 11.2, $J_{3,3}$ 17.3, CH*H*CO), 3.56 (3 H, s, CO_2CH_3), 3.66 (H, dd, $J_{2,3}$ 4.1, $J_{2,3}$ 11.2, $CHSO_3Na$), 3.91 (2 H, m, OCH_2); δ_C (DMSO-d_6) 10.79, 10.81 (C12), 13.90 (C10), 22.37 (C9), 23.09, 23.13 (C11), 28.31 (C8), 29.69 (C7), 34.08 (C3), 38.09, 38.11 (C6), 51.06 (CO_2CH_3), 61.16 (C2), 66.01, 66.03 (C5), 168.97 (C1), 171.00 (C4).

Sodium 1-(2-ethylhexyloxycarbonyl)-2-(2-ethylhexyloxycarbonyl)ethanesulfonate-5-d_2 ***D_2-14***. Prepared as described above for (***S,R***)-**11**, starting from monoester $\mathbf{D_2}$-**9** (250 mg, 0.75 mmol) and 2-ethylhexanol (195 mg, 1.5 mmol), DCC (300 mg, 1.5 mmol), DMAP (140 mg, 1.1 mmol) and DMAP HCl (120 mg, 0.75 mmol) in DMF (10 mL) to provide the diester $\mathbf{D_2}$-**14** (240 mg, 72%) as a paste; ν_{max}(KBr)/cm^{-1} 1735 (CO_2R), 1051 (S=O); δ_H (DMSO-d_6) 0.83 (6 H, t, *J* 7.4, CH_3), 0.86 (6 H, t, *J* 6.8, CH_3), 1.23–1.32 (16 H, m, CH_2), 1.48 (2 H, m, CH), 2.78 (H, dd, $J_{2,3}$ 4, $J_{3,3}$ 17.3, C*H*HCO), 2.91 (H, dd, $J_{2,3}$ 11.4, $J_{3,3}$ 17.3, CH*H*CO), 3.63 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.88 (2 H, m, OCH_2); δ_C (DMSO-d_6) 10.75 (C12′), 10.80, 10.82 (C12), 13.90 (C10′), 13.93 (C10), 22.39 (C9), 22.42 (C9′), 22.98 (C11′), 23.13 (C11), 28.33 (C8′, C8), 29.55, 29.61 (C7′), 29.69 (C7), 34.10 (C3), 37.92, 37.94 (C6), 38.13, 38.17 (C6′), 61.41 (C2), 66.05 (CD_2, t, J_{C-D} 4, C5), 66.18, 66.11 (C5′), 168.33 (C1), 171.06 (C4).

*Sodium 1-[(S)-2-ethylhex-5-enyloxycarbonyl]-2-[(S)-2-ethylhexyloxycarbonyl]ethanesulfonate (****S,S****)-****15****.* Prepared as described above for (***S,R***)-**11**, starting from monoester (***S***)-**9** (125 mg, 0.4 mmol) and alcohol (***S***)-**2a** (ee ~ 99%, 50 mg, 0.4 mmol), DCC (165 mg, 0.8 mmol), DMAP (95 mg, 0.8 mmol) and DMAP HCl (45 mg, 0.3 mmol) in DMF (5 mL) to provide the diester (***S,S***)-**15** (95 mg, 58%) as a paste; ν_{max}(KBr)/cm^{-1} 1736 (CO_2R), 1641 (C=C), 1049 (S=O); δ_H (DMSO-d_6) 0.84 (6 H, t, *J* 7.4, CH_3), 0.86 (3 H, t, *J* 6.6, CH_3), 1.23–1.35 (12 H, m, CH_2), 1.52 (2 H, m, CH), 2.79 (H, dd, $J_{2,3}$ 4, $J_{3,3}$ 17.3, C*H*HCO), 2.87 (H, dd, $J_{2,3}$ 11.4, $J_{3,3}$ 17.3, CH*H*CO), 3.63 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 11.4, $CHSO_3Na$), 3.91 (4 H, m, OCH_2), 4.93 (2 H, dm, *J* 10.3, =C*H*H), 5.01 (2 H, dm, *J* 17, =CH*H*), 5.79 (2 H, ddt, *J* 17, *J* 10.3, *J* 6.6, CH=); δ_C (DMSO-d_6) 10.74, 10.76 (C12′), 10.80, 10.83 (C12), 13.90 (C10), 22.39 (C9), 22.84, 22.88 (C11′), 23.15, 23.18 (C11), 28.33 (C7′, C7), 29.14, 29.22 (C8′), 29.73 (C8), 34.09 (C3), 37.67, 37.69 (C6′), 38.08, 38.11 (C6), 61.40 (C2), 65.91 (C5), 66.06, 66.10 (C5′), 114.65 (C10′), 138.85 (C9′), 168.32 (C1), 171.06 (C4).

Preparation of sulfosuccinate 13 from the disilver salt of 9. *Disilver 1-carboxy-2-(2-ethylhexyloxycarbonyl)ethanesulfonate* ***9***. A solution of $AgNO_3$ (8.68 g, 51 mmol) in 40 mL H_2O was added to a solution of *rac*-**9** (4.5 g, 12.8 mmol) (obtained as described above from *rac*-2-ethylhexanol) in 40 mL H_2O. After stirring under darkness for 24 h, the precipitated disilver salt is recovered by filtration and dried under vacuum until constant weight (6.15 g, 92%); ν_{max}(Nujol)/cm^{-1} 1750 (CO_2R), 1600 (CO_2Ag), 1180, 1050 (SO_3Ag).

1-(Methyloxycarbonyl)-2-(2-ethylhexyloxycarbonyl)ethanesulfonic acid methyl ester ***16***. To a suspension of disilver salt (1.5 g, 2.86 mmol) in 50 mL distilled toluene were added 1.8 mL of iodomethane (28.6 mmol). After stirring for 16 h at 40 °C under darkness, the reaction mixture was filtered and the filtrate concentrated under reduced pressure. The crude product contains a mixture of **13** and **16**. The purification of the crude product by chromatography on silica gel with an elution gradient Et_2O–petroleum ether 1 : 1, then EtOAc–MeOH 4 : 1 affords **13**, in acidic form (158 mg), R_f (EtOAc–MeOH 4 : 1) 0.29, as a paste and **16** (745 mg, 77%) as a liquid; R_f (Et_2O–petroleum ether 1 : 1, dichlorofluorescein) 0.36; ν_{max}(film)/cm^{-1} 1750 (C=O), 1390 (S=O), 990 (S-OCH_3); δ_H ($CDCl_3$) 0.88 (3 H, t, *J* 7.5, CH_3), 0.89 (3 H, t, *J* 7, CH_3), 1.27 (8 H, m, CH_2), 1.6 (H, m, CH), 3.08 (H, dd, $J_{2,3}$ 4, $J_{3,3}$ 17.5, C*H*HCO), 3.31 (H, dd, $J_{2,3}$ 10.7, $J_{3,3}$ 17.5, CH*H*CO), 3.89 (3 H, s, CO_2CH_3), 4.0 (3 H, s, SO_3CH_3), 4.04 (4 H, m, OCH_2), 4.49 (H, dd, $J_{2,3}$ 4, $J_{2,3}$ 10.7, $CHSO_3$); δ_C ($CDCl_3$) 10.92 (C12), 14.02 (C10), 23.08 (C9), 23.63 (C11), 29.07 (C8), 30.46 (C7), 32.54 (C3), 38.90 (C6), 54.07 (CO_2CH_3), 58.22 (SO_3CH_3), 61.51 (C2), 68.56 (C5), 166 (C1), 170.52 (C4); *m/z* (CI, NH_3) 339.1 (MH^+), 356 ($MH^+ + NH_3$).

*Sodium 1-(methyloxycarbonyl)-2-[(S)-2-ethylhexyloxycarbonyl]ethanesulfonate (****S****)-****13****.* A solution of sodium bromide (1.5 g, 15 mmol) in 10 ml of water was added to a solution of the crude product obtained above in 100 ml of acetone. The reaction mixture was allowed to stir at room temperature for 48 h. **13** (850 mg, 92%) was isolated after removal of acetone under vacuum and extraction with ethyl acetate.

Determination of the critical micelle concentrations

The critical micelle concentrations of AOT-related compounds and normal AOT (purified by the same experimental procedure) have been determined by surface tension and conductivity measurements of aqueous solutions of concentrations ranging from 5×10^{-5} to 5×10^{-3} M in ultra-pure water (MilliQ).

The surface tension γ in mN m^{-1} was given with a precision 0.1 mN m^{-1} and was measured until constant values (the equilibrium was usually reached after 15 min). For a given concentration at least three measurements were made. The ring was rinsed successively with conc. HCl, ultra-pure water (MilliQ) and dried in a flame between each set of measurements.

Below the cmc γ decreases linearly with the log of concentration according to Gibbs' equation [eqn. (1)]. The surface

$$\Gamma = -\frac{C}{2RT}\frac{d\gamma}{dC} = -\frac{1}{2.3 \times 2RT}\frac{d\gamma}{d(\log C)} \quad (1)$$

$$\text{with } a_s = \frac{1}{N\Gamma}\ (N = \text{Avogadro's number})$$

tension remains constant above the cmc. The superficial excess Γ (mol m^{-2}) and the area per head group at the air–water interface a_s (Å^2 molecule^{-1}) at the air–water interface were determined from the slope $\gamma = f(\log C)$ below the cmc.

For conductivity measurements, the cmc was deduced from the break of the slope in the plot of the equivalent conductivity Λ (mS cm l^{-1} mol^{-1}) *versus* the square root of the concentration.

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