Synthesis and comparative behaviour study of fluorocarbon and hydrocarbon cationic surfactants in aqueous media

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ABSTRACT

A series of perfluorinated cationic surfactants and their corresponding hydrocarbon ones whose general formula is $C_nX_{2n+1}-C(O)NH-(CH_2)_3-N^+Me_3, I^-$, with X = F, H and n = 9, 11, have been synthesized via two steps. Their aggregative and surface-active properties were studied in aqueous solution using tensiometry and conductimetry. The critical micelle concentrations and the molecular areas at the air/water interface of fluorinated surfactants are lower than those of their hydrocarbon homologues. Micellar aggregation numbers and geometric packing parameters have been investigated. The results indicated that fluorocarbon surfactants tend to form lamellar aggregates while the hydrocarbon ones associate into spherical aggregates.

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1. Introduction

Amphiphilic molecules with cationic or anionic polar head groups and hydrocarbon tails have been widely studied. Depending on their chemical structure and on environmental conditions, the most noteworthy characteristics of surfactants are, on one hand, their ability to adsorb on aqueous solution surfaces and to lower the water surface tension, and on the other hand their aqueous solution behaviour. They self-assemble to form aggregates, above a concentration known as the critical micelle concentration (CMC), to achieve segregation of their hydrophobic moieties from water. In fluorinated surfactants, hydrogen of the hydrocarbon tail has been partially or entirely replaced by fluorine. The compounds thus obtained are highly surface-active agents with both hydrophobic and lipophobic properties [1]. Consequently and as is widely known, fluorinated surfactants are more surface-active and more hydrophobic than their corresponding hydrocarbon analogues [2–5] in terms of surface tension and CMC lowering. Given the higher atomic size of fluorine than hydrogen, the reduced conformational freedom of the perfluorinated tails leads to bulky and stiff chains, and to aggregate structures with less curvature. Fluorinated surfactants have then the property that even single chain surfactants can form bilayer aggregates or

vesicles, although this is usually unfavorable for single chain hydrocarbon ones [3]. In addition fluorinated compounds show specific features such as thermal and chemical stability, ability to dissolve gases, low lipid and very low water solubilities. Hence they are of a growing interest in a wide range of applications, and particularly in medical formulations including perfluorocarbons, given the biological inertness of perfluorocarbons [6,7]. Then perfluorinated amphiphiles have a high biomedical potential and can be used as passive carriers for gas, drug and gene delivery [8]. Despite many reports on fluorinated surfactants, cationic perfluorosurfactants are however much less investigated in the literature than anionic ones, due mostly to difficulties in their preparation and purification.

Structural specifications about cationic lipid surfactants have been previously investigated for the purpose of use as gene delivery systems. Relationships between the chemical structure and their efficiency as carriers via liposomes in the transfection process of nucleic acids into cells have been established [9–11]. Parameters such as the positively charged polar head, the type of linker, the length at once for the spacer arm and of the hydrophobic tail, biodegradability and cytotoxicity, have been widely examined [12,13]. It has been generally established that the best yields of transfection were obtained with: amide as linker, a spacer arm of three methylene groups and iodide as counterion [14]. Taking into account these structural specifications, we have synthesized new surfactants presenting various hydrophobic tails such as hydrocarbon or fluorocarbon ones with different chain lengths.

The aim of this work is to compare in pairs the influence of a perfluoroalkyl tail C_nF_{2n+1} and of its hydrocarbon counterparts

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C_nH_{2n+1} with $n = 9$, 11 on the amphiphilic properties of the respective cationic compounds C_nX_{2n+1}–C(O)NH–$(CH_2)_3$–N$^+$Me$_3$, I$^-$ with X = F or H, denoted later as Xn-A-H3-AmI, which follows recent indications about the use of Fn or Hn notations [7]. To carry out this study, micellization is investigated by using the electrical conductivity technique together with tensiometry which also permits the investigation of their aqueous surface properties.

2. Results and discussion

The synthesis of N,N,N-trimethyl N-(3-alkylamidopropyl) ammonium iodides (Hn-A-H3-AmI with $n = 9$, 11) and of their perfluorocarbon counterparts (Fn-A-H3-AmI with $n = 9$, 11) is outlined in Scheme 1.

The first step proceeds by the reaction of the methyl alcanoate or methyl perfluoroalcanoate with 3-N,N-dimethyl-1-propylamine to give the corresponding amide, after first unsuccessful attempts have been undertaken on the reaction between alcanoyl or perfluoro alcanoyl chlorides and 3-N,N-dimethyl-1-propylamine which lead to much impurities. As a matter of fact, the synthesis from acyl chloride [15,16] forms HCl, which can lead to surface-active impurities, whose elimination by conventional methods of purification is impossible as it is notified elsewhere [17]. Therefore to avoid the contamination of our lipids and the formation of surface-actives mixtures, the synthesis has been carried out by the aminolysis reaction. The use of commercially available methyl esters as reagents enables the formation of the amido-amines without impurities as it is evidenced by the absence of artifact in the surface tension versus surfactant concentration plot. This method seems to be easier than the drastic procedure described in reference [17] from chromatographically pure carboxylic acids. The operating conditions in terms of solvent, temperature and relative amount of the reagents are optimized to give the corresponding amide until complete disappearance of the ester band at ca. 1740 cm^{-1} in the IR spectra. The conditions are indicated in the experimental part. In the case of the perfluoroalkylated compounds, the use of equivalent amounts of the 3-N,N-dimethyl-1-propylamine and the appropriate methyl ester with refluxing methanol as solvent at 65 °C leads to the corresponding amide quantitatively. The quaternization has been carried out by methyl iodide added in excess in the mixture at ambient temperature. However for the hydrocarbon compounds, the reaction is only quantitative if it is undertaken in the absence of methanol, with a large excess of 3-N,N-dimethyl-1-propylamine used together as reagent and solvent, at a high temperature (around 120–130 °C) corresponding to its boiling point. Hence the diamine excess is removed before the second step which consists in the quaternization of the amides previously obtained by methyl iodide at ambient temperature, with diethylether or diethylether-methanol solution as solvent.
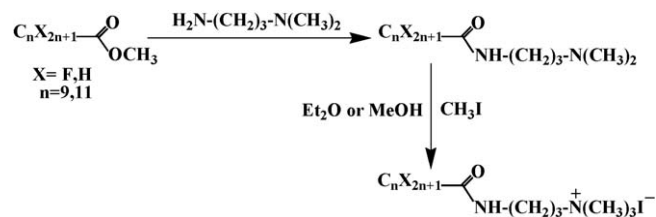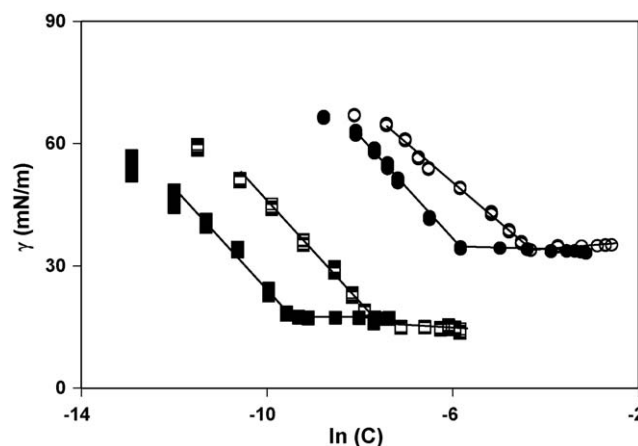

Scheme 1.

Fig. 1. Surface tension variations as a function of ln C (C, surfactant concentration expressed in mol/L) at 45 °C (dark squares: F11-A-H3-AmI, open squares: F9-A-H3-AmI, dark circles: H11-A-H3-AmI, open circles: H9-A-H3-AmI).

In the two methods and after purification by column chromatography and several washings, the final dried ammonium salts are obtained in good yields (from 62 to 80%).

Given the low solubility of the F11-A-H3-AmI compound in water at 25 °C, all measurements have been undertaken at 45 °C. The surface-active properties of N,N,N-trimethyl-(3-N-perfluoroalkylamidopropyl) ammonium iodide (Fn-A-H3-AmI with $n = 9$, 11) and of their homologous hydrocarbon compounds (Hn-A-H3-AmI with $n = 9$, 11) in water are presented in Fig. 1 where the surface tension γ is plotted against the neperien logarithm of surfactant molar concentration C.

The cationic perfluorosurfactants with different alkyl chain lengths ($n = 9$, 11) induce a surface tension decrease down to γ limit values around 15–17 mN/m. Such values are usually obtained for aqueous solutions in presence of fluorinated surfactants, whereas the presence of cationic hydrocarbon surfactants leads to higher γ limit values (around 34–35 mN/m). The CMCs are determined at the break point of these curves and are gathered in Table 1. Both hydrocarbon surfactants show higher CMC values

Table 1

Critical micelle concentrations (CMC) obtained from surface tension and conductivity measurements, surface excess Γ, molecular area a_0, micellar ionization degree β, aggregation number (N_{ag}) and geometric packing parameter P of Xn-A-H3-AmI with X = H and $n = 9$; 11 or X = F and $n = 9$;11 at 45 °C.

Compound	H9-A-H3-AmI	H11-A-H3-AmI	F9-A-H3-AmI	F11-A-H3-AmI
CMC ($\times 10^{-3}$ mol/L) by tensiometry	12	3.5	0.5	0.07
CMC ($\times 10^{-3}$ mol/L) by conductimetry	26	7.5	0.7	0.06
Γ (surface excess) ($\times 10^{-6}$ mol/m^2)	1.83	2.30	2.40	2.47
a_0 (nm^2/molecule)	0.90	0.72	0.69	0.67
S_2/S_1[a]	0.26	0.22	0.22	0.31
β	0.18	0.15	0.14	0.17
N_{ag}	67	86	86	53
Geometric parameter P	0.23	0.29	0.41[b]–0.44[c]	0.42[b]–0.45[c]

[a] Ratio of the slopes above and below the CMC from the plot x vs C.
[b] Calculated by Eq. (2).
[c] Calculated by Eq. (3).

than those of their fluorinated homologues. Moreover for the hydrocarbon surfactants, a reduction in the CMC is noticed with an increase in the hydrophobic tail, whereas such an effect is twice enhanced as hydrogen atoms are replaced by fluorine atoms. These results evidence the better ability of fluorinated surfactants toward micellization than hydrocarbon ones, and also their stronger hydrophobic character.

In addition to the determination of the CMC values and the minimum surface tension achievable, surface tension curves yield useful information such as the surface excess concentration of surfactant at the air/water interface Γ, defined by the following Gibbs equation: $\Gamma = (-1/2RT)(d\gamma/d\ln C)$, where R and T are respectively the gas constant and the absolute temperature. The Γ values are thus calculated from the slope of the linear portion of the γ versus $\ln C$ curves. The values of the cross-section molecular area of the surfactant a_0 are then given by: $a_0 = 1/(N_A \Gamma)$, where N_A is the Avogadro's number. Both Γ and a_0 values are given in Table 1. Despite the same tail length, fluorinated compounds exhibit much lower molecular surface areas than their hydrocarbon counterparts. Such behaviour is probably due to the better packing ability exhibited by the fluorocarbon tails. Furthermore the hydrophobic effect on a_0 is particularly noticeable in the case of the hydrocarbon surfactants whose a_0 value becomes noticeably smaller as the hydrocarbon chain length increases but remains higher than that of the longer fluorinated homologue. Fluorocarbon surfactants are known to exhibit very tight packing at the interface [18], and the length of their hydrophobic chain has very little effect below a chain length of 16 carbon atoms [19].

Aggregative properties such as CMC and micellar ionization degrees ($\beta = 1 - \alpha$) are examined by conductimetry at 45 °C. The conductivity (χ) variations as a function of surfactant concentration C are shown on Figs. 2 and 3 for the four compounds investigated in the present study.

The CMCs which are determined at the break point of these curves are gathered in Table 1. Such values are quite higher than those obtained from surface tension measurements except for both fluorinated compounds where CMC values are quite close to surface tension ones. The micelle ionization degrees β are generally taken, at a first approximation, as the ratio of the slopes of the two straight lines above (S_2) and below (S_1) the CMC from the plot of the electrical conductivity against the surfactant concentration [20,21]. Given the expressions of the slopes S_1 and S_2 can be written respectively as follows: $S_1 = \lambda_X + \lambda_S$ and $S_2 = \beta(\lambda_X + Fu_{mic})$ where λ_X and λ_S are the respective molar conductivities of the counterion (denoted as X) and of the surface-active ion (denoted as S), and u_{mic} is the electrophoretic surface-active ion mobility, the β values estimation method from $S_2/S_1 \approx \beta$ has to consider $\lambda_S \approx Fu_{mic}$. Because of its simplicity, this approach appears very useful. However it can lead to overestimated β values [22] as it has been shown in the case of α-sulfonatomyristic acid methyl ester [23]. According to the authors, the S_2/S_1 ratio is empirically
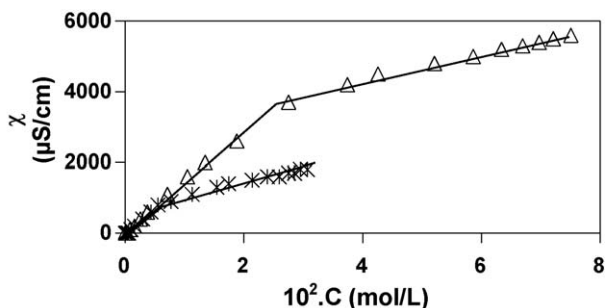
Fig. 2. Variation of the conductivity χ as a function of surfactant concentration C (open triangles: H9-A-H3-AmI, stars: H11-A-H3-AmI) at 45 °C.
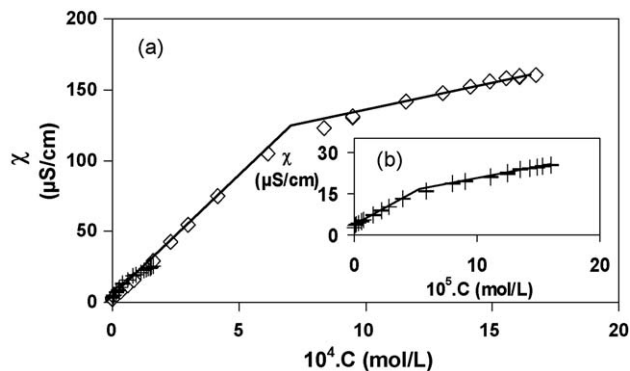
Fig. 3. Variation of the conductivity χ as a function of surfactant concentration C (open diamonds: F9-A-H3-AmI (a), crosses: F11-A-H3-AmI (b)) at 45 °C.

correlated with β as: $S_2/S_1 \approx 2.5\beta$. Moreover this equation can be also obtained theoretically by introducing the ratio of the electrophoretic micelle mobility and the electrophoretic surface-active ion mobility: $k = u_{mic}/u_S = Fu_{mic}/\lambda_S$ in the S_2 expression, reminding that for a (1:1) surfactant type, $u_S = \lambda_S/F$, and for micelles of aggregation number N_{ag} and charge $|z_{mic}| = N_{ag}\beta$, $u_{mic} = \lambda_{mic}/N_{ag} \cdot \beta \cdot F$. Then the expressions of S_2 and of the S_2/S_1 ratio become respectively:

$$S_2 = \beta(\lambda_X + k.\lambda_S) = \beta[k.S_1 + (1-k)\lambda_X] \quad \text{and}$$

$$\frac{S_2}{S_1} = \beta\left[\frac{\lambda_X}{S_1} + k\left(1 - \frac{\lambda_X}{S_1}\right)\right].$$

Taking $k = 6.3$ in the case of α-sulfonatomyristic acid methyl ester leads to $S_2/S_1 \approx 2.5\beta$

In addition to CMC and counterion association degree values, conductimetry can also lead to micellar aggregation numbers N_{ag} by the Evans equation [24]:

$$N_{ag}^{2/3} = \left[\frac{1000 S_2 - \beta\lambda_X}{\beta^2(1000 S_1 - \lambda_X)}\right]$$

if S_1 and S_2 are expressed in mS cm^2 mol^{-1}, and λ_X in S cm^2 mol^{-1}, which becomes

$$N_{ag} = \left[\frac{S_2 - \beta\lambda_X}{\beta^2(S_1 - \lambda_X)}\right]^{3/2}$$

if S_1, S_2 and λ_X are expressed in the same units. Usually application of this equation concerns the calculation of the degree of counterion dissociation β. It requires knowledge of the aggregation number N_{ag} obtained from light scattering measurements or others physical methods. To avoid the uncertainty associated with the calculation of β, we propose a better estimation of this parameter using an other approach of the Evans equation. Furthermore, introducing the previous S_2/S_1 equation into:

$$N_{ag}^{2/3} = \left[\frac{S_2 - \beta\lambda_X}{\beta^2(S_1 - \lambda_X)}\right]$$

leads to:

$$N_{ag}^{2/3} = \frac{\beta S_1[(\lambda_X/S_1) + k(1 - (\lambda_X/S_1))] - \beta\lambda_X}{\beta^2 S_1(1 - (\lambda_X/S_1))}$$

which simplifies to: $N_{ag}^{2/3} = k/\beta$.

With $k' = (\lambda_X/S_1) + k(1 - (\lambda_X/S_1))$, the Evans equation becomes:

$$N_{ag} = (s_1/s_2)^{3/2}(k.k')^{3/2} \text{ and } s_2/s_1 = \beta k'.$$

It can be noticed that in the simple case where β is taken as the S_2/S_1 ratio, the k and k' values are both equal to unity, and $N_{ag} = N_{ag}^* = (S_1/S_2)^{3/2}$. In the present study, the $(k.k')^{3/2}$ factor can

be estimated through known N_{ag} and S_2/S_1 values about homologous surfactants Hn-A-H3-AmCl compounds where iodide ions are replaced by chloride ions [17] by assuming that u_{mic}/u_s and λ_X/S_1 do not change significantly with a change in counterions. For example, the aggregation number of H9-A-H3-AmCl is found around 44 at 25 °C and $S_2/S_1 = 0.34$. Then $(k \cdot k')^{3/2} = 9$ (or $k \cdot k' = 4.33$). Moreover the k and k' values can be separately determined from the second order equation of k: $k \cdot k' = 4.33 = k\lambda_X/S_1 + k^2(1 - \lambda_X/S_1)$ where the λ_X value of I^- counterion is calculated at $\theta = 45$ °C from the following equation [25]: $\lambda_{I^-} = 76.5 \times 10^{-4} + 1.50893 \times 10^{-4}(\theta - 25) + 0.43750 \times 10^{-6}(\theta - 25)^2 - 0.2170 \times 10^{-8}(\theta - 25)^3 = 108.60 \times 10^{-4}\,\mathrm{S\,m^2\,mol^{-1}}$. This permits a better estimation of the micellar ionization degree through $\beta = (1/k')(S_2/S_1)$ than the estimation from $\beta = S_2/S_1$. For comparison the values of the S_2/S_1 ratio and of β are indicated in Table 1. From previous results about Hn-A-H3-AmCl compounds where iodide ions are replaced by chloride ions, $\beta = 0.34$ for $n = 9$ at 25 °C, decreases down to 0.19 for $n = 11$ and remains almost constant for $n = 13$ and 15. The β values obtained in the present work for Hn-A-H3-AmI with $n = 9$ or 11 are lower (0.15–0.18) than those obtained for Hn-A-H3-AmCl. This may be attributed to the higher solvation degree of the smaller (Cl^-) counterions than that of I^-, which favors dissociation between the surface-active ion and its counterion and thus leads to higher micelle ionization degrees [26]. For the perfluoroalkylated series, β values are quite close to those of their hydrocarbon counterparts.

Application of the equation $N_{ag} = (k/\beta)^{3/2}$ leads to higher aggregation numbers of hydrocarbon surfactants with iodide as counterions than those of their hydrocarbon homologues with chloride as counterions. This may be associated to the higher hydration of chloride ions, which inhibits counterion association to the micellar aggregates and also reduces the neutralization effect of the micelles, thus leading to weaker aggregation. The results also indicate an increase in N_{ag} as n increases, which is usually observed for hydrocarbon surfactants. For fluorocarbon surfactants, larger aggregates are obtained with F9-A-H3-AmI compared to H9-A-H3-AmI. However small aggregates are noticed for $n = 11$, which may be attributed to a different behaviour associated to different aggregate type.

From the Israelachvili packing parameter P [27], it is possible to predict the shape of the equilibrium aggregate. The P parameter is defined as v_0/a_0l_C where v_0 is the molecular volume of the surfactant tail with n_C carbon atoms and l_C is the maximal length of the hydrophobic chain, which can be calculated from the following equations:

for a hydrocarbon tail [28]:

$$v_0\,(\mathrm{nm^3}) = 0.0274 + 0.0269n_C \text{ and } l_C\,(\mathrm{nm}) = 0.154 + 0.127n_C \quad (1)$$

for a fluorocarbon tail [29,30]:

$$v_0\,(\mathrm{nm^3}) = 0.0545 + 0.0380n_C \text{ and } l_C\,(\mathrm{nm}) = 0.200 + 0.134n_C \quad (2)$$

or

$$v_0\,(\mathrm{nm^3}) = 0.0424 + 0.0416n_C \text{ and } l_C\,(\mathrm{nm}) = 0.204 + 0.130n_C \quad (3)$$

The P values for prediction of spherical, cylindrical and lamellar aggregates are respectively for $P \leq 0.33$, $0.33 \leq P \leq 0.5$ and $0.5 \leq P \leq 1$. In the case of both hydrocarbon surfactants spherical aggregates are predicted. For both fluorocarbon ones, P values are rather close to 1/2, which is characteristic of cylindrical or lamellar structures. Since the fluorocarbon chains are bulkier than the hydrocarbon ones, fluorocarbon surfactant need to have a very large headgroup to form a spherical aggregate in order to balance the effect of the bulky perfluoroalkylated tail [31].

3. Experimental

3.1. Materials

Perfluorodecanoic acid methyl ester (96%) and perfluorododecanoic acid methyl ester (96%), decanoic acid methyl ester (96%), dodecanoic acid methyl ester (99%), iodomethane (99%) are furnished by Alfa Aesar. 3-N,N-Dimethylamino-1-propylamine (99%), silicagel (230–400 mesh, 60 Å) and anhydrous solvents were obtained from Aldrich.

3.2. Methods

Solutions are prepared using deionized water with specific conductivity less than $3\,\mu S\,cm^{-1}$. The surface tensions were measured by the Du Nouy ring method at 45 °C. A simple cell with constant temperature (± 0.1 °C) water passing through its jacket is used. Electrical conductivity of aqueous surfactant solutions is measured using a conductimeter and a cell, whose constant was determined by means of KCl solutions. Solutions were maintained at constant temperature using a water bath. CMCs are rather derived from the break points in the specific conductivity χ versus surfactant concentration C curve.

NMR spectra were obtained with a Bruker Avance DTX 200 spectrometer, IR spectra were recorded on Perkin Elmer FT-IR spectrometer model Spectrum 1000.

3.3. Synthesis of N,N,N-trimethyl-N-(3-perfluoroalkylamidopropyl) ammonium iodide (Fn-A-H3-AmI) and N,N,N-trimethyl-N-(3-alkylamidopropyl) ammonium iodide (Hn-A-H3-AmI)

N,N,N-Trimethyl-N-(3-perfluoroalkylamidopropyl) ammonium iodide and N,N,N-trimethyl-N-(3-alkylamidopropyl) ammonium iodide are prepared by a two steps method. The first step concerns the synthesis of N-(3-N,N-dimethylamidopropyl) perfluoroalkylamide or N-(3-N,N-dimethylamidopropyl) alkylamide from the corresponding methyl esters and freshly distilled 3-N,N-dimethyl-1-propylamine (on calcium hydride). The second step is the quaternization of the amide by methyl iodide in methanol or diethyl ether media, according to Scheme 1.

For X = F and $n = 10$; 12, a solution of 3-N,N-dimethyl-1-propylamine (10^{-2} mol in 15 mL of absolute methanol), is droply added to a solution of methyl perfluoroalkanoate (10^{-2} mol in 25 mL of absolute methanol) under magnetic stirring at 0 °C. The reaction mixture is heated to reflux around 65 °C for 24 h. For X = H, 3-N,N-dimethyl-1-propylamine (2×10^{-2} mol) is added to the appropriate methyl ester (10^{-2} mol) under magnetic stirring at room temperature. The reaction mixture was refluxed around 120–130 °C. The reaction progress is followed by measuring the complete disappearance of the $v_{C=O}$ vibration peak at $1740\,cm^{-1}$. 24 h are required for reaction completion. Then the unreacted amine was removed in high vacuum. For $n = 12$ the residues are purified by column chromatography on silica gel (chloroform:methanol = 8:2 (v/v)) to give the corresponding amide before quaternization.

Then the quaternization is undertaken as follows: to the pure amide or the amide reaction medium previously obtained (methanol media) are added diethylether (40 mL) and dropwise freshly distilled methyl iodide (4.4×10^{-2} mol) at 0 °C under stirring. The solution is stirred at room temperature for 15 h (for X = F) or 24 h (for X = H) and the solid is obtained either by filtration or by evaporation of the solvent. Moreover the H9-A-H3-AmI compound is previously washed twice with acetonitrile and purified by recrystallization from ethanol/acetone solution before the chromatographic step. Then all the solids are purified by repetitive column chromatography on silica gel (chloroform:methanol = 3:7 for X = F, and 8:2 for X = H).

The final white and very hygroscopic solids are then dried under reduced pressure, and their spectral characteristics are given below.

3.3.1. F9-A-H3-AmI

Yield 80%, IR (KBr, ν (cm^{-1})); 3433 (ν_{N-H}), 1706 ($\nu_{C=O}$), 1154 (ν_{C-F}); ^{1}H NMR (200 MHz, DMSO): δ 1.94 (2H, m, CH$_2{}^b$), 3.07 (9H, s, (CH$_3$)$_3{}^d$), 3.31 (2H, m, CH$_2{}^c$), 3.40 (2H, m, CH$_2{}^a$) for CF$_3$(CF$_2$)$_8$CONH-CH$_2{}^a$CH$_2{}^b$CH$_2{}^c$N(CH$_3$)$_3{}^d$I.

3.3.2. F11-A-H3-AmI

Yield 70%, IR (KBr, ν (cm^{-1})); 3334 (ν_{N-H}), 1693 ($\nu_{C=O}$), 1152 (ν_{C-F}); ^{1}H NMR (200 MHz, DMSO): δ 1.95 (2H, m, CH$_2{}^b$), 3.08 (9H, s, (CH$_3$)$_3{}^d$), 3.29 (2H, m, CH$_2{}^c$), 3.35 (2H, m, CH$_2{}^a$) for CF$_3$(CF$_2$)$_{10}$CONHCH$_2{}^a$CH$_2{}^b$CH$_2{}^c$N(CH$_3$)$_3{}^d$I.

3.3.3. H9-A-H3-AmI

Yield 65%, IR (KBr, ν (cm^{-1})); 3310 (ν_{N-H}), 1642 ($\nu_{C=O}$); ^{1}H NMR (200 MHz, D$_2$O): δ 0.848 (3H, t, CH$_3{}^a$), 1.26 (14H, s, (CH$_2$)$_7{}^b$), 1.6 (2H, m, CH$_2{}^c$), 2.21 (2H, t, CH$_2{}^d$), 3.5 (2H, q, CH$_2{}^f$), 2.1 (2H, m, CH$_2{}^g$), 3.3 (2H, t, CH$_2{}^h$), 3.18 (9H, s, N(CH$_3$)$_3{}^i$ I) for CH$_3{}^a$(CH$_2$)$_7{}^b$CH$_2{}^c$CH$_2{}^d$CONH^{e}CH$_2{}^f$CH$_2{}^g$CH$_2{}^h$ N(CH$_3$)$_3{}^i$ I.

3.3.4. H11-A-H3-AmI

Yield 62%, IR (KBr, ν (cm^{-1})); 3313 (ν_{N-H}), 1642 ($\nu_{C=O}$); ^{1}H NMR (200 MHz, D$_2$O): δ 0.845 (3H, t, CH$_3{}^a$), 1.26 (18H, s, (CH$_2$)$_7{}^b$), 1.6 (2H, m, CH$_2{}^c$), 2.27 (2H, t, CH$_2{}^d$), 3.5 (2H, q, CH$_2{}^f$), 2.15 (2H, m, CH$_2{}^g$), 3.29 (2H, t, CH$_2{}^h$), 3.16 (9H, s, N(CH$_3$)$_3{}^i$ I) for CH$_3{}^a$(CH$_2$)$_9{}^b$CH$_2{}^c$CH$_2{}^d$CONH^{e}CH$_2{}^f$CH$_2{}^g$CH$_2{}^h$ N(CH$_3$)$_3{}^i$ I.

4. Conclusion

Four cationic fluorocarbon or hydrocarbon surfactants with an amide linker group have been synthesized from the corresponding methyl ester via a two steps method and their aqueous solution behaviour has been investigated. As the hydrophobic tail length increases, the CMC of fluorocarbon and hydrocarbon surfactants decreases, and more noticeably for fluorocarbon ones whose strong hydrophobic character is also evidenced by their high packing ability at the air/water interface. Hydrocarbon surfactants with iodide counterions associate with larger micellar aggregation numbers than their chloride counterparts. Moreover as it can be predicted such compounds tend to form spherical aggregates whereas fluorocarbon surfactants tend to associate into lamellar aggregates as their geometric packing parameter is very close to 1/2. Thus *N,N,N*-trimethyl-*N*-(3-perfluorodecylamidopropyl) ammonium iodide and *N,N,N*-trimethyl-*N*-(3-perfluorododecylamidopropyl) ammonium iodide are good candidates to be further involved in vesicular formulation for cellular transfection applications.

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