Chemistry and Physics of Lipids 160 (2009) 105–108

Contents lists available at ScienceDirect

Chemistry and Physics of Lipids

journal homepage: www.elsevier.com/locate/chemphyslip

Polycations. 19. The synthesis of symmetrical dicationic lipids with internal dimethylazonia functionalities separated by a spacer unit and pendant chains

Robert Engel[a,*], JaimeLee Iolani Rizzo[b], Diego Montenegro[a], Jay Leb[a], Delroy Coleman[a], Carolyn Hong[a], Herby Jeanty[b], Marie Thomas[a,c]

[a] Department of Chemistry and Biochemistry, Queens College of CUNY, 65-30 Kissena Boulevard, Flushing, NY 11367, USA
[b] Department of Chemistry and Physical Sciences, Pace University, 1 Pace Plaza, New York, NY 10038, USA
[c] Doctoral Program in Chemistry, The Graduate Center of CUNY, 365 5th Avenue, New York, NY 10016, USA

ARTICLE INFO

Article history:
Received 10 February 2009
Received in revised form 23 April 2009
Accepted 27 April 2009
Available online 3 May 2009

Keywords:
Cationic lipid
Polycation
Quaternary ammonium salt
Antihydrophobic effect
Diol
Tetraol

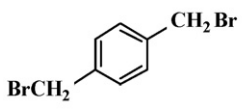
ABSTRACT

Herein is reported the preparation of several series of symmetrical polyammonium salts that serve as cationic lipids or precursors thereof, and are structurally based on several series of parent diamines where dimethylazonia functionalities are present, separated by a central structural unit, and pendant terminal chains. The resultant materials are of significant interest for a variety of purposes, such as serving as antihydrophobic species and as transfectins, the details of which are provided in separate reports. Attempts to effect selective alkylation to provide the corresponding unsymmetrical cationic lipids were without success, always leading to relatively useless mixtures of products.

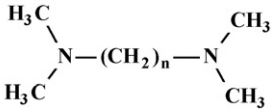
1. Introduction

In the course of our investigations of polyammonium salts for their application to a variety of purposes, we had cause to prepare several series of cationic lipids wherein the bulk of the molecule was arranged structurally in a flexible linear manner. Such polycationic species have been referred to as polycationic "strings." In a recent report (Engel et al., in press) we have discussed the syntheses of several series of such polycationic strings in which the cationic sites were located at the nitrogens of 1,4-diazabicyclo[2.2.2]octane (dabco) components incorporated along the string. In the current work we are reporting the syntheses of several series of similar polycationic lipids that are structurally based on: (a) several α,ω-bis(dimethylamino)alkanes (as shown below) with the nitrogen atoms again providing the cationic sites, and (b) α,ω-dihalo species which can be used in alkylation of *two* substituted dimethylaminoalkane units.

Although most of the new compounds synthesized and reported herein are prepared by alkylation of simple di-tertiary amines of the type α,ω-bis(dimethylamino) alkanes, this is not the situation in all instances. In certain instances other approaches toward the construction of such species have been used, for example, those syntheses wherein "end-components" bearing a tertiary amine have been used in displacement reaction upon a "central-component" bearing two reactive halogen sites. An example of this type of system is provided by using a dihalo reagent such as α,α′-dibromo-*p*-xylene (shown below as **A**) in reaction with two equivalent amounts of a terminal dimethylaminoalkane (shown below as **B**).



A



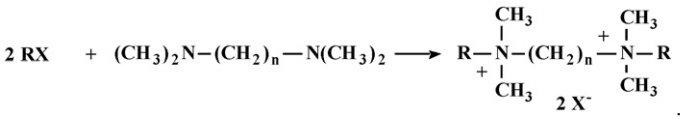
B

Dicationic lipids of this type (regardless of their route of synthesis) can provide salts bearing structural features of varying types rendering them useful for numerous applications. Included among these types are gemini lipids for which application has been found in the construction of artificial membranes (Iwamoto et al., 2000, 2004; Bhattacharya and Bajaj, 2007; Bajaj et al., 2008) and as transfectins (Camilleri et al., 2000; Martin et al., 2005). The polycationic lipids reported herein are based on relatively simpler structures (polycationic strings) and can be anticipated to exhibit properties varying as a function of terminal chain length, charge separation, and appended functional groups (hydroxyl groups) as noted.

* Corresponding author. Fax: +1 728 997 5531.
E-mail address: robert.engel@qc.cuny.edu (R. Engel).

0009-3084/$ – see front matter © 2009 Elsevier Ireland Ltd. All rights reserved.
doi:10.1016/j.chemphyslip.2009.04.004

Table 1
Analytical and yield data for newly synthesized dicationic strings.



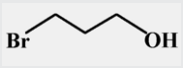
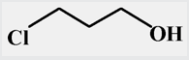
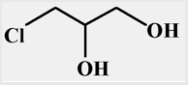
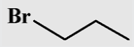
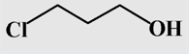
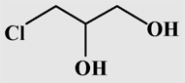
Cpd. no.	RX	*n*	Yield	^{1}H NMR (solvent) (δ)	^{13}C NMR (δ)	Analyses
1		2	82.5%	(D_2O) 1.88–1.91 (4H) *br*, 3.12 (12H) *s*, 3.30–3.50 (8H) *br*, 3.65 (4H) *t*	26.1, 53.3, 60.4, 62.6, 64.8	Calcd: $C_{12}H_{30}N_2O_2Br_2(H_2O)$; C: 34.96%; H: 7.82%; found: C: 34.71%; H: 7.87%
2		3	61.5%	(D_2O) 0.88 (6H) *t*, 1.70 (4H) *br*, 2.20 (2H) *br*, 3.03 (12H) *s*, 3.21–3.32 (8H) *br*	9.7, 15.7, 16.7, 50.6, 60.1, 66.2	Calcd: $C_{13}H_{32}N_2Br_2$; C: 41.50%; H: 8.57%; found: C: 41.31%; H: 8.66%
3		3	64.0%	(D_2O) 1.90–2.01 (4H) *br*, 2.22–3.20 (2H) *br*, 3.10 (12H) *s*, 3.33–3.55 (8H) *br*, 3.69 (4H) *t*	19.1, 27.4, 53.2, 60.4, 62.6, 64.8	Calcd: $C_{13}H_{32}N_2O_2Cl_2$; C: 48.90%; H: 10.10%; found: C: 48.99%; H: 10.39%
4		3	88.0%	(D_2O) 2.33 (2H) *br*, 3.17 (6H) *s*, 3.19 (6H) *s*, 3.44–3.54 (12H) *br*, 4.23 (2H) *m*	16.9, 51.9, 52.1, 61.2, 61.4, 63.6, 66.0, 66.2	Calcd: $C_{13}H_{32}N_2O_2Cl_2(H_2O)$; C: 48.59%; H: 10.66%; found: C: 48.31%; H: 10.84%
5	$Cl(CH_2)_6OH$	3	74.2%	(D_2O) 1.30–1.37 (8H) *br*, 1.45–1.62 (4H) *br*, 1.68–1.78 (4H) *br*, 2.20–2.28 (2H) *br*, 3.07 (12H) *s*, 3.25–3.34 (8H) *m*, 3.51 (4H) *t*	14.8, 20.0, 22.8, 23.3, 29.1, 48.8, 58.1, 59.7, 62.9,	Calcd: $C_{19}H_{44}N_2O_2Cl_2$; C: 56.56%; H: 10.99%; found: C: 56.81%; H: 10.70%
6	$CH_3(CH_2)_{11}Br$	3	74.3%	($CDCl_3$) 0.82 (6H) *t*, 1.12–1.35 (34H) *br*, 1.66 (4H) *br*, 1.87 (4H) *br*, 3.30 (12H) *s*, 3.46–3.52 (8H) *br*	14.1, 20.9, 22.6, 22.8, 26.2, 29.2, 29.26, 29.34, 29.4, 29.5, 31.8, 45.2, 51.4, 55.6, 64.1	Calcd: $C_{31}H_{68}N_2Br_2$; C: 59.22%; H: 10.90%; found: C: 59.13%; H: 10.98%
7		4	54.3%	(D_2O) 1.23–1.38 (4H) *m*, 1.40–1.55 (4H) *br*, 2.98 (12H) *s*, 3.17–3.32 (8H) *br*, 3.50 (4H) *t*	20.0, 22.6, 51.3, 62.3, 63.7, 65.0	Calcd: $C_{14}H_{34}N_2O_2Cl_2$; C: 50.44%; H: 10.28%; found: C: 50.80%; H: 10.21%
8	$Cl(CH_2)_6OH$	4	73.0%	(D_2O) 1.33–1.47 (8H) *br*, 1.48–1.49 (4H) *br*, 1.61–1.64 (8H) *br*, 3.16 (12H) *s*, 3.33 (8H) *m*, 3.69 (4H) *t*	18.8, 21.5, 24.2, 24.9, 30.6, 50.2, 61.2, 62.5, 63.9	Calcd: $C_{20}H_{46}N_2O_2Cl_2$; C: 57.54%; H: 11.11%; found: C: 57.27%; H: 11.40%
9	$Cl(CH_2)_{10}OH$	4	68.5%	(D_2O) 1.35–1.49 (20H) *br*, 1.51–1.52 (8H) *br*, 1.63–1.66 (8H) *br*, 3.19 (12H) *s*, 3.35 (8H) *m*, 3.71 (4H) *t*	18.2, 18.5, 18.8, 19.2, 19.7, 21.5, 24.3, 24.9, 30.7, 50.2, 61.2, 62.6, 63.9	Calcd: $C_{28}H_{62}N_2O_2Cl_2$; C: 63.49%; H: 11.80%; found: C: 63.41%; H: 11.91%
10	$CH_3(CH_2)_{16}Br$	4	88.5%	($CDCl_3$) 0.81 (6H) *t*, 1.11–1.31 (52H) *br*, 1.68 (4H) *br*, 2.09 (4H) *br*, 3.21 (12H) *s*, 3.35 (4H) *br*, 3.86 (4H) *br*	14.2, 19.9, 22.7, 22.9, 26.3, 27.3, 29.2, 29.3, 29.4, 29.49, 29.51, 29.63, 29.66, 29.68, 29.72, 31.9, 42.7, 50.9, 63.7	Calcd: $C_{40}H_{86}N_2Br_2$; C: 63.64%; H: 11.48%; found: C: 63.62%; H: 11.57%
11	CH_3I	6	91.5%	(D_2O) 1.34 (4H) *br*, 1.71 (4H) *br*, 3.01 (18H) *s*, 3.23 (4H) *br*	22.2, 25.0, 52.8, 66.4	Calcd: $C_{12}H_{30}N_2I_2$; C: 31.59%; H: 6.63%; found: C: 31.48%; H: 6.72%
12		6	87.0%	(D_2O) 0.86 (6H) *t*, 1.29 (4H) *br*, 1.78 (8H) *br*, 2.94 (12H) *s*, 3.16 (8H) *br*	14.7, 18.2, 20.9, 24.2, 49.6, 62.9, 64.5	Calcd: $C_{16}H_{38}N_2I_2$; C: 37.51%; H: 7.48%; found: C: 37.44%; H: 7.62%
13		6	77.6%	(D_2O) 1.23–1.38 (8H) *m*, 1.38–1.51 (4H) *m*, 2.90 (12H) *s*, 3.12–3.25 (8H) *m*, 3.45–3.58 (4H) *t*	24.1, 26.8, 27.5, 52.8, 63.4, 66.0, 66.2	Calcd: $C_{16}H_{38}N_2O_2Cl_2(H_2O)$; C: 50.65%; H: 10.63%; found: C: 50.88%; H: 10.59%
14		6	47.0%	(D_2O) 1.32 (4H) *br*, 1.69 (4H) *br*, 3.05 (6H) *s*, 3.06 (6H) *s*, 3.28–3.34 (8H) *m*, 3.46–3.48 (4H) *m*, 4.15 (2H) *m*	21.8, 25.0, 51.5, 51.7, 63.6, 65.3, 65.6, 66.1	Calcd: $C_{16}H_{38}N_2O_4Cl_2$; C: 48.85%; H: 9.74%; found: C: 48.48%; H: 9.54%
15	$CH_3(CH_2)_3Br$	6	72.0%	(D_2O) 0.83 (6H) *t*, 1.29 (8H) *br*, 1.61 (8H) *br*, 2.92 (12H) *s*, 3.17 (8H) *br*	12.8, 19.0, 21.8, 23.8, 25.1, 42.5, 50.4, 63.6	Calcd: $C_{18}H_{42}N_2Br_2$; C: 48.44%; H: 9.48%; found: C: 48.21%; H: 9.59%
16	$Cl(CH_2)_6OH$	6	60.1%	(D_2O) 1.28–1.32 (12H) *br*, 1.43–1.49 (4H) *br*, 1.66–1.67 (8H) *br*, 2.94 (12H) *s*, 3.16–3.20 (8H) *m*, 3.49 (4H) *t*	22.2, 24.7, 24.9, 25.5, 25.6, 31.3, 46.1, 62.1, 64.1, 64.3	Calcd: $C_{22}H_{50}N_2O_2Cl_2$; C: 59.31%; H: 11.31%; found: C: 59.38%; H: 11.41%
17	$C_6H_5CH_2Cl$	6	37.0%	(D_2O) 1.33 (4H) *br*, 1.80 (4H) *br*, 2.91 (12H) *s*, 3.19 (4H) *br*, 4.28 (4H) *br*, 7.57 (10H) *br*	22.0, 25.2, 42.9, 49.6, 67.8, 127.2, 129.1, 130.8, 132.8	Calcd: $C_{24}H_{38}N_2Cl_2$; C: 71.47%; H: 7.89%; found: C: 71.48%; H: 8.13%

Table 1 (*Continued*)

Cpd. no.	RX	*n*	Yield	^{1}H NMR (solvent) (δ)	^{13}C NMR (δ)	Analyses
18	$CH_3(CH_2)_7Cl$	6	46.0%	($CDCl_3$) 0.87 (6H) *t*, 1.26–1.35 (24H) *br*, 1.72 (4H) *br*, 2.00 (4H) *br*, 3.39 (12H) *s*, 3.50 (4H) *br*, 3.73 (4H) *br*	14.0, 21.7, 22.6, 22.9, 24.4, 26.3, 29.0, 29.2, 31.6, 51.0, 64.2, 64.8	Calcd: $C_{26}H_{58}N_2Cl_2$; C: 66.49%; H: 12.45%; found: C: 66.24%; H: 12.61%
19	$CH_3(CH_2)_9Cl$	6	38.0%	($CDCl_3$) 0.81 (4H) *t*, 1.19–1.26 (22H) *br*, 1.36–1.41 (8H) *br*, 1.67–1.71 (4H) *br*, 2.13 (12H) *s*, 2.15–2.19 (12H) *br*, 3.45 (4H) *t*	14.0, 22.6, 26.8, 27.4, 27.7, 28.8, 29.2, 29.4, 29.5, 31.8, 32.6, 45.0, 45.4, 59.8	Calcd: $C_{30}H_{66}N_2Cl_2$; C: 68.53%; H: 12.65%; found: C: 68.39%; H: 12.81%
20	$CH_3(CH_2)_{11}Cl$	6	51.0%	($CDCl_3$) 0.74 (6H) *t*, 1.10–1.30 (40H) *br*, 1.59 (4H) *br*, 1.83 (4H) *br*, 3.25 (12H) *s*, 3.39 (4H) *br*, 3.54 (4H) *br*	14.0, 21.7, 22.5, 22.8, 24.7, 25.7, 26.2, 27.1, 29.2, 29.3, 29.4, 31.8, 44.8, 50.9, 64.0, 64.5	Calcd: $C_{34}H_{74}N_2Cl_2$; C: 70.18%; H: 12.82%; found: C: 70.04%; H: 12.93%
21	$CH_3(CH_2)_{13}Br$	6	51.8%	($CDCl_3$) 0.81 (6H) *t*, 1.16–1.38 (48H) *br*, 1.55 (4H) *br*, 1.69 (4H) *br*, 3.36 (12H) *s*, 3.41 (4H) *br*, 3.69 (4H) *br*	14.1, 21.5, 22.7, 22.9, 24.0, 26.3, 29.3, 29.4, 29.47, 29.51, 29.59, 29.65, 29.68, 31.9, 51.1, 64.2, 64.9	Calcd: $C_{38}H_{82}N_2Br_2$; C: 62.79%; H: 11.37%; found: C: 62.58%; H: 11.41%
22	$CH_3(CH_2)_{15}Br$	6	52.2%	($CDCl_3$) 0.83 (6H) *t*, 1.21–1.38 (56H) *br*, 1.59 (4H) *br*, 1.71 (4H) *br*, 3.37 (12H) *s*, 3.45 (4H) *br*, 3.49 (4H) *br*	14.1, 21.6, 22.7, 22.9, 24.4, 26.3, 26.8, 27.2, 29.28, 29.35, 29.41, 29.49, 29.60, 29.65, 29.69, 31.9, 45.4, 51.1, 59.3, 64.2	Calcd: $C_{42}H_{90}N_2Br_2$; C: 64.43%; H: 11.59%; found: C: 64.19%; H: 11.82%
23	$CH_3(CH_2)_{17}Br$	6	83.0%	($CDCl_3$) 0.88 (6H) *t*, 1.26–1.48 (68H) *br*, 1.71 (4H) *br*, 3.37 (12H) *s*, 3.42–3.50 (8H) *br*	14.1, 22.7, 22.8, 26.1, 26.3, 26.9, 27.3, 29.23, 29.29, 29.35, 29.38, 29.46, 29.59, 29.62, 29.65, 29.70, 31.9, 45.4, 51.2, 59.3, 63.8	Calcd: $C_{46}H_{98}N_2Br_2$; C: 65.84%; H: 11.77%; found: C: 65.79%; H: 11.83%
24	$Cl(CH_2)_3OH$	8	61.4%	(D_2O) 1.30 (8H) *br*, 1.65–1.75 (4H) *br*, 1.85–1.95 (4H) *br*, 2.99 (12H) *s*, 3.15–3.35 (8H) *br*, 3.61 (4H) *t*	20.9, 24.5, 25.0, 27.1, 49.8, 58.1, 60.6, 63.4	Calcd: $C_{18}H_{42}N_2O_2Cl_2(H_2O)$; C: 53.05%; H: 10.88%; found: C: 52.75%; H: 10.91%

Prior efforts of these laboratories have been reported in which a variety of polycationic salts have been constructed and used for a variety of purposes including the investigation of the antihydrophobic effect (Cohen et al., 1998) and for the preparation of ionic liquids (Lall et al., 2002). Additional summaries of these efforts have also been published (Cohen and Engel, 1998, 2002).

2. Results and discussion

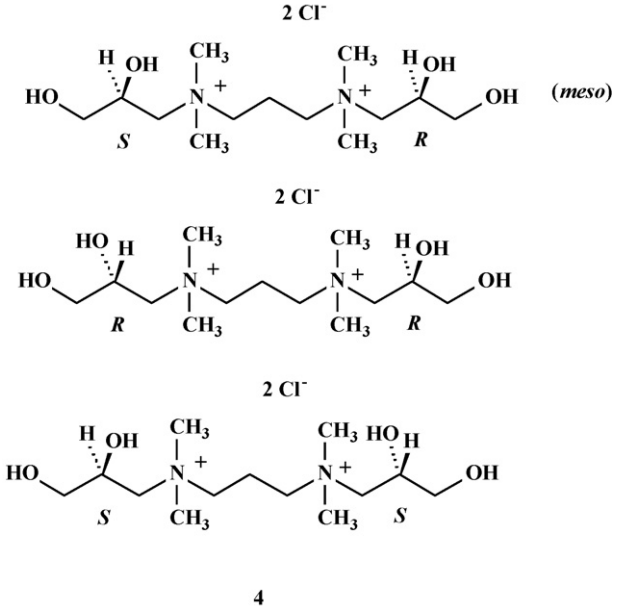
The series of dicationic lipids and related salts have for the most part been synthesized by the reaction of a central unit consisting of an α,ω-bis(dimethylamino)alkane, acting as a nucleophile, with a primary haloalkane or substituted haloalkane acting as the electrophile. In all instances the isolated pure products are composed of the skeletal portions of a "central unit" and two terminal units.

Numerous attempts were made to accomplish in reasonable yield the addition of only *one* terminal unit to a central unit. Attainment of this goal was attempted through variation of solvent systems as well as ratios of reactants. In all instances, these attempts were unsuccessful toward the preparation of monocationic species in readily isolable reasonable yield. Earlier attempts at the preparation of unsymmetrical polycationic lipids based on the di-tertiary amine 1,4-diazabicyclo[2.2.2]octane (dabco) were quite successful through the use of a proper reactant ratio and choice of solvent (Engel et al., in press). Apparently the proximity of the nitrogen sites and the stereoelectronic effect within the dabco ring system allows such a differentiation of the reactivity of the sites while in the more distant and spatially variant nitrogens of the species of the class α,ω-bis(dimethylamino)alkane permits independent action of these sites which precludes their facile chemical differentiation.

The organization of the compounds newly synthesized by reaction of the α,ω-bis(dimethylamino)alkanes and shown within Table 1, as well as in Section 3, is based on the structural factors; the initial factor is the distance between the cationic sites (*n* in Table 1), followed by the length of the terminal chains, the second modified by pendant functional groups on the terminal units.

While all of these newyl prepared cationic lipid materials exhibit some water solubility, with some it is significantly greater than with others. As anticipated, with increasing chain length (lipophilicity) water solubility decreases and solubility in ordinary organic solvents increases. In some instances (*i.e.* compounds **4**, **13**, and **24**) the hydrophilic character was sufficient that even after drying under high vacuum, upon exposure to ordinary air the materials rapidly picked up water such that their analyses were of the hydrated forms rather than anhydrous. In each of these instances each of the termini of the chains involved a primary hydroxyl group.

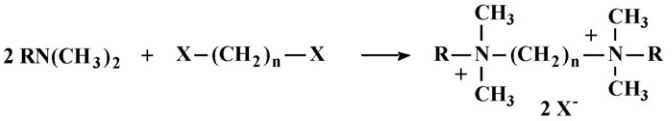
It should also be noted in the instance of the material **4** that, since a racemic mixture of the 3-chloro-1,2-propanediol was used as the reagent, it consists of a mixture of diastereoisomers, as shown below.



4

The mixture consists of a *meso*-species and a racemate, evidence for which may be found in the ^{13}C NMR spectrum. While not *all* carbon atoms are differentiable for the racemate and *meso*-species, two resonances may be observed for diastereotopic methyl carbon atoms on nitrogen and for the diastereotopic carbon atoms of the terminal chains attached to nitrogen and adjacent to the stereogenic sites. These types of observations have been discussed in work concerned with ionic liquid materials of related struc-

Table 2
Yield data for newly synthesized dicationic strings prepared by the reaction.



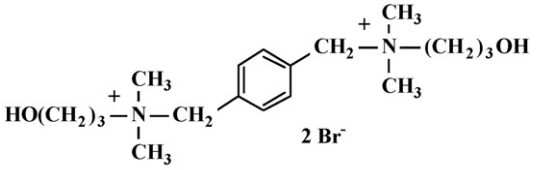
.

Cpd. no.	*n*	Yield
1	2	82.5%
5	3	64.0%
13	6	77.6%
24	8	61.4%

ture (Thomas et al., in press) and are dependent on the associated anion.

An alternative approach to the preparation of several of these compounds (**1**, **5**, **13**, and **24**) has been investigated. This involves the use of the appropriate α,ω-dihaloalkane (for the central portion of the target material) in reaction with 3-dimethylamino1-propanol. The analytical data for materials prepared in this manner correspond with those listed in Table 1, but yields are different. The yields of products prepared in this manner are shown in Table 2. This alternative approach toward construction of the dicationic species has also been used for the preparation of *N*,*N*,*N*′,*N*′-tetramethyl-*N*,*N*′-bis(3-hydroxypropyl-1,4-diazoniamethyl)benzene dibromide (**25**). Full details on this preparation are provided in Section 3.

The variability of isolated yields for the series of compounds prepared would appear to be a function of both their residual solubility in the solvent systems used, as well as their ability to absorb water from atmospheric sources. Best isolated yields for each are reported.



25

3. Experimental

3.1. General

All chemicals and solvents used in these syntheses and purifications were of commercial reagent quality and used without further purification. All ^{1}H and ^{13}C NMR spectra were measured with samples in commercial deuterated solvents using a Brüker 400 MHz DPX400 instrument. Elemental analyses were performed by Schwarzkopf Microanalytical Services of Woodside, NY.

3.2. Preparation of dicationic lipid salts by the reaction of α,ω-bis(dimethylamino)alkanes with haloalkanes General procedure (*1*–*24*)

The appropriate α,ω-bis(dimethylamino)alkane (1.5 mmol) was dissolved in acetonitrile (75 mL) and to it at ambient temperature was added dropwise with stirring the appropriate 1-haloalkane reagent (3.0 mmol). The resulting mixture was heated to reflux and stirred for 4 days. After cooling, the resultant white powder precipitate was collected by suction filtration through sintered glass, washed with anhydrous ether (3 × 30 mL) and dried under high vacuum. If residual impurities were detected by NMR analysis, the solid was further washed with anhydrous ether until no impurities could be detected beyond the limits of the analytical method (NMR). The resultant materials were isolated in the yields with analytical data as noted in Table 1.

3.3. Preparation of dicationic lipid salts by the reaction of α,ω-dihaloalkanes with 3-dimethylamino-1-propanol General procedure (*1*–*5*, *13*, *24*)

The appropriate α,ω-dihaloalkane (5 mmol) was dissolved in absolute ethanol (75 mL) and the 3-dimethylamino-1-propanol was added to it dropwise with stirring. The reaction mixture was then heated to reflux and stirred for 3 days. After cooling, volatile materials were evaporated under reduced pressure and the residual solid was dried under high vacuum. Preliminary NMR analysis was performed to determine any impurities present, and, if so, the solid was washed with anhydrous ether until the NMR spectrum exhibited no further impurities. The NMR analyses were in accord with those obtained for the materials obtained by the alternative procedure for their preparation (see Table 1). Yield data for the materials prepared in this manner are shown in Table 2.

3.4. Preparation of N,N,N′,N′-tetramethyl-N,N′-bis(3-hydroxypropyl-1,4-diazoniamethyl)benzene dibromide (*25*)

α,α′-Dibromo-*p*-xylene (**A**, 1.00 g; 3.79 mmol) was dissolved in absolute ethanol (75 mL) and to it was added dropwise with stirring 3-dimethylamino-1-propanol (0.78 g; 7.58 mmol). The reaction mixture was stirred at room temperature for 2 days after which time volatile materials were evaporated under reduced pressure and the residual solid was dried under high vacuum. In this way was isolated the desired product (1.25 g; 70.2% yield) which exhibited the following NMR spectra: ^{1}H: (δ, D_2O) 2.00 (4H) *m*; 2.95 (12H) *s*; 3.33 (4H) *m*; 3.57 (4H) *m*; 4.52 (4H) *s*; 7.61 (4H) *s*. ^{13}C: 25.7, 50.5, 58.8, 67.7, 67.8, 130.3, 134.3. Calcd. for $C_{18}H_{34}N_2O_2Br_2$: C: 45.97%; H: 7.28%. Found: C: 45.73%; H: 7.20%.

Acknowledgements

We are grateful to the Magnet Program at the CUNY Graduate Center and the NYC LSAMP for financial support to one of us (MT), as well as the Howard Hughes Medical Institute for financial support of the pre-college research experience, as well as Pace University Scholarly Research and Kenan Awards (JR), and finally the PSC-CUNY Research Award program for general financial support of this effort.

References

Bajaj, A., Kondaiah, P., Bhattacharya, S., 2008. Biomacromolecules 9, 991.
Bhattacharya, S., Bajaj, A., 2007. J. Phys. Chem. B 111, 13511.
Camilleri, P., Kremer, A., Edwards, A.J., Jennings, K.H., Jenkins, O., Marshall, I., McGregor, C., Neville, W., Rice, S.Q., Smith, R.J., Wilkinson, M.J., Kirby, A.J., 2000. Chem. Commun., 1253.
Cohen, J.I., Traficante, L., Schwartz, P.W., Engel, R., 1998. Tetrahedron Lett. 39, 8617.
Cohen, J.I., Engel, R., 1998. Trends Org. Chem. 7, 151.
Cohen, J.I., Engel, R., 2002. Curr. Org. Chem. 6, 1453.
Engel, R., Rizzo, J.I., Rivera, C., Ramirez, M., Huang, M.L., Montenegro, D., Capodiferro, C., Behaj, V., Thomas, M., Klaritch-vrana, B., Engel, J.F., Chem. Phys. Lipids, in press.
Iwamoto, S., Kawanami, S.-i., Sasaki, Y., Ariga, K., Kikuchi, J.-i., 2000. Abstr. Symp. Biofunct. Chem. 15, 204.
Iwamoto, S., Otsuki, M., Sasaki, Y., Ikeda, A., Kikuchi, J.-i., 2004. Tetrahedron 60, 9841.
Lall, S.I., Behaj, V., Mancheno, D., Castano, R., Thomas, M., Rikin, A., Gaillard, J., Raju, R., Scumpia, A., Castro, S., Engel, R., Cohen, J.I., 2002. Synthesis, 1430.
Martin, B., Sainlos, M., Aissaoui, A., Oudrhiri, N., Hauchecorne, M., Vigneron, J.-P., Lehn, J.-M., Lehn, P., 2005. Curr. Pharm. Des. 11, 375.
Thomas, M., Rothman, L., Hatcher, J., Agarkar, P., Ramkirath, R., Lall-Ramnarine, S., Engel, R., Synthesis, in press.