Electron Impact Mass Spectrometry of New Tris(polyoxalkyl)amines (Tridents)

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The mass spectrometric behavior of new tris(polyoxalkyl)amines (tridents) **1-5** have been studied and compared with N-(3,6,9,12-tetraoxatridecyl)-16-aza-18-crown-6 (**6**) and 1-morpholino-3,6,9-trioxadecane (**7**). The peculiar fragmentation patterns are emphasized.

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Introduction.

It is known that the octopus molecules or polypodands are acyclic many armed polyethers in which a number of polyethereal chains of different length and number of donor atoms are linked to the same bonding centre. These open-chain ligands show the ability to form stable complexes with alkali and alkaline metal salts and are particulary important in biologically relevant transport and catalytic processes [1-3].

Recently there has been much interest in the mass spectrometry of macrocyclic compounds as substituted macrocyclic polyethers which include derivatives containing benzo [4,5] furo [4], thieno [4], pyrido [6,7] rings and ester linkages [8].

These compounds show abundant $[M+H]^+$ ions in electron impact (EI) spectra due either to the intrinsic basicity of the neutral compounds or to the intrinsic acidity of corresponding molecular ions, thus giving interesting information on the chemical behavior of this class of compounds [8]. The fragmentations of these compounds are often accompanied by ring contraction and ejection of single molecules with hydrogen transfers [8].

Pursuing our interest in the mass spectrometry of macrocyclic compounds [9] and open-chain ligands (podands) [10], in this paper we have now undertaken the synthesis and study of the mass spectrometry of tris(3-oxabutyl)amine (**1**), tris(3,6-dioxaheptyl)amine (**2**), tris(3,6,9-trioxadecyl)amine (**3**), tris(3,6,9,12-tetraoxatridecyl)amine (**4**), tris(3,6,9,12,15-pentaoxaheptacosyl)-amine (**5**), *N*-(3,6,9,12-tetraoxatridecyl)-16-aza-18-crown-6 (**6**) and 1-morpholino-3,6,9-trioxadecane (**7**) under electron impact (EI) conditions, with the aim of determining the influence of the length of the ethereal chains on their fragmentation pattern.

Compounds **1** and **3-5** were simply obtained by reaction of triethanolamine with corresponding polyethylene glycol monomethyl ether tosylate and purified by column chromatography (Scheme 1). Compound **6** was prepared from *N*-(2-hydroxyethyl)16-aza-18-crown-6 [11] and triethyleneglycol monomethyl ether tosylate. Compound **7** was prepared from 2-morpholinoethanol and diethyleneglycol monomethyl ether tosylate.

All samples were characterized by infra-red and nuclear magnetic resonance as well as mass spectrometry and elemental analyses, full details of which are reported in the experimental section.

Scheme 1

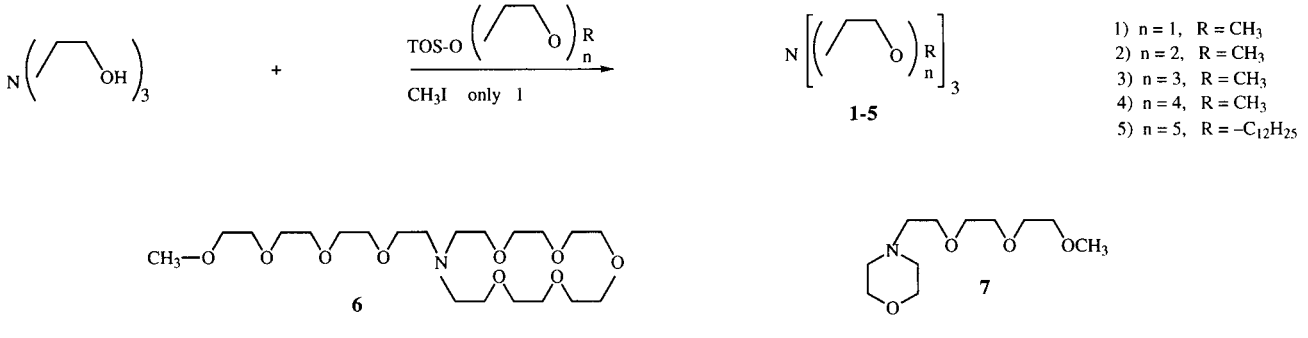


Table 1

The More Abundant and Significant Ionic Species Originating from the EI Spectra of Compounds **1-7**

Ionic Species	Compounds						
	1	**2**	**3**	**4**	**5**	**6**	**7**
$[M]^+$	191 (3) [a]	323 (33)	455 (1)	588 (1)	1183 (–)	453 (4)	233 (1)
$[M\text{-}C_{12}H_{25}O]^+$	–	–	–	–	988 (1)	–	–
$[M\text{-}C_{21}H_{40}O_5]^+$	–	–	–	–	811 (81)	–	–
$[M\text{-}H]^+$	190 (15)	322 (5)	–	–	–	–	–
$[M\text{-}CH_2O]^+$	161 (1)	293 (1)	425 (0.5)	558 (1)	–	423 (1)	–
$[M\text{-}CH_3O]^+$	160 (2)	292 (2)	–	–	–	–	202 (4)
$[M\text{-}C_2H_4O]^+$	147 (1)	279 (1)	411 (1)	544 (3)	–	409 (2)	–
$[M\text{-}C_2H_5O]^+$	146 (18)	278 (9)	–	–	–	–	–
$[M\text{-}2C_2H_4O]^+$	103 (3)	234 (100)	367 (2)	500 (1)	–	365 (4)	–
$[M\text{-}3C_2H_4O]^+$	–	191 (2)	323 (100)	456 (1)	–	321 (3)	–
$[M\text{-}4C_2H_4O]^+$	–	147 (1)	279 (6)	412 (29)	437 (3)	277 (1)	–
$[C_{26}H_{55}O_6]^+$	–	–	–	–	478 (3)	–	–
$[C_{21}H_{43}O_5]^+$	–	–	–	–	375 (10)	–	–
$[C_{19}H_{40}NO_8]^+$	–	–	–	411 (100)	–	–	–
$[C_{13}H_{28}NO_5]^+$	–	–	–	278 (0.7)	–	–	–
$[C_{13}H_{26}NO_5]^+$	–	–	276 (1)	276 (1)	276 (2)	276 (100)	–
$[C_{11}H_{24}NO_4]^+$	–	–	234 (2)	234 (2)	–	–	–
$[C_{11}H_{22}NO_4]^+$	–	–	232 (2)	232 (3)	232 (21)	232 (9)	–
$[C_9H_{20}NO_3]^+$	–	190 (18)	190 (4)	–	–	–	–
$[C_9H_{18}NO_3]^+$	–	–	188 (8)	188 (11)	188 (6)	188 (12)	188 (1)
$[C_8H_{17}O_4]^+$	–	–	–	177 (1)	–	–	–
$[C_7H_{14}NO_2]^+$	–	–	144 (53)	144 (10)	144 (7)	144 (9)	144 (2)
$[C_6H_{13}O_3]^+$	–	–	133 (5)	133 (0.5)	–	–	–
$[C_5H_{10}NO]^+$	100 (71)	100 (27)	100 (37)	100 (12)	100 (13)	100 (18)	100 (100)
$[C_4H_9O_2]^+$	–	89 (6)	89 (4)	89 (2)	89 (15)	89 (18)	89 (1)
$[C_4H_9NO]^+$	87 (8)	87 (4)	87 (7)	87 (1)	87 (12)	87 (11)	87 (13)
$[C_4H_8O]^+$	–	72 (8)	72 (13)	72 (3)	72 (12)	72 (10)	72 (6)
$[C_4H_7O]^+$	–	71 (8)	71 (20)	71 (3)	71 (4)	71 (9)	71 (9)
$[C_4H_6O]^+$	–	70 (12)	70 (24)	70 (4)	70 (21)	70 (12)	71 (31)
$[C_4H_5O]^+$	–	69 (3)	69 (5)	69 (–)	69 (18)	69 (9)	69 (1)
$[C_3H_7O]^+$	59 (30)	59 (80)	59 (100)	59 (63)	59 (16)	59 (47)	59 (23)
$[C_3H_5O]^+$	57 (100)	57 (11)	57 (18)	57 (4)	57 (100)	57 (13)	57 (11)
$[C_2H_5O]^+$	45 (59)	45 (29)	45 (100)	45 (25)	45 (52)	45 (36)	45 (25)

[a] m/z value with relative abundance in parentheses.

Results and Discussion.

Compounds **1-7** generally give rise to clear mass spectra, well related to the structure of the neutrals (for example, see Figure 1-3). The more abundant and significant ionic species in the EI mass spectra of the examined compounds are reported in Table 1.

Compounds **1-4** and **6-7** show well detectable molecular ions, while the $[M + H]^+$ species, which are common in the EI mass spectrometry of macrocyclic polyether-ester compounds [8], are completely absent. The molecular ion was never detected in the EI mass spectrum of **5**. The highest mass ion is at m/z 998 due to the loss of one $OC_{12}H_{25}$ ethereal chain. The common fragmentation patterns are reported in Schemes 2 and 3. All tris(polyoxaalkyl)amines **1-5** are acyclic analogs of aza-crown-ether.

In compounds **2**, **4** and **6**, quite intense ions **a** are present at m/z 146, 239, 322, 411, and 496 originating from the C-C cleavage in α of the aminic group, while in compounds **2** and **4** ions **a** are the base peaks. The ionic species **a** give rise to ions **b** $[C_5H_{10}NO]^+$, (m/z 100) through rupture SS2 of the ethereal bonds and annulation reaction. This behavior is typical of both polyethylene glycol chains and crown-ethers. Another primary decomposition pathway, originating from the cleavage of the two side-chains through cleavage SS1 and SS2, leads to ions **c**, at m/z 144, 188, 232, 276, 318, whose reasonable structures are shown in Scheme 2. These ionic species further decompose through loss of the ethereal chains to give ions **b**. Rupture SS1 also fragments ions **d** at m/z 45, 89, 133, 177, and 375, which are shifted 44u from

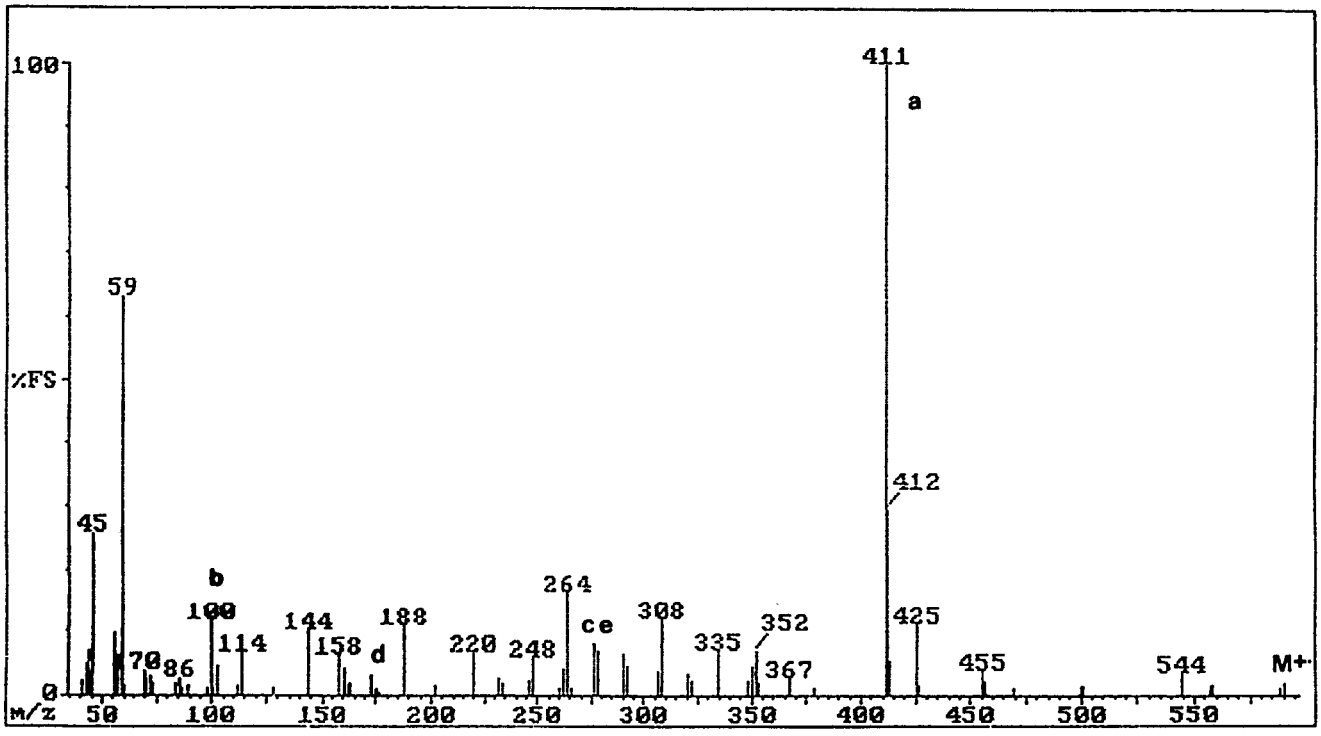


Figure 1. 70 eV EI mass spectrum of compound **4**.

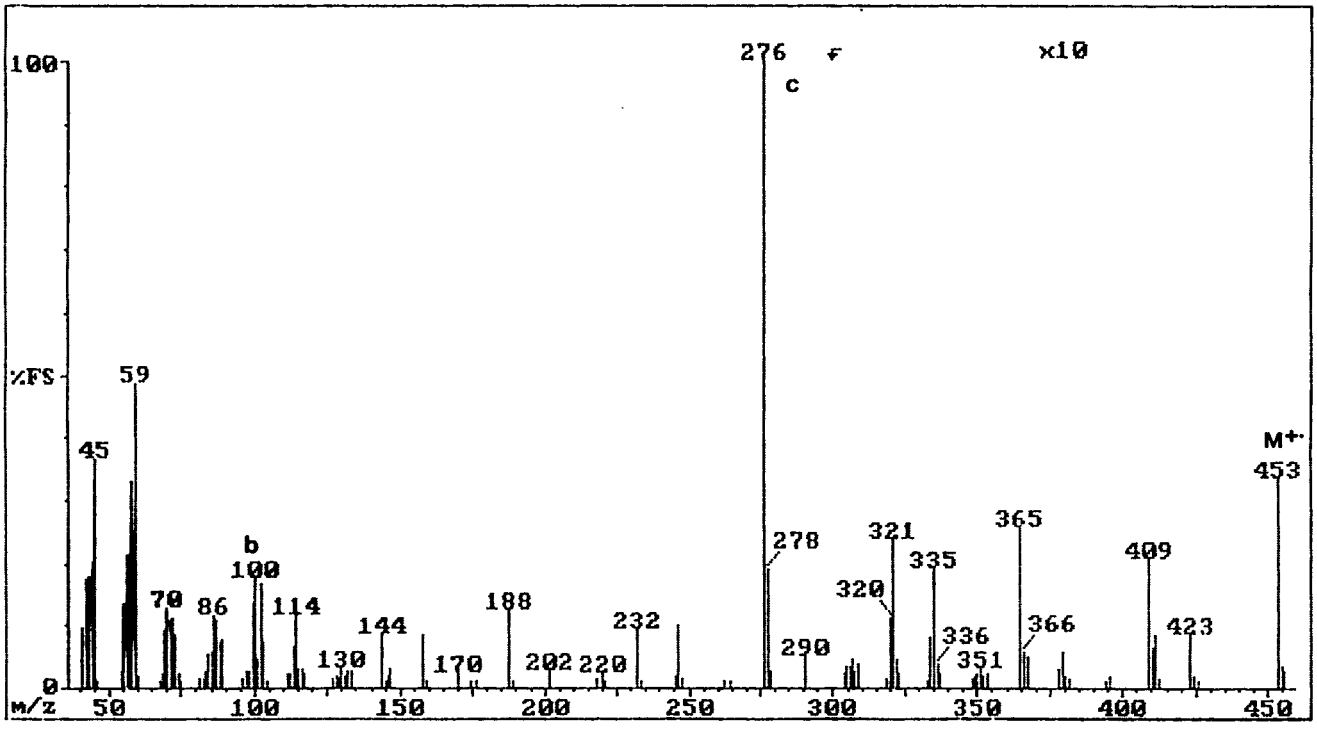
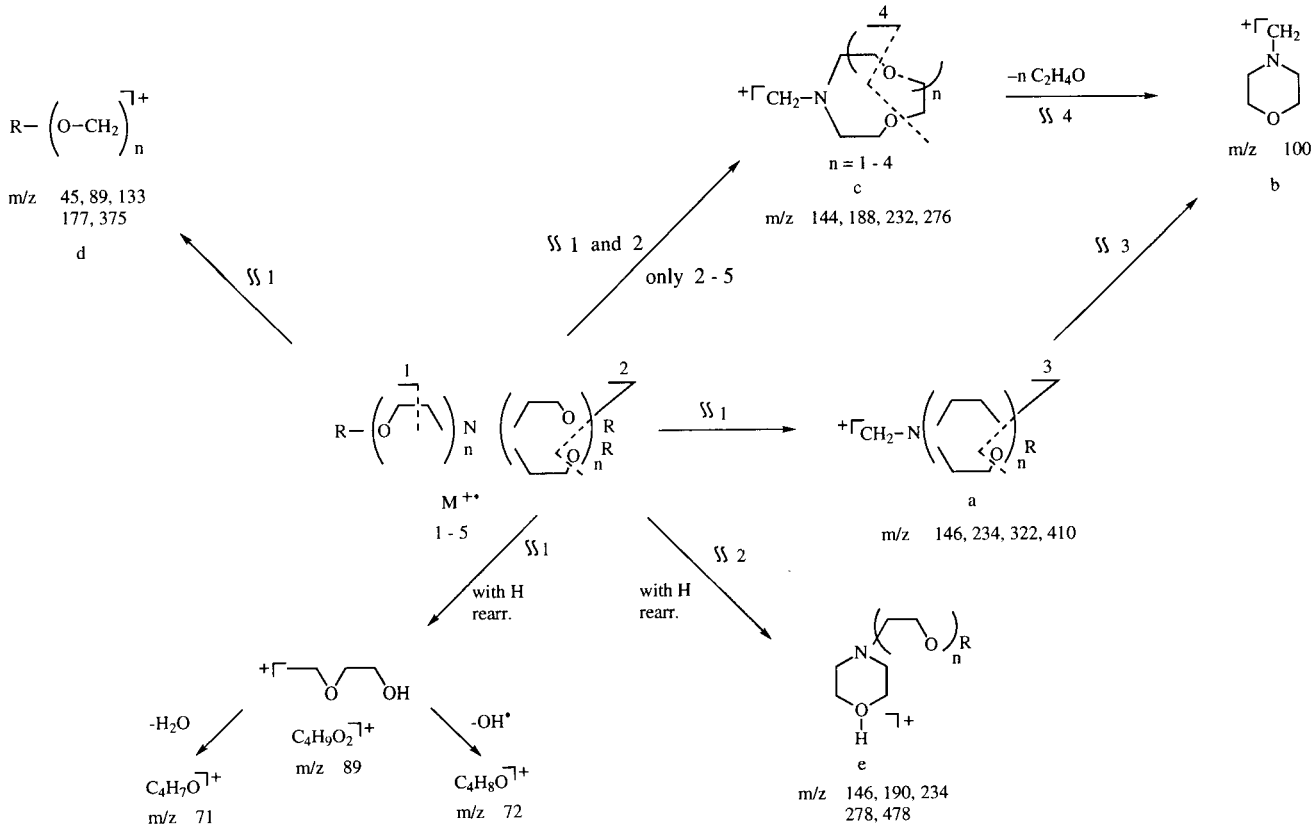


Figure 2. 70 eV EI mass spectrum of compound **6**.

each other. Ionic species $[C_4H_9O_2]^+$ (m/z 89) and $[C_4H_7O_2]^+$ (m/z 87) are present in compounds **2-7**, always originating from cleavage of the ethereal chains with H rearrangement. These ions further decompose giving rise to

Scheme 2



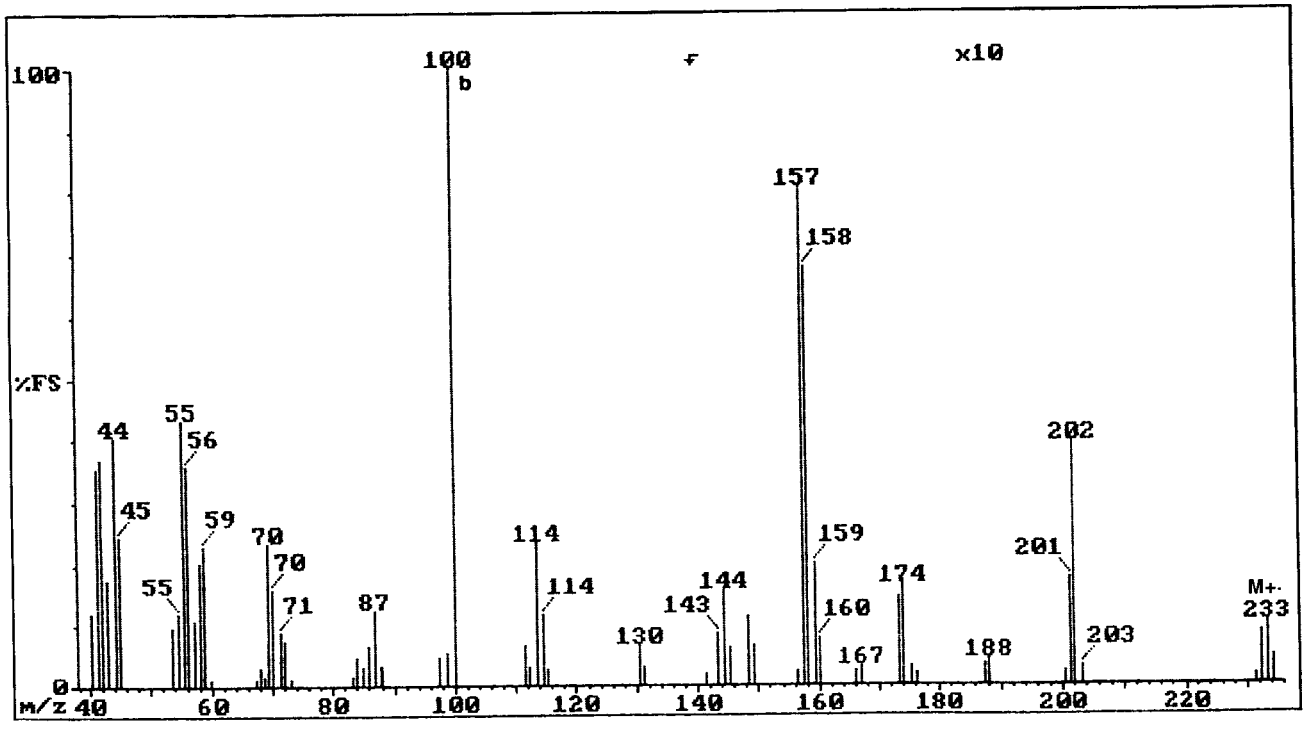
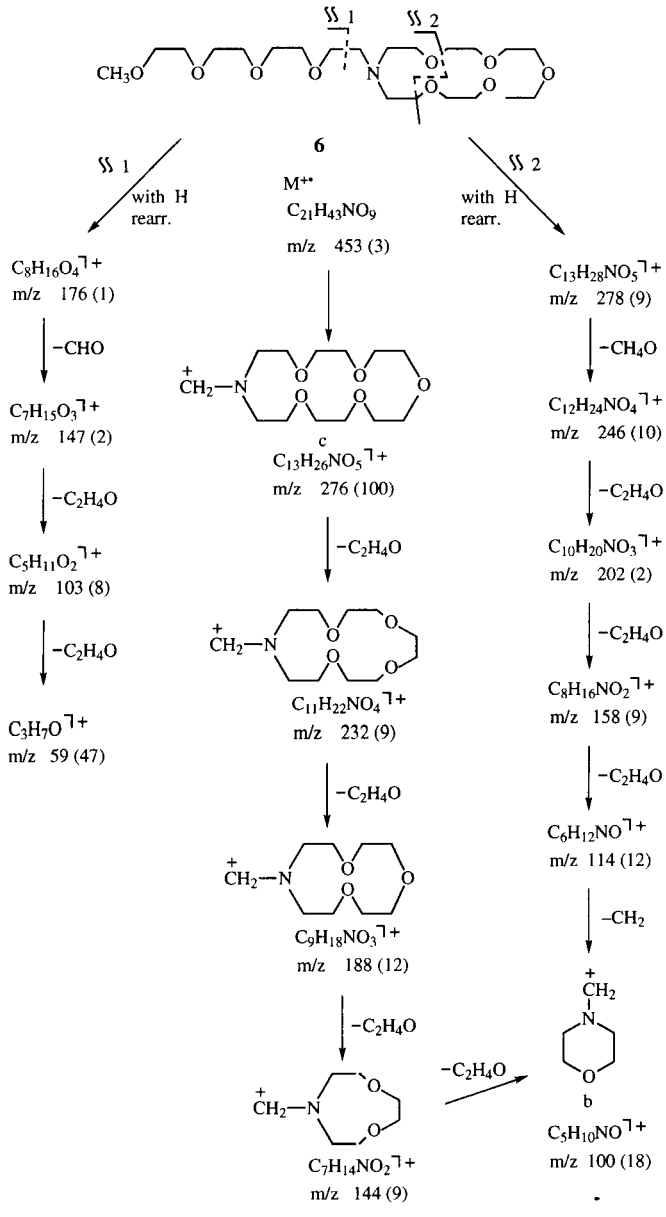


Figure 3. 70 eV EI mass spectrum of compound **7**.

Scheme 3



the species $[C_4H_8O]^+$ (m/z 72), $[C_4H_7O]^+$ (m/z 71), $[C_4H_6O]^+$ (m/z 70) and $[C_4H_5O]^+$ (m/z 69) through losses of OH• and H_2O. The $[C_2H_5O]^+$ ions (m/z 45) are present in all examined compounds and derive from further fragmentation of ions at m/z 87, whose structure has been amply studied [9]. For compound **6** a common fragmentation pattern is shown and described in Scheme 3. Its behavior is similar to that of the aza-crown ethers and polyethylene glycol chains. The cleavage and formation of many of these fragment ions are comparable to those formed in **2-5**.

Compound **6** showed a well detectable molecular ion, $[C_{21}H_{43}NO_2]$ (m/z 453) and most of the fragmentation pathways are governed by the usual rupture of the aza-crown ring, usually at the ethereal chains [8], with formation of sequentially smaller rings (Figure 2). In fact, after cleavage SS1 and formation of the ion $[C_{13}H_{26}NO_5]^+$ (m/z 276) as the base peak, the sequential loss of the C_2H_4O moieties leads to a series of fragment ions shifted 44u from each other, at m/z 232, 188, 144, 100. These ions are also present in **2-5**. Compound **7** fragments through ruptures of ethereal bonds eventually giving rise to ion $[C_5H_{10}NO]^+$ (m/z 100) which is the base peak (Figure 3). In compounds **1-5**, however, the formation of $[C_5H_{10}NO]^+$ ion is probably due to an annulation reaction between two chains of tris(polyoxaalkyl)amines, which is comparable with those found in **6** .

Finally, it should be emphasized that fragmentation routes involving rupture of tris(polyoxyalkyl)amines give rise to fragment ions comparable with those obtained in aza-crown ethers and polyoxyalkyl ethers.

EXPERIMENTAL

Electron Impact (EI) experiments were performed on a Carlo Erba QMD mass spectrometer operating at 70 eV and 200 μA with an ion source temperature of 200°. The samples were introduced directly into the ion source. The ir spectra were recorded on a Perkin Elmer 157 spectrometer; the ^1H nmr spectra were recorded on a Varian 300 MHz using tetramethyl silane as internal standard. Microanalyses for CHN were carried out on a Carlo Erba model 1106 Elemental Analyzer.

Triethanol amine, methyl iodide, diethyleneglycol monomethyl ether, triethyleneglycol monomethyl ether, tetraethyleneglycol monododecyl ether, *p*-toluenesulfonyl chloride, 4-(2-hydroxyethyl)morpholine, 1-aza-18-crown-6- and tris(3,6-dioxaethyl)amine were commercially available compounds used as purchased *N*-2-hydroxyethyl-16-aza-18-crown-6 were prepared according to a previously reported procedure [11]. The diethyleneglycol monomethyl ether tosylate, triethylene glycol monomethyl ether tosylate, and tetraethyleneglycol monododecyl ether tosylate were prepared following the general method described in literature [12].

Synthesis of Compounds **1**, **3-7**.

Tris(3-oxabutyl)amine **1**.

In a 100 ml three-necked flask equipped with a magnetic stirrer, reflux condenser and dropping funnel were mixed dry sodium hydride (0.06 mole, 1.38 g) and 20 ml of tetrahydrofuran (THF). To this suspension a solution of triethanol amine (0.02 mole, 2.98 g) in 50 ml of dry THF was added. To this stirred mixture, a solution of methyl iodide (0.06 mole, 8.82 g) in 10 ml of THF was added dropwise and stirring was continued for 48 hours of refluxing. The reaction mixture was filtered and the remaining solid was washed with dichloromethane. On removing the solvent from the combined solution under reduced pressure, a viscous liquid was obtained and purified by column chromatography, (alumina:dichloromethane) to afford **1** as a colorless oil, yield 75%; $n_D^{20} = 1.4623$; ir (film): 1120-1060 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ 3.50 (t, 6H, O-CH_2), 3.30 (s, 9H, OCH_3), 2.7 (t, 6H, N-CH_2).

Anal. Calcd. for $C_9H_{21}NO_3$: C, 56.54; H, 10.99; N, 7.32. Found: C, 56.52; H, 11.98; N, 7.36.

Tris(3,6,9-trioxadecyl)amine **3**.

To a suspension of sodium hydride (0.035 mole, 1 g) and 10 ml of dry THF, a solution of triethanol amine (0.01 mole, 1.49 g) in 50 ml of dry THF was added dropwise and stirred at reflux for 6 hours. To the reaction mixture a solution of diethyleneglycol monomethyl ether tosylate (0.035 mole, 11.09 g) in 150 ml of dry THF was added dropwise and stirring was continued for 48 hours at reflux. Purification of the crude product was accomplished by column chromatography (alumina:dichloromethane/methanol 40:1 as eluent) to afford **3** as a colorless compound, yield 60%; n_D^{20} = 1.4543; ir (film): 1120-1040 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ 3.8-3.4 (m, 30H, OCH_2), 3.3 (s, 9H, OCH_3), 2.7 (t, 6H, NCH_2).

Anal. Calcd. for $C_{21}H_{45}NO_9$: C, 55.38; H, 9.89; N, 3.07. Found: C, 55.35; H, 9.95; N, 3.06.

Tris(3,6,9,12-tetraoxatridecyl)amine **4**.

This compound was prepared using the appropriate synthons as described for **3** and obtained as a viscous colorless oil, yield 56%; n_D^{19} = 1.4490; ir (film): 1120-1020 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ 3.8-3.4 (m, 42H, OCH_2), 3.3 (s, 9H, OCH_3), 2.7 (t, 6H, NCH_2).

Anal. Calcd. for $C_{27}H_{57}NO_{12}$: C, 55.2; H, 9.71; N, 2.39. Found: C, 55.16; H, 9.77; N, 2.36.

Tris(3,6,9,12,15-pentaoxaheptacosyl)amine **5**.

This compound was prepared, using the appropriate synthons as described for **3**, yield 55%; n_D^{18} = 1.4664; ir (film): 1120-1040 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ 3.8-3.4 (m, 60H, OCH_2), 2.7 (t, 6H, NCH_2), 1.6-1.1 (m, 60H, CH_2).

Anal. Calcd. for $C_{66}H_{135}NO_{15}$: C, 67.1; H, 11.43; N, 1.19. Found: C, 67.01; H, 11.50; N, 1.16.

N-(3,6,9,12-tetraoxatridecyl)-16-aza-18-crown-6 **6**.

This compound was prepared using *N*-(2-hydroxyethyl)-16-aza-18-crown-6 (0.018 mole, 5.56 g) and triethyleneglycol monomethylether tosylate (0.019 mole, 6 g) and proceeding as described for **3**, yield 75%; n_D^{19} = 1.4598; ir (film): 1120-1060 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ = 3.6 (m, 34H, OCH_2), 3.3 (s, 3H, OCH_3), 2.6 (t, 6H, N-CH_2).

Anal. Calcd. for $C_{21}H_{43}NO_9$: C, 55.6; H, 9.5; N, 3.1. Found: C, 55.61; H, 9.54; N, 3.07.

1-Morpholino-3,6,9-trioxadecane **7**.

This compound was prepared using 2-morpholinoethanol (0.024 mole, 3.2 g) and diethyleneglycol monomethylether tosylate (0.026 mole, 7.12 g) and proceeding as described for **3**, yield 35%; n_D^{20} = 1.4575; ir (film): 1140-1150-1060 cm^{-1} (O-CH_2); ^1H nmr (deuteriochloroform): δ 3.6 (m, 14H, OCH_2), 3.3 (s, 3H, O-CH_3), 2.5 (t, 6H, NCH_2).

Anal. Calcd. for $C_{11}H_{23}NO_4$: C, 56.65; H, 9.87; N, 6.00. Found: C, 56.61; H, 9.95; N, 6.01.

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