# ALKYLATION OF BENZO- AND DIBENZOCROWN ETHERS BY VARIOUS ALCOHOLS

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New alkyl derivatives of benzo-15-crown-5, benzo-18-crown-6, dibenzo-18-crown-6, dibenzo-24-crown-8, and dibenzo-30-crown-10 have been obtained by their alkylation with various alcohols in the presence of polyphosphoric acid.

The present communication is a continuation of our work on the synthesis of substituted derivatives of benzocrown ethers [1-6]. Investigations in biological and artificial membranes of acyl and n-alkyl derivatives of benzo- and dibenzocrown ethers obtained previously have shown that the n-alkyl derivatives are more effective membrane active acompounds [7] and are better fillers of ion-selective electrodes [8] than the corresponding initial crown ethers and their acyl derivatives.

tert-Butyl derivatives of benzo-15-crown-5 and of benzo-18-crown-6, and also di-tert-butyl derivatives of dibenzo-18-crown-6 and of dibenzo-30-crown-10, obtained by the condensation of 4-tert-butylpyrocatechol with dichlorides of the corresponding polyethyleneglycols, have been described in the literature [9].

We have previously developed a method of obtaining isoalkyl derivatives of benzocrown ethers using, as an example, the alkylation of dibenzo-18-crown-6 with isometric butyl alcohols in polyphosphoric acid (PPA) [5, 6]. The alkylation of the same crown ether with tert-amyl alcohol has been performed under similar conditions [10].

An investigation of the isoalkyl derivatives obtained and a comparison of their properties with those of n-alkyl-substituted dibenzo-18-crown-6's have shown that the nature of the branching of the alkyl substituents in the benzene rings affects the ionophoric activity of these compounds [7]. It was of interest to trace this relationship on other crown ethers. Furthermore, effective phase-transfer catalysts have been found among the isoalkyl derivatives of dibenzo-18-crown-6 [10-12].

The present communication is devoted to the alkylation of benzo-15-crown-5 (I), benzo-18-crown-6 (II), dibenzo-18-crown-6 (XI), dibenzo-24-crown-8 (XII), and dibenzo-30-crown-10 (XIII). The alkylating agents used were normal propyl and isopropyl, sec- and tert-butyl, n- and tert-amyl, allyl, and benzyl alcohols and cyclohexanol.

It was found that alkylation takes place at 60-70°C in the course of 2-5 h with a twofold excess of alkylating agent per benzene ring. A fivefold excess of PPA by weight with respect to the crown ether is sufficient for performing the reaction. As in the case of normal butyl alcohol [5], the alkylation with normal propyl and normal amyl alcohols takes place under more severe conditions, with isomerization to the corresponding secondary radical. The alkylation products were isolated by column chromatography on alumina followed by crystallization. Their structures were shown with the aid of their PMR spectra and were confirmed by their IR and mass spectra. The structures of the compounds synthesized are given below, and their spectral characteristics are reported in Tables 1 and 2.

The alkylation of the monobenzocrown ethers (I) and (II) with tert-butyl and tert-amyl alcohols led to the formation of the monosubstituted products (III)-(VI). On alkylation with tertiary alcohols the dibenzocrown ethers (XI-XIII) formed predominantly (65-80%) disubstituted products consisting of mixtures of the 4',4"- and 4',5"- structural isomers — (XV and XVII-XXI). In the case of dibenzo-18-crown-6, the monosubstituted derivatives (XIV) and (XVI) were also isolated with yields of ~15%, and for dibenzo-24-crown-8 and dibenzo-30-crown-10 the formation of the analogous derivatives was detected only on TLC. The di-tert-amyldibenzo-18-crown-6 (XVII) described in the literature was isolated in the form of

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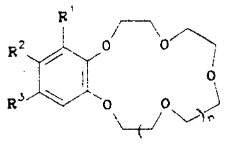
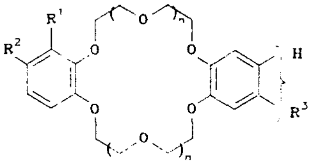
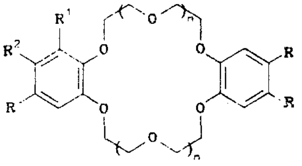
0009-3122/86/2211-1178$12.50



I-X



XI-XXVIII



XXIX-XXXVI

I $n=1$, $R^1=R^2=R^3=H$; II $n=2$, $R^1=R^2=R^3=H$; III $n=1$, $R^1=R^3=H$; $R^2=-C(CH_3)_3$; IV $n=1$, $R^1=R^3=H$; $R^2=-C(CH_3)_2CH_2CH_3$; V $n=2$, $R^1=R^3=H$; $R^2=-C(CH_3)_3$; VI $n=2$, $R^1=R^3=H$; $R^2=-C(CH_3)_2CH_2CH_3$; VII $n=1$, $R^1=H$; $R^2=R^3=-CH(CH_3)CH_2CH_3$; VIII $n=1$, $R^1=R^3=-CH(CH_3)CH_2CH_3$; $R^2=H$; IX $n=2$ $R^1=H$; $R^2=R^3=-CH(CH_3)CH_2CH_3$; X $n=2$, $R^1=R^3=-CH(CH_3)CH_2CH_3$; $R^2=H$; XI $n=1$, $R^1=R^2=R^3=H$; XII $n=2$, $R^1=R^2=R^3=H$; XIII $n=3$, $R^1=R^2=R^3=H$; XIV $n=1$, $R^1=R^3=H$; $R^2=-C(CH_3)_3$; XV $n=1$, $R^1=H$; $R^2=R^3=-C(CH_3)_3$; XVI $n=1$, $R^1=R^3=H$; $R^2=-C(CH_3)_2CH_2CH_3$; XVII $n=1$, $R^1=H$; $R^2=R^3=-C(CH_3)_2CH_2CH_3$; XVIII $n=2$, $R^1=H$; $R^2=R^3=-C(CH_3)_3$; XIX $n=2$, $R^1=H$; $R^2=R^3=-C(CH_3)_2CH_2CH_3$; XX $n=3$, $R^1=H$; $R^2=R^3=-C(CH_3)_3$; XXI $n=3$, $R^1=H$; $R^2=R^3=-C(CH_3)_2CH_2CH_3$; XXII $n=1$, $R^1=R^3=H$; $R^2=-CH(CH_3)CH_2CH_3$; XXIII $n=1$, $R^1=H$; $R^2=R^3=-CH(CH_3)CH_2CH_3$; XXIV $n=1$, $R^1=H$; $R^2=R^3=-CH(CH_3)_2$; XXV $n=1$, $R^1=R=-CH(CH_3)_2$; $R^2=H$; XXVI $n=1$, $R^1=H$; $R^2=R^3=-CH(CH_3)CH_2CH_2CH_3$; XXVII $n=1$, $R^1=R^3=-CH(CH_3)CH_2CH_2CH_3$; $R^2=H$; XXVIII $n=1$, $R^1=H$; $R^2=R^3=-C_6H_{11}$; XXIX $n=1$, $R=R^1=-CH(CH_3)CH_2CH_3$; $R^2=H$; XXX $n=2$, $R=R^1=-CH(CH_3)CH_2CH_3$; $R^2=H$; XXXI $n=1$, $R=R^1=-CH(CH_3)_2$; $R^2=H$; XXXII $n=1$, tetra-sec-amyl; XXXIII, XXXIV $n=1$, tricyclohexyl; XXXV, XXXVI $n=1$, $R=R^2=-C_6H_{11}$; $R^1=H$

an oil and consisted of a mixture of 4',4"- and 4',5"- isomers [10]. In addition to an oily (the main) product, we also succeeded in isolating a crystalline product (15%) with $T_m$ 85-88°C having the same $R_f$ value and identical spectral characteristics (Table 2). This product was apparently enriched with one isomer.

TABLE 1. Spectral Characteristics of the New Isoalkyl Derivatives of Benzocrown Ethers (III-X)

| Compound | Mol. wt. (mass spectr.) | PMR spectrum, ppm | IR spectrum, $cm^{-1}$ |
|---|---|---|---|
| III | 324 | 6,50—6,80 (3H, m, ArH); 3,88—4,10 (4H, m), 3,68—3,88 (4H, m), 3,56 (8H, s) —$OCH_2$; 1,22 (9H, s, $CH_3$) | 1610, 1590, 1520 (=CH); 2960, 2910, 2870, 1270, 1220, 1135 (COC); 885, 860, 810 (1,2,4-subs. benzene) |
| IV | 338 | 6,58—6,78 (3H, m, ArH); 3,84—4,04 (4H, m), 3,64—3,82 (4H, m), 3,54 (8H, s) —$OCH_2$; 1,52 (2H, q $CH_2$); 1,20 (3H, s), 1,14 (3H, s) —α-$CH_3$, 0,60 (3H, t, β-$CH_3$) | 1610, 1600, 1520 (CH); 2970, 2920, 2870, 1270, 1220, 1150 (COC); 890, 870, 815 (1,2,4-subs. benzene) |
| V | 368 | 6,62—6,84 (3H, m, ArH); 3,90—4,12 (4H, m), 3,70—3,84 (4H, m), 3,58 (8H, s), 3,49 (4H, s) —$OCH_2$; 1,20 (9H, s $CH_3$) | 1595, 1525 (=CH); 2950, 2935, 2880, 1255, 1225, 1125 (COC); 890, 865, 815 (1,2,4-subs. benzene) |
| VI | 382 | 6,66—6,80 (3H, m, ArH); 3,90—4,10 (4H, m), 3,66—3,86 (4H, m), 3,56 (8H, s), 3,48 (4H, s) —$OCH_2$; 1,52 (2H, q, $CH_2$); 1,20 (3H, s), 1,16 (3H, s) —α-$CH_3$; 0,62 (3H, t, β-$CH_3$) | 1600, 1520 (=CH); 2970, 2930, 2870, 1260, 1220, 1160—1120 (COC); 880, 850, 815 (1,2,4-subs. benzene) |
| VII | 380 | 6,50 (2H, s, ArH); 3,88—4,04 (4H, m), 3,66—3,88 (4H, m), 3,58 (8H, s) —$OCH_2$; 2,82 (2H, sext., CH); 1,49 (2H, q), 1,47 (2H, q) —$CH_2$; 1,10 (3H, d), 1,04 (3H, d) —α-$CH_3$; 0,77 (3H, t), 0,75 (3H, t) —β-$CH_3$ | 1610, 1520 (=CH); 2960, 2930, 2870, 1270, 1225, 1130 (COC); 900, 855, 795 (1,2,4,5-subs. benzene) |
| VIII | 380 | 6,37 (1H, d), 6,35 (1H, d) —ArH; 3,89—4,08 (4H, m), 3,70—3,89 (4H, m), 3,58 (8H, s) —$OCH_2$; 2,98 (1H, sext), 2,42 (1H, sext) —CH; 1,50 (2H, q), 1,48 (2H, q) —$CH_2$; 1,15 (3H, d), 1,11 (3H, d) —α-$CH_3$; 0,77 (6H, t, β-$CH_3$) | 1590, 1500 (=CH); 2970, 2930, 2870, 1260, 1215, 1140 (COC); 880, 850 (1,2,3,5-subs. benzene) |
| IX | 424 | 6,52 (2H, s, ArH); 3,90—4,10 (4H, m), 3,70—3,88 (4H, m), 3,58 (8H, s), 3,50 (4H, s) —$OCH_2$; 2,84 (2H, sext, CH); 1,52 (2H, q), 1,49 (2H, q) —$CH_2$; 1,12 (3H, d), 1,08 (3H, d) —α-$CH_3$; 0,78 (3H, t), 0,76 (3H, t) —β-$CH_3$ | 1590, 1520 (=CH); 2970, 2930, 2880, 1255, 1220, 1140 (COC); 885, 845, 790 (1,2,4,5-subs. benzene) |
| X | 424 | 6,39 (1H, d), 6,36 (1H, d) —ArH; 3,88—4,14 (4H, m), 3,70—3,88 (4H, m), 3,58 (8H, s), 3,50 (4H, s) —$OCH_2$; 3,00 (1H, sext), 2,40 (1H, sext) —CH; 1,49 (2H, q), 1,46 (2H, q) —$CH_2$; 1,18 (3H, d), 1,14 (3H, d) —α-$CH_3$; 0,78 (6H, t, β-$CH_3$) | 1590, 1520 (=CH); 2970, 2930, 2880, 1260, 1220, 1140 (COC); 870, 850 (1,2,3,5-subs. benzene) |

TABLE 2. Spectral Characteristics of the New Isoalkyl Derivatives of Dibenzocrown Ethers (XIV-XXXVI)

| Compound | Mol. wt. (mass spectr.) | PMR spectrum, ppm | IR spectrum, $cm^{-1}$ |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| XIV* | 416 | 6,72 (4H, s), 6,60—6,80 (3H, m)—ArH; 3,86—4,10 (16H, m, $OCH_2$); 1,22 (9H, s, $CH_3$) | 1600, 1520 (=CH); 2970, 2880, 1260, 1150, 1130 (COC); 890, 865, 830, 770, 730 (1,2,4- and 1,2-subs. benzene) |
| XV* | 472 | 6,50—6,78 (6H, m ArH); 3,80—4,16 (16H, m, $OCH_2$); 1,20 (18H, s, $CH_3$) | 1595, 1520 (=CH); 2980, 2890, 1270, 1150, 1130 (COC); 900, 870, 825 (1,2,4-subs. benzene) |
| XVI | 430 | 6,68 (4H, s), 6,58—6,80 (3H, m)—ArH; 3,78—4,10 (16H, m, $OCH_2$); 1,51 (2H, q, $CH_2$); 1,20 (3H, s), 1,16 (3H, s)—$\alpha$-$CH_3$; 0,60 (3H, t, $\beta$-$CH_3$) | 1610, 1515 (=CH); 2975, 2890, 1265, 1145, 1130 (COC); 865, 820, 800, 765 (1,2,4- and 1,2-subs. benzene) |
| XVII | 500 | 6,50—6,76 (6H, m, ArH); 3,76—4,12 (16H, m, $OCH_2$); 1,54 (4H, q, $CH_2$); 1,20 (6H, s), 1,15 (6H, s)—$\alpha$-$CH_3$; 0,60 (6H, t, $\beta$-$CH_3$) | 1600, 1520 (=CH); 2970, 2880, 1250, 1150, 1125 (COC); 870, 810, 790 (1,2,4-subs. benzene) |
| XVIII | 560 | 6,50—6,80 (6H, m, ArH); 3,86—4,12 (8H, m), 3,64—3,86 (8H, m), 3,62 (8H, s) —$OCH_2$; 1,20 (18H, s, $CH_3$) | 1600, 1520 (=CH); 2970, 2930, 2870, 1270, 1215, 1150 (COC); 880, 850, 810 (1,2,4-subs. benzene) |
| XIX | 584 | 6,60—6,80 (6H, m, ArH); 3,90—4,14 (8H, m), 3,66—3,86 (8H, m), 3,62 (8H, s) —$OCH_2$; 1,56 (4H, q, $CH_2$); 1,22 (6H, s), 1,17 (6H, s)—$\alpha$-$CH_3$; 0,63 (6H, t, $\beta$-$CH_3$) | 1600, 1520 (=CH); 2970, 2930, 2870, 1260, 1220, 1150 (COC); 880, 855, 820 (1,2,4-subs. benzene) |
| XX | 648 | 6,60—6,80 (6H, m ArH); 3,89—4,12 (8H, m), 3,64—3,84 (8H, m), 3,40—3,64 (16H, m)—$OCH_2$; 1,20 (18H, s, $CH_3$) | 1610, 1590, 1520 (=CH); 2965, 2930, 2875, 1270, 1220, 1150, 1125, 1110 (COC); 880, 860, 820 (1,2,4-subs. benzene) |
| XXI | 676 | 6,72—6,80 (6H, m ArH); 4,00—4,20 (8H, m), 3,76—3,96 (8H, m), 3,68—3,76 (16H, m)—$OCH_2$; 1,54 (4H, q, $CH_2$); 1,22 (6H, s), 1,17 (6H, s)—$\alpha$-$CH_3$; 0,60 (6H, t, $\beta$-$CH_3$) | 1610, 1590, 1520 (=CH); 2960, 2940, 2870, 1270, 1220, 1150, 1130, 1120 (COC); 870, 850, 810 (1,2,4-subs. benzene) |
| XXII* | 416 | 6,78 (4H, s), 6,46—6,82 (3H, m)—ArH; 3,80—4,20 (16H, m $OCH_2$); 2,44 (1H, sext, CH); 1,46 (2H, q, $CH_2$); 1,14 (3H, d, $\alpha$-$CH_3$); 0,76 (3H, t, $\beta$-$CH_3$) | 1600, 1520 (=CH); 2970, 2945, 2890, 1260, 1130 (COC); 890, 865, 830, 775, 740 (1,2,4- and 1,2-subs. benzene) |
| XXIII* | 472 | 6,45—6,76 (6H, m, ArH); 3,80—4,20 (16H, m $OCH_2$); 2,43 (2H, sext., CH); 1,51 (4H, q, $CH_2$); 1,16 (6H, d., $\alpha$-$CH_3$); 0,78 (6H, t, $\beta$-$CH_3$) | 1595, 1520 (=CH); 2975, 2945, 2890, 1270, 1140, 1130 (COC); 900, 870, 830 (1,2,4-subs. benzene) |
| XXIV | 444 | 6,50—6,78 (6H, m, ArH); 3,82—4,30 (16H, m, $OCH_2$); 2,76 (2H, sept, CH); 1,15 (12H, d, $CH_3$) | 1600, 1590, 1520 (=CH); 2950, 2920, 2870, 1260, 1240, 1150 (COC); 855, 845, 810 (1,2,4-subs. benzene) |
| XXV | 444 | 6,54—6,86 (6H, m ArH); 3,82—4,20 (16H, m, $OCH_2$); 3,12 (1H, sept), 2,76 (1H, sept)—CH; 1,14 (6H, d), 1,12 (6H, d)—$CH_3$ | 1610, 1590, 1515 (=CH); 2970, 2940, 2890, 1270, 1140 (COC); 860, 845, 800, 785 (1,2,4- and 1,2,3-subs. benzene) |
| XXVI | 500 | 6,46—6,82 (6H, m, ArH); 3,72—4,10 (16H, m, $OCH_2$); 2,54 (2H, sext., CH); 1,25—1,70 (8H, m, $CH_2$); 1,12 (6H, d., $\alpha$-$CH_3$); 0,67 (6H, t, $\gamma$-$CH_3$) | 1590, 1520 (=CH); 2970, 2935, 2880, 1260, 1235, 1140 (COC); 880, 860, 810 (1,2,4-subs. benzene) |
| XXVII | 500 | 6,44—6,82 (6H, m, ArH); 3,76—4,28 (16H, m, $OCH_2$); 2,54 (1H, sext), 2,18 (1H, sext)—CH; 1,28—1,64 (8H, m $CH_2$); 1,18 (3H, d), 1,12 (3H, d) —$\alpha$-$CH_3$; 0,78 (3H, t), 0,68 (3H, t) —$\gamma$-$CH_3$ | 1600, 1520 (=CH); 2970, 2935, 2880, 1240, 1150 (COC); 860, 850, 810, 790 (1,2,4- and 1,2,3-subs. benzene) |
| XXVIII | 524 | 6,42—6,72 (6H, m., ArH); 3,74—4,14 (16H, m, $OCH_2$); 2,10—2,48 (2H, m, CH); 1,06—1,92 (20H, m, $CH_2$) | 1610, 1590, 1515 (=CH); 2930, 2850, 1265, 1240, 1220, 1140 (COC); 1450, 760 ($CH_2$); 890, 850, 790 (1,2,4-subs. benzene) |
| XXIX* | 584 | 6,57 (1H, s), 6,55 (1H, s), 6,39 (1H, d), 6,37 (1H, d)—ArH; 3,76—4,20 (16H, m, $OCH_2$); 3,02 (1H, sext), 2,84 (2H, sext), 2,42 (1H, sext)—CH; 1,51 (4H, q), 1,48 (4H, q)—$CH_2$; 1,18 (3H, d), 1,14 (3H, d), 1,12 (6H, d)—$\alpha$-$CH_3$; 0,78 (12H, t, $\beta$-$CH_3$) | 1590, 1520 (=CH); 2980, 2945, 2890, 1275, 1150, 1140 (COC); 880, 860, 820, 780 (1,2,3,5- and 1,2,4,5- subs. benzene) |

TABLE 2 (continued)

| 1 | 2 | 3 | 4 |
|---|---|---|---|
| XXX | 672 | 6,52 (2H, s), 6,38 (1H, d), 6.36 (1H, d) —ArH; 3,84—4,12 (8H, m), 3,64—3,84 (8H, m), 3,64 (8H, s)—$OCH_2$; 2,94 (1H, sext), 2,80 (2H, sext), 2,42 (1H, sext) —CH; 1,32—1,66 (8H, m, $CH_2$); 1,17 (3H, q), 1,13 (3H, d), 1,08 (6H, d) —α-$CH_3$; 0.75 (12H, t, β-$CH_3$) | 1610, 1520 (=CH); 2960, 2935, 2870, 1270, 1205, 1150, 1120 (COC); 885, 870, 845, 820, 785 (1,2,3,5- and 1,2,4,5- subs. benzene) |
| XXXI | 528 | 6,46—6,96 (4H, m, ArH); 3,80—4,36 (16H, m, $OCH_2$); 2,98—3,52 (3H, m), 2,76 (1H, sept)—CH; 1,28 (6H, d), 1,14 (18H, d)—$CH_3$ | 1580, 1480 (=CH); 2960, 2930, 2870, 1280, 1135 (COC); 890, 880, 850, 810, 780 (1,2,3,5- and 1,2,4,5- subs, benzene) |
| XXXII | 640 | 6,34—6,94 (4H, m, ArH); 3,76—4,26 (16H, m, $OCH_2$); 3,10 (2H, sext), 2.76 (0,5H, m), 2,56 (1H, sext), 2,12 (0,5H, m)—CH; 1,28—1,80 (16H, m, $CH_2$); 1,14 and 1,12 (12H, two d, α-$CH_3$); 0,80 (9H, t) 0,68 (3H, t)—γ-$CH_3$ | 1580, 1500 (=CH); 2950, 2920, 2870, 1270—1210, 1130 (COC); 900, 850, 800, 790 (1,2,3,5- and 1,2,4,5- subs, benzene) |
| XXXIII | 606 | 6,32—6,74 (5H, m, ArH); 3.62—4,20 (16H, m, $OCH_2$); 2,60—3,10 (1H, m), 2,10—2,60 (2H, m)—CH; 0,96—2,04 (30H, m, $CH_2$) | 1610, 1590, 1520 (=CH); 2930, 2850, 1270, 1240, 1210, 1140 (COC); 1450, 760 ($CH_2$); 890, 850, 815, 800, 725 (tri- and tetrasubs. benzene) |
| XXXIV | 606 | 6,40—6.70 (5H, m, ArH); 3,70—4,16 (16H, m, $OCH_2$); 2,10—2,76 (3H, m, CH); 1,04—1,96 (30H, m, $CH_2$) | 1610, 1595, 1520 (=CH); 2930, 2860, 1260, 1240, 1230, 1150 (COC); 1450, 760 ($CH_2$); 880, 860, 810, 790, 740 (tri- and tetrasubs. benzene) |
| XXXV | 688 | 6,56 (4H, s, ArH); 3,72—4,16 (16H, m, $OCH_2$); 2,40—2,80 (4H, m, CH); 1,00—2,00 (40H, m, $CH_2$) | 1610, 1585, 1520 (=CH); 2940, 2850, 1260, 1245, 1225, 1140 (COC); 1450, 760, 790 ($CH_2$); 890, 860, 805 (1,2,4-5-subs. benzene) |
| XXXVI | 688 | 6,56 (4H, s, ArH); 3,72—4,16 (16H, m, $OCH_3$); 2,40—2,80 (4H, m, CH); 1,00—2,00 (40H, m, $CH_2$) | 1610, 1590, 1520 (=CH); 2930, 2860, 1260, 1245, 1220, 1145 (COC); 1455, 790 ($CH_2$); 890, 850, 810 (1,2,4,5-subs. benzene) |

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*According to the literature [5].

In contrast to the acyl derivatives [1, 4], for the alkyl derivatives of benzo- and dibenzocrown ethers having one substituent in each benzene ring the difference in the chemical shifts of the aromatic protons in the PMR spectra does not exceed 6-7 Hz. This leads to the formation of a common poorly resolved multiplet of aromatic protons in which it is impossible to isolate fragments of the AB and ABC types of splitting. This circumstance was observed both in the n-alkyl derivatives obtained by Clemmensen reduction [2, 4] and also in the present work for compounds with various isoalkyl substituents. Consequently, in these cases the signals of the aromatic protons were used only to calculate the number of substituents (integral curve). The values of the chemical shifts of the aliphatic protons of the substituents agreed well with their positions.

In the IR spectrum of the tert-butyl and tert-amyl derivatives as in other 4',4"(5")-alkyl derivatives, in the 900-700 cm$^{-1}$ region three absorption bands with a repeating ratio of intensities were observed: at 900-880 cm$^{-1}$ — weak; at 870-850 cm$^{-1}$ — medium; and at 820-800 cm$^{-1}$ — strong. Similar absorption bands but with lower intensities were observed in the IR spectra of 4'-acyl- and 4',4"(5")-diacyl derivatives that we obtained previously [1, 4, 5], and also in the products of their reduction [2-5].

A more complex pattern was observed on alkylation with secondary alcohols. The alkylation of the crown ethers (I) and (II) with sec-butyl alcohol led to the formation of a mixture of disubstituted derivatives having different $R_f$ values that were separated by column chromatography and by crystallization.

An analysis of their PMR and IR spectra (Table 1) permitted the assignment to them of the structures of compounds (VII-X). 3',5'-Substitution was established for compounds (VIII) and (X) from the existence of two doublets at 6.35 and 6.37 ppm with SSCCs of 2.0 Hz, which is possible in a benzene ring only for protons in the meta position. The 3',4'-isomer should also give two doublets, but with large SSCCs. We did not isolate such an isomer. The nature of the 3',5'-substitution was also confirmed by the presence of two sextets corresponding to two protons of CH groups, at 2.98 ppm (3' position) and 2.42 ppm (5' position).

Two absorption bands appeared in the spectra of the 3',5'-isomer in the 900-700 $cm^{-1}$ region: at 800-860 $cm^{-1}$ — medium; and at 860-840 $cm^{-1}$ — strong.

In the PMR spectra of the second isomers isolated (compounds (VII) and (IX)), the signals of the aromatic protons appeared as singlets at 6.50 and 6.52 ppm, respectively. This is possible both in the 4',5'- and also in the 3',6'-isomers. The nature of the substitution was therefore shown in the basis of the chemical shifts of the signals of the protons of the CH groups of the substituents. In the case of the 3',6'-isomer, these signals should coincide with the corresponding signals of the protons of the substituent in position 3' of the 3',5'-isomer. However, no such coincidence was observed. In the PMR spectra of compounds (VII) and (IX), a common signal was observed at 2.82 ppm which corresponded to two protons of CH groups and differed from the signals of the CH protons in the 3' and 5' positions in the 3',5'-isomer. This is possible only for the 4',5'-isomer.

In the IR spectra of the 4',5'-isomers, as in the 4'- derivatives, three analogous absorption bands were observed in the 900-700 $cm^{-1}$ region, but with a different intensity ratio: at 900-890 $cm^{-1}$ — weak or medium; at 860-850 $cm^{-1}$ — strong; and at 800-790 $cm^{-1}$ — medium.

The mass spectra also agreed with the proposed structures [13, 14].

The alkylation of the crown ether (XII) with sec-butyl alcohol led to the formation of a mixture of products with different degrees of substitution, the main one being, as in the case of the crown ether (XI) [5], the 3',4",5',5"-tetra-sec-butyl derivative (XXX) (Table 2). The structure of this compound was shown on the basis of its PMR spectrum. It must be mentioned that the signals of the protons of the CH groups in the 3' position (at 2.94 ppm) and in the 4" and 5" positions (at 2.80 ppm) partially overlapped. The proton of the CH group in position 5' gave a signal in the form of an isolated sextet at 2.42 ppm.

Analysis of the IR spectrum of compound (XXX), as of other compounds with an unsymmetrical arrangement of the substituents, proved to be more complex, since the superposition of two types of substitution — 1,2,3,5 and 1,2,4,5 — took place.

When compound (XI) was alkylated with n-propyl, isopropyl, and n-amyl alcohols, the mai products were, in the case of sec-butyl alcohol [5], mixtures of isomeric tetrasubstituted derivatives (40-50%) from which it was possible to isolate compound (XXXI) and a fraction enriched with compound (XXXII). In addition to this, 20-25% of the disubstituted derivatives (XXIV-XXVII) was isolated. The monosubstituted products were not isolated, although their formation was detected by TLC. The diisopropyl derivatives were isolated in the form of two types of structural isomers: 4,4"(5") (XXIV) and 3',4"(5") (XXV). Their structures were shown by analysis of their PMR spectra. The two protons of the CH groups of compounds (XXIV) formed a septet at 2.76 ppm. The protons of the $CH_3$ groups appeared as a doublet at 1.15 ppm. In contrast to this, in compound (XXV) the two protons of CH groups present in different positions with respect to the macromolecule appeared as two septets at 2.76 ppm (4"(5") position) and 3.12 ppm (3' position). The protons of the $CH_3$ groups also formed two doublets, at 1.14 and 1.12 ppm.

In the IR spectrum of compound (XXIV) a set of absorption bands characteristic for a 1,2,4-substituted benzene was observed. In contrast to this, compound (XXV) showed the superposition of two types of substitution: 1,2,4- and 1,2,3-. This led to a marked increase in the intensity of the absorption band at 800 $cm^{-1}$. The same characteristic feature was observed in the PMR and IR spectra of the di-sec-amyl-derivatives (XXVI) and (XXVII

In contrast to the tetra-sec-butyl derivatives (XXIX) and (XXX), the aromatic protons of the tetraisopropylbenzo-18-crown-6 formed a multiplet in the 6.46-6.96 ppm region which did not provide the possibility of judging the positions of the substituents. But a comparison of the signals of the aliphatic protons of this compound with the spectra of compounds

(XXIX) and (XXX), and also of (XXIV) and (XXV), permitted the structure of the 3',4",5',5"-isomer (XXXI) to be assigned to it. In compound (XXXI), the three protons of the CH groups of the isopropyl substituents appeared in the form of a complex multiplet in the 2.98-3.52 ppm region which consisted of the signals of one proton in the 3' position and of two protons in the 4" and 5" positions. The protons of the CH group in position 5' appeared as a septet at 2.76 ppm. The protons of the $CH_3$ groups gave two nonequivalent doublets at 1.28 ppm corresponding to the signals of six protons and at 1.14 ppm corresponding to the signals of eighteen protons. Tetra-sec-amylbenzo-18-crown-6 was obtained in the form of a mixture of isomers. A fraction was isolated, the signals of the aliphatic protons of which mainly corresponded to the 3',4",5',5"-isomer (XXXII), with the exception of a multiplet at 2.76 ppm, corresponding to ~0.5 of a proton of CH groups.

The IR spectra of compounds (XXXI) and (XXXII) showed the superposition of absorption bands characteristic for 1,2,3,5- and 1,2,4,5-substituted benzenes.

The alkylation of (XI) with cyclohexanol led to a mixture of products with different degrees of substitution, from mono- to hexa- (mass-spectroscopic results), from which it was possible to isolate di-, tri-, and tetracyclohexyl derivatives. The main reaction products were the trisubstituted derivatives (XXXIII) and (XXXIV), differing by their $R_f$ values and their melting points. It was impossible to establish the positions of the substituents from their PMR and IR spectra. The disubstituted product consisted of a mixture of structural 4',4"(5")-isomers (XXVIII). The formation of several tetrasubstituted isomers with different $R_f$ values was observed, but it was possible to isolate only one substance with $R_f$ 0.54, which was separated by crystallization from hexane into two isomers with $T_m$ 186-188°C (the main product, compound (XXXV)) and 194-196°C (compound XXXVI). The first of them was more soluble. The PMR spectra of the two isomers showed symmetry of substitution in the benzene rings in positions 4',4",5',5" and had singlet signals at 6.56 ppm corresponding to four aromatic protons present in the para positions with respect to one another. The PMR spectra of the two isomers were identical, with the exception of the 2.40-2.80 ppm region, the signals in which corresponded to vibrations of CH groups of cyclohexane rings: for the low-melting isomer, the half-height width of the signal was ~18 Hz, and for the high-melting isomer it was ≈22 Hz. The IR spectra of the two isomers had identical characteristic absorption bands which, however, differed greatly in relative intensities.

The benzylation of (I), (XI), and (XII) gave a complex mixture of products with different degrees of substitution also containing polycondensation products of the benzyl alcohol itself. It was impossible to isolate individual products.

An attempt was made to alkylate compound (XI) with allyl alcohol. However, because of the rapid polymerization of the latter the reaction did not take place.

## EXPERIMENTAL

PMR spectra in $CDCl_3$ were obtained on a Varian XL-100 (100 MHz) spectrometer with HMDS as internal standard, δ scale. IR spectra in KBr were measured on a UR-20 or a Specord IR-75 spectrophotometer. Molecular weights were determined mass-spectrometrically on a Varian MAT-311 instrument at an energy of the ionizing electrons of 70 eV and are given for the peaks of the main isotopes ($^{12}C$, $^{1}H$, $^{16}O$). Neutral alumina with activity grade IV was used for thin-layer chromatography.

The initial cyclopolyethers (I, II, and XI-XIII) were obtained by Pedersen's method [9] and were purified by column chromatography on alumina followed by crystallization.

General Alkylation Procedure. The benzo- or dibenzocrown ether was dissolved in a fivefold excess of PPA at 70°C and a twofold molar excess of the corresponding alcohol for each benzene ring of the crown ether was added, after which the mixture was heated at the same temperature for 2-5 h. Then it was decomposed with water and extracted with chloroform. The organic layer was washed with salt solution and with water to neutrality. The solvent was evaporated off in a rotary evaporator. The reaction products were purified and separated by column chromatography on alumina in the chloroform—hexane—acetone (2:3:0.5) system, followed by crystallization from dry hexane.

4'-tert-Butylbenzo-15-crown-5 (III). A mixture of 0.8 g (3 mmole) of compound (I), 4 g of PPA, and 0.6 ml (6 mmole) of tert-butyl alcohol yielded 0.92 g (96%) of compound (III) with $T_m$ 42-44°C. According to the literature [9], $T_m$ 43.5-44.5°C. Found, %: C 67.0, H 8.9. $C_{18}H_{28}O_5$. Calculated, %: C 66.6, H 8.7.

4'-tert-Butylbenzo-18-crown-6 (V). From 0.47 g (1.5 mmole) of compound (II), 3 g of PPA, and 0.28 ml (3 mmole) of tert-butyl alcohol was obtained 0.47 g (85%) of compound (V) with $T_m$ 35-36°C. According to the literature [9], $T_m$ 35-37°C. Found, %: C 65.5, H 8.9. $C_{20}H_{32}O_6$. Calculated, %: C 65.2, H 8.8.

4',4"(5")-Di-tert-butylbenzo-24-crown-8 (XVIII). From 0.66 g (1.5 mmole) of compound (XII), 4 g of PPA, and 0.55 ml (6 mmole) of tert-butyl alcohol was obtained 0.56 g (67%) of compound (XVII) with $T_m$ 55-65°C. Found, %: C 68.8, H 8.7. $C_{32}H_{48}O_8$. Calculated, %: C 68.5, H 8.6.

4',4"(5")-Di-tert-butyldibenzo-30-crown-10 (XX). From 0.3 g (0.5 mmole) of compound (XIII), 3 g of PPA, and 0.21 ml (2 mmole) of tert-butyl alcohol was obtained 0.32 g (80%) of compound (XX), with $T_m$ 73-76°C. According to the literature [15], $T_m$ 71-73°C. Found, %: C 66.9, H 8.9. $C_{36}H_{56}O_{10}$. Calculated, %: C 66.6, H 8.7.

4'-tert-Amylbenzo-15-crown-5 (IV). From 0.8 g (3 mmole) of compound (I), 5 g of PPA, and 0.67 ml (6 mmole) of tert-amyl alcohol was obtained 0.8 g (80%) of compound (IV) with $T_m$ 15-17°C. Found, %: C 67.8, H 9.1. $C_{19}H_{30}O_5$. Calculated, %: C 67.4, H 8.9.

4'-tert-Amylbenzo-18-crown-6 (VI). From 0.5 g (1.5 mmole) of compound (II), 3 g of PPA, and 0.33 ml (3 mmole) of tert-amyl alcohol was obtained 0.5 g (82%) of compound (VI) in the form of an oil. Found, %: C 66.2, H 9.1. $C_{21}H_{34}O_6$. Calculated, %: C 65.9, H 9.0.

4',4"(5")-Di-tert-amyldibenzo-18-crown-6 (XVII). From 1.45 g (4 mmole) of compound (XI), 7.2 g of PPA, and 1.8 ml (1.6 mmole) of tert-amyl alcohol was obtained 1.3 g (65%) of a fraction of disubstituted derivatives in a form of an oil, from which 0.3 g (15%) of the crystalline substance (XVII) with $T_m$ 85-88°C, $R_f$ 0.49, was isolated. According to the literature [10], an oil. Found, %: C 72.3, H 9.0. $C_{30}H_{44}O_6$. Calculated, %: C 72.0, H 8.8. In addition, 0.2 g (12%) of the monosubstituted product (XVI) was isolated with $T_m$ 108-110°C, $R_f$ 0.37. Found, %: C 70.2, H 8.1. $C_{25}H_{34}O_6$. Calculated, %: C 69.7, H 8.0.

4,4"(5")-Di-tert-amylbenzo-24-crown-8 (XIX). From 0.9 g (2 mmole) of compound (XII), 5 g of PPA, and 0.84 ml (8 mmole) of tert-amyl alcohol was obtained 0.9 g (80%) of compound (XIX) with $T_m$ 65-69°C. Found, %: C 70.1, H 8.7. $C_{34}H_{52}O_8$. Calculated, %: C 69.9, H 9.0.

4',4"(5")-Di-tert-amyldibenzo-30-crown-10 (XXI). From 0.3 g (0.56 mmole) of compound (XIII), 3 g of PPA, and 0.25 ml (2.2 mmole) of tert-amyl alcohol was obtained 0.29 g (81%) of compound (XXI) with $T_m$ 62-65°C. Found, %: C 67.8, H 9.1. $C_{38}H_{60}O_{10}$. Calculated, %: C 67.4, H 8.9.

4',5'- and 3',5'-Di-sec-butylbenzo-15-crown-5s (VII) and (VIII). From 0.8 g (3 mmole) of compound (I), 4 g of PPA, and 0.6 ml (6 mmole) of sec-butyl alcohol was obtained 0.76 g (67%) of a mixture of disubstituted derivatives, which were separated into the isomers. Their amounts were 0.3 g of compound (VII) with $T_m$ 79-81°C, $R_f$ 0.69, and 0.04 g of compound (VIII), with $T_m$ 67-68°C, $R_f$ 0.90. Compound (VII). Found, %: C 69.7, H 9.7. $C_{22}H_{36}O_5$. Calculated, %: C 69.4, H 9.5. Compound (VIII). Found, %: C 69.7, H 9.6. $C_{22}H_{36}O_5$. Calculated, %: C 69.4, H 9.5.

4',5'- and 3',5'-Di-sec-butylbenzo-18-crown-6s (IX) and (X). From 0.47 g (1.5 mmole) of compound (II), 3 g of PPA, and 0.28 ml (3 mmole) of sec-butyl alcohol was obtained 0.43 g (77%) of a mixture of disubstituted derivatives from which were isolated 0.18 g of compound (IX), $T_m$ 44-45°C, $R_f$ 0.45, and 0.13 g of compound (X) in the form of an oil, $R_f$ 0.87. Compound (IX). Found, %: C 68.3, H 9.6. $C_{24}H_{40}O_6$. Calculated, %: C 67.9, H 9.5. Compound (X). Found, %: C 68.2, H 9.6. $C_{24}H_{40}O_6$. Calculated, %: C 67.9, H 9.5.

3',4",5',5"-Tetra-sec-butylbenzo-24-crown-8 (XXX). From 0.9 g (2 mmole) of compound (XII), 5 g of PPA, and 0.74 ml (8 mmole) of sec-butyl alcohol was obtained 0.57 g (41%) of the tetra-sec-butyl derivative with $T_m$ 93-96°C. Found, %: C 71.7, H 9.7. $C_{40}H_{64}O_8$. Calculated, %: C 71.4, H 9.6.

Isopropyl Derivatives of Dibenzo-18-crown-6 (XXIV, XXV, and XXXI). A mixture of alkyl derivatives was obtained from 36 g (100 mmole) of compound (XI), 170 g of PPA, and 31 ml (400 mmole) of isopropanol. From it were isolated 28 g (53.5%) of 3',4",5',5"-tetraisopropyldibenzo-18-crown-6 (XXXI) in the form of an oil, $R_f$ 0.85, and 9.8 g (22.5%) of diisopropyl derivatives in the form of a mixture of structural isomers which were separated by fractional crystallization from hexane into the 4',4"(5")-isomers (XXIV) with $T_m$ 128-132°C, $R_f$ 0.42, and the 3',4"(5")-isomers (XXV) with $T_m$ 107-112°C, $R_f$ 0.35. Compound (XXXI).

Found, %: C 73.1, H 9.3. $C_{22}H_{48}O_6$. Calculated, %: C 72.7, H 9.2. Compound (XXIV). Found, %: C 70.4, H 8.3. $C_{28}H_{36}O_6$. Calculated, %: C 70.2, H 8.2. Compound (XXV). Found, %: C 70.5, H 8.3. $C_{26}H_{36}O_6$. Calculated, %: C 70.2, H 8.2.

The sec-Amyl Derivatives of Dibenzo-18-crown-6 (XXVI, XXVII, and XXXII). A mixture of products was obtained from 1.2 g (3.3 mmole) of compound (XI), 6.4 g of PPA, and 1.5 ml (13 mmole) of n-amyl alcohol by heating at 95-100°C for 10 h. From this mixture was isolated 0.8 g (38%) of tetra-sec-amyldibenzo-18-crown-6 (XXXII) in the form of an oil, $R_f$ 0.96, and 0.4 g (23.5%) of a mixture of disubstituted products from which, by fractional crystallization from hexane, were isolated a substance with $T_m$ 89-92°C and $R_f$ 0.42 which was, according to its PMR spectrum, the 3',4"(5")-isomer (XXVII), and a substance with $T_m$ 75-80°C and $R_f$ 0.46, enriched with the 4',4"(5")-isomer (XXVI). The tetra-derivative (XXXII). Found, %: C 75.3, H 10.2. $C_{40}H_{64}O_6$. Calculated, %: C 75.0, H 10.1. Compound (XXVI). Found, %: C 72.3, H 9.0. $C_{30}H_{44}O_6$. Calculated, %: C 72.0, H 8.9. Compound (XXVII). Found, %: C 72.3, H 9.0. $C_{30}H_{44}O_6$. Calculated, %: C 72.0, H 8.9.

The Cyclohexyl Derivatives of Dibenzo-18-crown-6 (XXVIII and XXXIII-XXXVI). A mixture of alkylation products was obtained from 1.08 g (3 mmole) of compound (XI), 5.4 g of PPA, and 1.2 ml (12 mmole) of cyclohexanol, and from it were isolated: 0.2 g (12%) of 4'4"(5")-dicyclohexyldibenzo-18-crown-6 (XXVIII) with $R_f$ 0.30, $T_m$ 146-152°C; 0.9 g (50%) of the tricyclohexyldibenzo-18-crown-6 (XXXIII) with $R_f$ 0.9, $T_m$ 65-70°C; 0.4 g (22%) of the tricyclohexyldibenzo-18-crown-6 (XXXIV) with $R_f$ 0.40, $T_m$ 95-98°C; and 0.25 g (12%) of 4',4",5',5"-tetracyclohexyldibenzo-18-crown-6 (XXXV, XXXVI) with $R_f$ 0.54, $T_m$ 186-188 and 194-196°C. Compound (XXVIII). Found, %: C 73.5, H 8.6. $C_{32}H_{44}O_6$. Calculated, %: C 73.3, H 8.5. Compound (XXXIII). Found, %: C 75.6, H 9.1. $C_{38}H_{54}O_6$. Calculated, %: C 75.2, H 9.0. Compound (XXXIV). Found, %: C 75.5, H 9.1. $C_{38}H_{54}O_6$. Calculated, %: C 75.2, H 9.0. Compound (XXXV). Found, %: C 77.0, H 9.6. $C_{44}H_{64}O_6$. Calculated, %: C 76.7, H 9.4. Compound (XXXVI). Found, %: C 77.1, H 9.5. $C_{44}H_{64}O_6$. Calculated, %: C 76.7, H 9.4.

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