CHEMISTRY LETTERS, pp. 1773-1776, 1988.

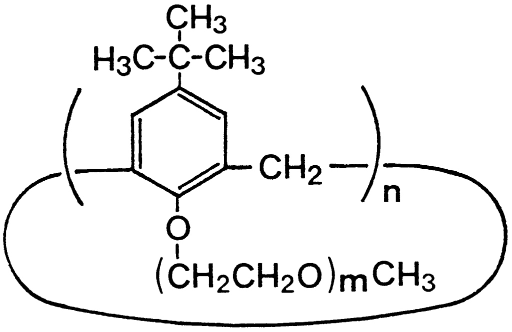
Catalytic Activity of an Octopus-type Calixarene on the Formation of Ethers1)

Hisaji TANIGUCHI* and Eisaku NOMURA
Wakayama Prefectural Industrial Research Institute,
60 Ogura, Wakayama 649-62

5,11,17,23,29,35-Hexa-p-tert-butyl-37,38,39,40,41,42-hexakis-(3,6,9-trioxadecyloxy)calix[6]arene catalyzes the formation of an ether and bisphenoxymethanes through the Williamson synthesis.

Calixarenes,2) which are macrocyclic oligomers from base-catalyzed condensation of para-substituted phenols with formaldehyde, have lately attracted considerable attention because their potential as enzyme mimics has been suggested.3)

Shinkai and co-workers have synthesized water-soluble calixarenes, which serve not only as host molecules in an aqueous system but also as a new class of surfactants and acid catalysts.4) Using the water-soluble calixarenes, they have also demonstrated the possibility of the selective extraction of uranyl ion from sea water.5) Gutsche and co-workers have shown the interaction, in solution, between calixarenes and amines.6) The existence of calixarene-organic solvent molecule clathrates7) and calixarene-alkali cation complexes8) has been shown by other workers. In paticular, octopus-type calixarenes(Fig.1) form complexes with alkali cations as crown ethers do.9) These calixarenes have both hydrophobic moiety and hydrophilic moiety within one molecule; they have the same nature as surfactants. Their interesting features prompted us to use them as catalysts for organic reactions. Thus, we investigated the catalytic activity of 5,11,17,23,29,35-hexa-p-tert-butyl-37,38,39,40,41,42-hexakis(3,6,9-trioxadecyloxy)calix[6]-arene(1) for the formation of ethers through the Williamson synthesis.



1. n=6, m=3

Fig. 1. Octopus-type calixarene.

The calixarene 1 was prepared by a modification of the literature procedure.10)

In order to assess the catalytic activity of 1 and to compare 1 with other various catalysts, we at first examined the reaction of phenol with benzyl bromide (Eq.1).11) After the reaction, the calixarene 1 could be easily removed by adsorption on silica gel. Moreover, the calixarene 1 could be used repeatedly as a catalyst after recovery from the silica gel.[11] Table 1 shows the results.

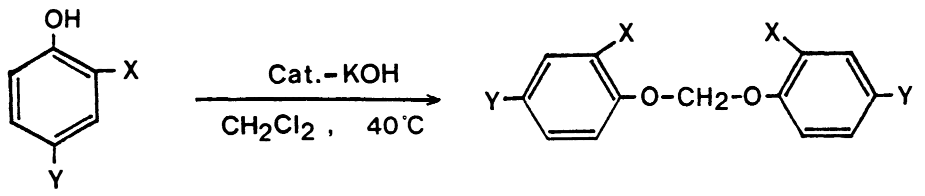
$$C_6H_5OH \; + \; C_6H_5CH_2Br \xrightarrow[CH_2Cl_2,\ 40\ °C]{Cat.\text{-}KOH} C_6H_5CH_2\text{-}O\text{-}C_6H_5 \qquad (1)$$

Table 1. The reaction of benzyl bromide with phenol[a]

Run	Cat.	PhOH/Cat[b]	Time/h	Yield of ether/%[c]
1	1	35	2	100
2	PEG-DEE 456[d]	5.8	3	80
3	BTAC[e]	4.8	20	100
4	none	-	20	30

a) C_6H_5OH(1.2 g, 12.8 mmol), benzyl bromide(2.2 g, 12.5 mmol), KOH(2.5 g), a guaranteed grade of commercial CH_2Cl_2(15 ml), temp at 40 °C. b) Molar ratio. c) We could not detect any by-product. d) Poly(ethylene glycol) diethyl ether(mol. wt.=456). e) Benzyltrimethylammonium chloride.

In this reaction, the catalyst 1 is the most excellent among the catalysts used. Within only 2 hours, the reaction was complete. Less efficient appear to be a quarternary ammonium salt and poly(ethylene glycol)diethyl ether. With the former a longer reaction time was required(20 h) than with the catalyst 1. With the latter the yield of the ether was lowered(80%). These findings suggest that the catalytic activity of the calixarene 1 is attributable to not only the hydrophilic moiety of 1 but also the hydrophobic moiety.



(2)

2a X = Y = H
b X = H, Y = Cl
c X = Y = Cl

5a X = Y = H
b X = H, Y = Cl
c X = Y = Cl

Quarternary ammonium salts are already known to be good catalysts for the formation of bisaryloxymethanes.[12] We have next applied the calixarene 1 as a catalyst to the formation of bisaryloxymethanes to assess its catalytic activity (Eq.2).[13] Substrates used in this investigation are 2a, 2b, and 2c. Table 2 shows the results. When 2a was used, the calixarene 1 catalyzed the reaction most excellently among the catalysts used to form bisphenoxymethane(5a). When the substrate was 2b and dichloromethane saturated with water was used, the calixarene 1 catalyzed, as well as benzyltrimethylammonium chloride, to form the corresponding bisphenoxymethane(5b). In this case, the use of dried dichloromethane lowered the yield of 5b(31%). A longer reaction time(144 h) was required to obtain a yield of 19% of 5b in a two-phase system. When 2c was used, the calixarene 1 did not catalyze the reaction, whereas benzyltrimethylammonium chloride acted as a good catalyst. As described above, it was found that the catalytic activity of the calixarene 1 varied with kinds of phenols.

Table 2. The reaction of phenols with dichloromethane a)

Run	Phenol	Cat.	PhOH/Cat b)	Time/h	Yield of 5/% c)
1	2a	1	24	24	100 d)
2	2a	PEG-DEE 456 e)	5.8	24	85 d)
3	2a	PEG 600 f)	0.77	195	23 d)
4	2a	BTAC g)	4.7	24	86 d)
5	2a	none	-	24	0.3 d)
6	2b	1	48	96	100 h)
7	2b	1	48	96	31 i)
8	2b	1	48	144	19 j)
9	2b	BTAC g)	4.7	72	100 d)
10	2c	1	48	168	trace d)
11	2c	BTAC g)	2.3	77	99 d)

a) Phenol(1.2 g, 12.8 mmol), KOH(2.5 g), CH_2Cl_2(50 ml), temp at 40 °C. b) Molar ratio. c) We could not detect any by-product. d) A guaranteed grade of commercial CH_2Cl_2 was employed for the reaction. e) Poly(ethylene glycol)diethyl ether (mol. wt.=456). f) Poly(ethylene glycol)(mol. wt.=600). g) Benzyltrimethylammonium chloride. h) Dichloromethane which was saturated with water was used. i) Dichloromethane dried over molecular sieves was used. j) The reaction was carried out in a two-phase system; CH_2Cl_2(50 ml) and water(5 ml).

References

1) Presented at the 54th National Meeting of the Chemical Society of Japan, Tokyo, April 1987, Abstr.II, 2 III F13.

2) C.D.Gutsche, B.Dhawan, K.Hyun No, and R.Muthukrishnan, J. Am. Chem. Soc., 103, 3782(1981); A.Ninagawa and H.Matsuda, Makromol. Chem. Rapid Commun., 3, 65 (1982); Y.Nakamoto and S.Ishida, J. Thermosetting Resins, 3, 71(1982); Y.Nakamoto and S.Ishida, Makromol. Chem. Rapid Commun., 3, 705(1982).

3) C.D.Gutsche, Acc. Chem. Res., 16, 161(1983).

4) S.Shinkai, S.Mori, T.Tsubaki, T.Sone, and O.Manabe, Tetrahedron Lett., 25, 5315 (1984); S.Shinkai, H.Koreishi, S.Mori, T.Sone, and O.Manabe, Chem. Lett., 1985, 1033; S.Shinkai, S.Mori, H.Koreishi, T.Tsubaki, and O.Manabe, J. Am. Chem. Soc., 108, 2409(1986).

5) S.Shinkai, H.Koreishi, K.Ueda, T.Arimura, and O.Manabe, J. Am. Chem. Soc., 109, 6371(1987).

6) L.J.Bauer and C.D.Gutsche, J. Am. Chem. Soc., 107, 6063(1985); C.D.Gutsche, M.Iqbal, and I.Alam, ibid., 109, 4314(1987).

7) T.Komoto, I.Ando, Y.Nakamoto, and S.Ishida, J. Chem. Soc., Chem. Commun., 1988, 135; M.Anthony Mckervey, E.M.Seward, G.Ferugson, and B.L.Ruhl, J. Org. Chem.,

51, 3581(1986).

8) D.N.Reinhoudt, P.T.Dijkstra, P.J.A. in't Velt, K.E.Bugge, S.Harkemt, R.Ungaro, and E.Ghidini, J. Am. Chem. Soc., 109, 4761(1987); S.G.Bott, A.W.Coleman, and J.L.Atwood, ibid., 108, 1709(1986); S.R.Izatt, R.T.Hawkins, J.J.Christensen, and R.M.Izatt, ibid., 107, 63(1985).

9) S.Ishida and Y.Nakamoto, J. Thermosetting Resins, 6, 37(1985).

10) H.Funada, Y.Nakamoto, and S.Ishida, Polymer Preprints, Japan, 34, 368(1985): p-tert-Butylcalix[6]arene(2.0 g, 1.37 mmol), 3,6,9-trioxadecyl p-toluenesulfonate(9.89 g, 31.1 mmol), KOH(3.65 g), and benzyltrimethylammonium chloride(1.0 g) were placed in a flask. To the flask, CH_2Cl_2(20 ml) was added all at once. The reaction mixture was stirred at 40 °C for 2 d, and then was poured into ice-water(100 ml). The aqueous solution was extracted with CH_2Cl_2 (2x30 ml). The extract was dried over $MgSO_4$. After the magnesium salts were removed, CH_2Cl_2 was evaporated under reduced pressure to give a viscous oil. Addition of a few drops of EtOH to the oil gave a white solid, which was recrystallized from EtOH to yield colorless prisms; mp 123-124 °C. Yield 94%. Found: C, 69.64; H, 9.39%. Calcd for $C_{108}H_{168}O_{24}\cdot C_2H_6O$: C, 69.66; H, 9.25%.

11) The reaction was carried out in the following manner: A mixture of PhOH(1.2 g, 12.8 mmol), benzyl bromide(2.2 g, 12.5 mmol), KOH(2.5 g), and the calixarene 1 (0.7 g) was placed in a flask. To the flask, CH_2Cl_2(15 ml) was added all at once. After stirring for 2 h at 40 °C, the reaction mixture was poured upon a Büchner funnel containing silica gel(ca. 10 g) and the silica gel was washed with CH_2Cl_2(ca. 100 ml). Silica gel adsorbed the calixarene 1, which was extracted with EtOH and used repeatedly. The filtrate was evaporated to dryness to give a white solid(benzyl phenyl ether); mp 39 °C. Yield 100%.

12) E.V.Dehmlow and J.Schmit, Tetrahedron Lett., 1976, 95.

13) The reaction was carried out in a similar manner described in Ref.11.

(Received July 25, 1988)