CHEMISTRY LETTERS, pp. 1551-1554, 1989.

Solvent Extraction of D- and L-Dibenzoyltartrate Anions with Dicationic Ion-Pair Extractants Featuring Chirality Recognition and Shape Recognition

Akira OHKI,* Ryo MIYASHITA, Makoto TAKAGI,[†] Toshio TAKESHITA, and Shigeru MAEDA
Department of Applied Chemistry, Faculty of Engineering,
Kagoshima University, Kagoshima 890
[†]Department of Organic Synthesis, Faculty of Engineering,
Kyushu University, Fukuoka 812

A new type of ion-pair extractant, **1**, was developed. **1** possesses an axial chirality (binaphthyl unit) between its two ionic centers, and exhibited the ability of chirality recognition in the solvent extraction of an organic dicarboxylate anion, dibenzoyltartrate. Further, the extraction of the anion was investigated from the viewpoint of molecular shape (ionic center interval) recognition.

Chirality recognition has long been studied in crystallization system and chromatography system, and much research effort has been devoted. On the contrary, only a few studies have concerned with the chirality recognition in liquid-liquid (solvent) extraction system,[1-3] because chirality recognition requires powerful recognition field such as crystal lattice formation or multistage interaction (chromatography). In order to realize the chirality recognition in one step solvent extraction system, it is essential for the extractant to have powerful chiral barrier unit. Cram and coworkers have achieved such an extraction system for cationic species (amino acids etc.) by use of chiral crown ether extractants (hosts) in which an axially chiral unit (binaphthyl unit) is combined with crown ethers.[1,2]

In this study, we prepared a novel type of chiral extractant for anionic species, (R)-(-)- and (S)-(+)-1,1'-binaphthyl-2,2'-diylbis(benzyldiphenylphosphonium) dibromide (abbreviated as (R)-**1** and (S)-**1**, Fig. 1), which possess an

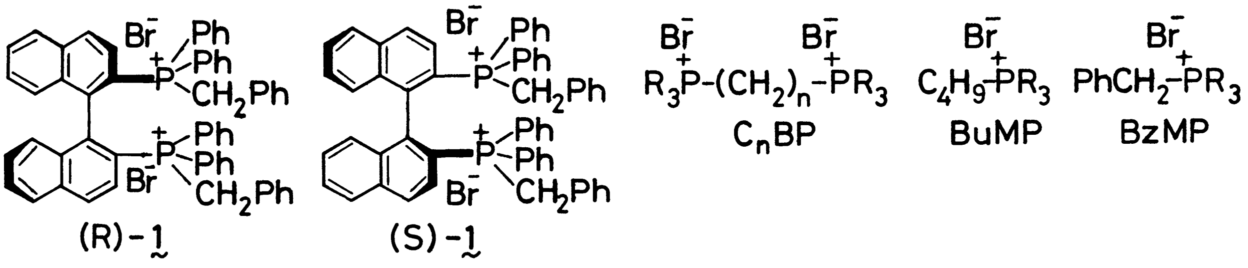

Fig. 1. Ion-pair extractants (R = octyl; n = 2 - 10).

axially chiral unit between the two ionic centers of dicationic ion-pair extractant. By use of the 1 extractants, the extraction of D- and L-dibenzoyltartrate anions was investigated. Further, we studied molecular shape (ionic center interval) recognition ability in the extraction of the organic anion with the aid of dicationic extractants having polymethylene-chain between the two ionic centers (C_nBPs, Fig. 1).

The synthesis of (R)-1 was as follows. (R)-(+)-2,2'-bis(diphenylphosphino)-1,1'-binaphthyl ((R)-BINAP; 1.0 g, 1.6 mmol), benzyl bromide (1.4 g, 8.0 mmol), and dimethylformamide (DMF, 10 mL) were charged in a glass tube, which was then sealed (along with a stirring magnet) under vacuum after several freeze-pump-thaw cycles. The sealed tube was heated at 60 °C for 3 days with internal stirring. After removal of DMF and unreacted benzyl bromide from the reaction mixture by evaporation with rotary pump, white crude product was obtained and recrystallized twice from ethanol. Colorless crystals were obtained. Yield (1.1 g, 71%). mp 207.5 - 208.5 °C. Found: C, 72.35; H, 4.90%. Calcd for $C_{58}H_{46}P_2Br_2$: C, 72.21; H, 4.80%. $[\alpha]_D^{25}$ -230° (c 0.5, CH_3OH). ^1H NMR (DMSO-d_6) δ = 4.7 - 5.0 (4H, m; PCH_2Ph) and 6.9 - 8.2 (42H, m; aromatic). ^{31}P NMR ($CDCl_3$ + DMF) δ^P (from H_3PO_4) = 21.0 (s). (S)-1 was similarly prepared from (S)-BINAP (Yield: 1.2 g, 78%), whose properties were identical with those of its enantiomer except in sign of rotation. Found: C, 72.29; H, 4.88%. The preparation of C_nBPs was described in our previous paper.4)

Extraction experiments were carried out as follows. An aqueous solution containing dibenzoyltartrate anion was shaken with an organic solution (1,2-dichloroethane) containing an ion-pair extractant in a stoppered centrifuge tube at 20° C for 20 min. In the extraction experiments performed at 0 °C, the tube was soaked in a water bath with a mixture of ice and salt for 40 min with an internal stirring. After phase separation, the concentration of the organic anion in the aqueous phase was determined by HPLC with a Shimadzu LC-6A instrument (4 mm X 25 mm ODS column; UV detector: 275 nm; eluent: water-methanol (7:4)). The amount of the anion extracted into the organic phase was taken as the difference between the amount initially added and that remained in the aqueous phase after equilibrium. In some runs, the material balance on the organic anion distribution between aqueous and organic phases was confirmed by back-extraction experiments.

Table 1 summarizes the extraction of dibenzoyltartrate enantiomeric anions by use of (R)-1 and (S)-1 extractants. When (R)-1 was used, L-dibenzoyltartrate was more preferably extracted than D-isomer (Run 1). However, in the case of (S)-1, the selectivity was reversed; the extraction of D-dibenzoyltartrate surpassed that of L-isomer (Run 2). It is found that "enantioselective" extraction exactly occurs by use of 1 extractant, and the separation factor (enantioselectivity) α = 1.3 was obtained.

The extractability of dibenzoyltartrate was gradually decreased with an increase in the concentration of bromide anion in the aqueous phase (Runs 2-5). This result suggests that the extraction proceeds <u>via</u> the exchange reaction between bromide counter anion of 1 and dibenzoyltartrate anion. However, the nature of enantioselective extraction was not changed; (S)-extractant preferred D-enantiomeric anion to its L-isomer. The enantioselectivity became slightly higher

Table 1. Extraction of dibenzoyltartrate enantiomeric anions with (R)- and (S)-**1** extractants[a]

Run	**1**	[NaBr]	Temp	More extractable	Distribution ratio[b]		α[c]
	R or S	mM	°C	enantiomeric anion	D_A	D_B	
1	R	1	20	L	0.43	0.34	1.3
2	S	1	20	D	0.42	0.32	1.3
3	S	0	20	D	0.58	0.44	1.3
4	S	1.5	20	D	0.36	0.26	1.4
5	S	2	20	D	0.33	0.24	1.4
6	R	0	0	L	0.32	0.20	1.6
7	S	0	0	D	0.31	0.19	1.6

a) Equal volumes (3 mL) of organic and aqueous solutions were equilibrated. The organic solution contained 1.0 mM (1 M = 1 mol/dm^3) (R)- or (S)-**1** while the aqueous solution contained 0.1 mM D- or L-dibenzoyltartaric acid, sodium bromide, and 5.0 mM phosphate buffer (pH 7.7).

b) D_A and D_B denote the distribution ratio of more extractable dibenzoyltartrate enantiomeric anion and that of less extractable enantiomeric anion, respectively.

c) Separation factor: $\alpha = D_A/D_B$.

when the bromide concentration in the aqueous phase was increased (Runs 4,5). When the extraction was carried out at 0 °C, a higher enantioselectivity was obtained (α = 1.6), while the extractability was considerably decreased (Runs 6,7).

The mechanism of chirality recognition can be explained as follows. The dibenzoyltartrate in the aqueous phase fully acts as a dianion under present pH condition (pH 7 - 8). Accordingly, through the two ion-pair interaction between the dicationic **1** extractant and the dianion, dibenzoyltartrate is tightly bound in powerful chiral barrier field constructed by the binaphthyl unit of **1**, resulting in the occurrence of enantioselectivity mentioned above. It is very likely that in the case of the extraction at 0 °C, the chiral structure of **1** becomes more rigid, so that a higher enantioselectivity is attained. Such a chirality recognition mechanism seems to be similar to that described in the studies of Cram's chiral crown ethers.[1,2] However, the crown ethers interact with cationic species such as amino acids and amines whereas **1** in the present study recognizes the chirality of anionic species.

Figure 2 shows the extraction of D-dibenzoyltartrate by use of dicationic extractants having polymethylene-chain between two ionic centers (polymethylene-bis(trioctylphosphonium) dibromide, abbreviated as C_nBP) as well as by use of monocationic extractants (BuMP and BzMP) whose structures are similar to those of C_nBPs. The extraction ability of C_nBPs was remarkably dependent on their methylene-chain length. The dicationic extractant having hexamethylene-chain

(C_6BP) exhibited the maximum extraction ability, probably because the ionic center interval within C_6BP can be compatible with that of dibenzoyltartrate. Moreover, the extraction ability of monocationic extractants (BuMP and BzMP) was greatly inferior to that of dicationic C_nBP extractants. These results suggest that "molecular shape (ionic center interval) recognition" is at work in the extraction of dibenzoyltartrate by use of C_nBP extractants. Needless to say, the extractability of L-dibenzoyltartrate was completely equal to that of D-isomer.

The extraction of dibenzoyltartrate was investigated by use of dicationic ion-pair extractants from the viewpoint of chirality recognition and shape recognition. As a result, the space interposed by the two ionic centers of dicationic ion-pair extractant proved to offer an effective molecular recognition field. Such a concept can be applied not only to solvent extraction but also both to ion-selective electrode and to ion-pair chromatography. More extended studies to more general anionic species are now in progress.

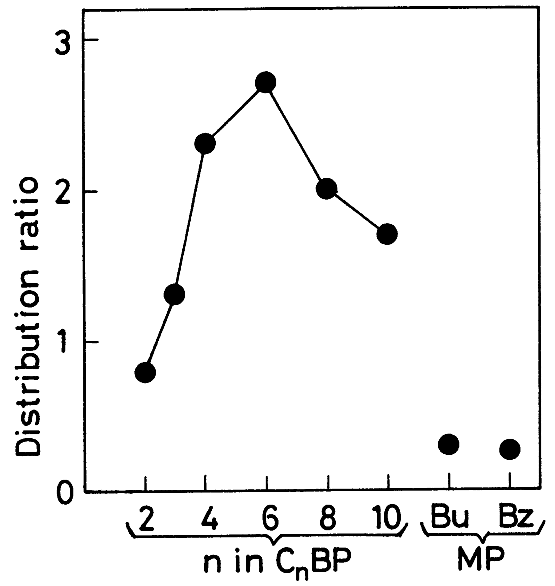

Fig. 2. Extraction of dibenzoyltartrate by C_nBPs, BuMP, and BzMP.$^{5)}$

The authors are grateful to Professor M. Nakatani, Kagoshima University, for his helpful suggestions in the experiments on the nature of optical activity, and wish to express their thanks to Takasago Research Institute, Inc. for their generous gifts of products (BINAP).

References

1) E. P. Kyba, K. Koga, L. R. Soura, M. G. Siegel, and D. J. Cram, J. Am. Chem. Soc., 95, 2692 (1973).
2) D. S. Lingenfelter, R. C. Helgeson, and D. J. Cram, J. Org. Chem., 46, 393 (1981) and references cited therein.
3) T. Takeuchi, R. Horikawa, and T. Tanimura, Anal. Chem., 56, 1152 (1984).
4) A. Ohki, M. Yamura, S. Kumamoto, S. Ide, S. Maeda, and T. Takeshita, Sovent Extr. Ion Exch., 7, 57 (1989).
5) Conditions: Equal volumes (10 mL) of organic and aqueous solutions were equilibrated (20 °C). The organic solution contained an extractant (0.5 mM for C_nBP; 1.0 mM for BuMP and BzMP) while the aqueous solution contained 0.1 mM D-dibenzoyltartaric acid, 2.0 mM sodium bromide, and 5.0 mM phosphate buffer (pH 7.0).

(Received June 7, 1989)