BULLETIN OF THE CHEMICAL SOCIETY OF JAPAN, VOL. 46, 553—556 (1973)

Synthetic Studies by the Use of Carbonates. III.[1] The Condensation Reactions of Ethylene Carbonate with a Variety of Phenols Catalyzed by Lithium Hydride or Tetraethylammonium Halides

Teruo Yoshino, Shigeru Inaba, and Yoshiharu Ishido

Department of Chemistry, Faculty of Science, Tokyo Institute of Technology, O-okayama, Meguro-ku, Tokyo

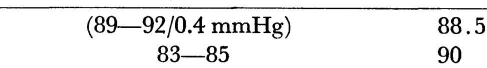
(Received June 14, 1972)

The condensation reactions of ethylene carbonate with a variety of phenols in the presence of tetraethylammonium halides were examined; they were found to give the corresponding aryl β-hydroxyethyl ethers in good yields. The reactions in the presence of lithium hydride in place of the tetraethylammonium halides were also examined for the sake of comparison, and these results were discussed.

The first paper of this series[2] described the condensation reactions of ethylene carbonate(**1**) with hydrohalides of various amines, which resulted in the formation of β-hydroxyethylated ammonium salts in good yields. Although the condensation reaction of **1** with phenols in the presence of potassium carbonate or sodium hydride had previously been reported,[3] the present authors investigated the reaction in the presence of lithium hydride or tetraethylammonium halides in place of the above inorganic salt or hydride because of their greater wieldiness; we also investigated the possibility that the reaction might be carried out under completely neutral conditions by the use of the ammonium halides.

Results and Discussion

Reactions Catalyzed by Lithium Hydride. Phenols were subjected to a condensation reaction with an equimolar amount of **1** in the presence of the corresponding phenoxide ion, which had been generated by treating the phenols with a catalytic amount of lithium hydride, as is shown in Scheme 1; the results are shown in Table 1. Phenol, *p*-nitrophenol, salicylanilide, and



1

Scheme I.

Table 1. Reactions of ethylene carbonate (**1**) with some phenols catalyzed by lithium hydride[a)]

Phenols	Reaction conditions		Products	
	Temp, °C	Period, hr	Mp (Bp), °C	Yield, %
Phenol	145—150	7	(89—92/0.4 mmHg)	88.5
p-Nitrophenol	150	6	83—85	90
2,4-Dinitrophenol	150—160	3	—	—[b)]
Salicylanilide	145	2.5	109—112	86
β-Naphthol	145	2	72—74	74

a) All the reactions were carried out by the use of 10 mmol of **1** and 11 mmol of phenols in dimethylformamide (5 ml) and a catalytic amount of lithium hydride was applied as catalyst.

b) This phenol was quantitatively recovered.

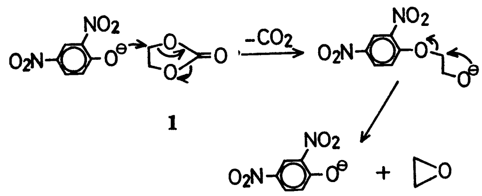
---

[1] H. Komura, T. Yoshino, and Y. Ishido, This Bulletin, **46**, 550 (1973).

[2] T. Yoshino, S. Inaba, H. Komura, and Y. Ishido, *ibid.*, in contribution.

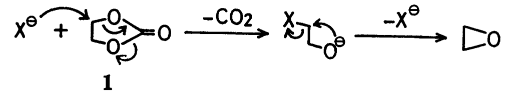
[3] a) W. W. Carlson and L. H. Cretcher, *J. Amer. Chem. Soc.*, **69**, 1952 (1947). b) W. W. Carlson, U. S. Pat. 2448767 (1948). c) S. Fumasoni, *Ann. Chem.* (Rome), **54**, 73 (1964).

β-naphthol gave the corresponding aryl β-hydroxyethyl ethers in 88.5, 90, 86, and 74% yields respectively. However, 2,4-dinitrophenol gave none of the expected ether and was recovered quantitatively in spite of the almost quantitative evolution of carbon dioxide gas. Even the use of an equimolar amount of sodium hydride resulted in a quantitative recovery of 2,4-dinitrophenol. The difference observed between the case of the phenol and those of the other phenols can be explained by supposing that the β-2,4-dinitrophenoxyethoxide ion formed in the course of the reaction might be subject to a subsequent intramolecular substitution reaction to give ethylene oxide and the 2,4-dinitrophenoxide ion because of the lowered electron density on the β-methylene carbon arising from the strong electron-withdrawing effect of the 2,4-dinitrophenyl group (Scheme II).



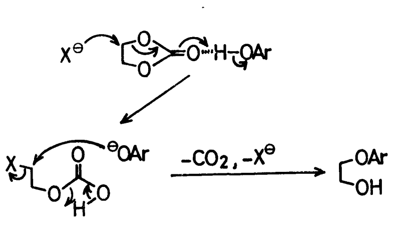
Scheme II.

Reactions Catalyzed by Tetraethylammonium Halides. The decomposition reaction of **1** in the presence of metal halides[4] or tetraalkylammonium halides[5] has been shown to give ethylene-oxide *via* the β-haloethoxide ion, accompanied by the evolution of carbon dioxide gas. In view of the reaction mechanism (Scheme III),



Scheme III.

the addition of phenols to the reaction system was assumed to bring about the formation of the corresponding aryl β-hydroxyethyl ethers, as is depicted in Scheme IV; *i.e.*, the resultant β-haloethoxide ion may abstract a proton from the phenols to afford ethylene halohydrin and the phenoxide ion, and the halohydrin may then be subject to the nucleophilic attack by the anion to afford the corresponding aryl β-hydroxyethyl ethers. On the basis of this assumption, a variety of phenols were heated with **1** at 140°C in the presence of tetraethylammonium halides as the catalyst until the evolution of carbon dioxide gas ceased. The series of phenols shown in Table 2 gave the corresponding aryl β-hydroxyethyl ethers in high yields. In contrast with the above case, in which lithium hydride was used as the catalyst, 2,4-dinitrophenol gave the corresponding ether in a 73% yield.



Scheme IV

The reaction may be explained as proceeding *via* a concerted mechanism (Scheme IV)[6] in view of the facts that the reaction of **1** with tetraethylammonium halides giving ethylene oxide requires a reaction temperature above 160°C at least,[2] that no reaction of **1** with phenols takes place even at 180°C, and that the reactions described here can easily take place even at 130—140°C, *i.e.*, the reaction may be induced by the nucleophilic attack of the halide ion as well as by the electron-withdrawing effect of the carbonyl group of **1** enhanced by the hydrogen bonding with phenols. The reaction is apparently different from that catalyzed by lithium hydride, since no basic species are involved in the final reaction mixture.

The procedure is, furthermore, characterized by the following points: 1) Aryl β-hydroxyethyl ethers are obtainable in high yields under completely neutral conditions. 2) The end-point of the reaction can be noticed by measuring the volume of carbon dioxide

Table 2. Reactions of ethylene carbonate (**1**) with a variety of phenols catalyzed by tetraethylammonium halides[a)]

Phenols	Reaction conditions		Products	
	Temp, °C	Period, hr	Mp (Bp), °C	Yield, %
Phenol[b)]	140	4.0	(116/12.5 mmHg)	95
p-Nitrophenol[b)]	150	4.0	83—85	91
o-Nitrophenol[b)]	135	10.0	(170—180/10—15)	78
m-Nitrophenol[c)]	170	0.5	86—87.5	93
2,4-Dinitrophenol[b)]	140	2.3	110.5—111	73
p-Methoxyphenol[c)]	155—160	2.5	63—65	81
p-Cresol	170	1.3	(84—95/0.4)	80
β-Naphthol	130	4.0	72—73	98
p,p'-Isopropylidenediphenol[b)]	130	6.0	100.5—101.5	77

a) All the reactions were carried out by the use of 10 mmol of **1** and 11 mmol of phenols. b) These reactions were carried out in the presence of tetraethylammonium iodide (3.6 mmol) as catalyst. c) These reactions were carried out in the presence of tetraethylammonium bromide as catalyst in dimethylformamide (5 ml).

---

4) a) A. Hilt, J. Trived, und K. Hamann, *Makromol. Chem.*, **89**, 177 (1965). b) K. Gulbins, G. Benzing, R. Maysenhölden, und K. Hamann, *Chem. Ber.*, **93**, 1975 (1960).

5) A. L. Shapiro, *Zh. Org. Khim.*, **4**, 2065 (1968): *ibid.*, **5**, 1207 (1967).

6) A kinetic study is now in progress in our laboratory, and will be reported elsewhere.

gas evolved. 3) The easy separation of the catalysts from the resultant reaction mixture is possible by distributing them between the organic solvent and water, and the catalysts can be recovered in almost quantitative yields by the concentration of the aqueous layer.

Experimental

All the melting points are uncorrected. The IR spectra were taken with a Hitachi EPI-2S apparatus, while the NMR spectra were measured with a Varian T-60 spectrometer, using tetramethylsilane (TMS) or sodium 2,2-dimethylsilapentanesulfonate (DSS) as the internal standard.

Preparation of Aryl β-Hydroxyethyl Ethers by the Use of Lithium Hydride as a Catalyst. *β-Hydroxyethyl Phenyl Ether*: A solution of phenol (2.8 g, 30 mmol) in dimethylformamide (DMF, 5 ml) was treated with lithium hydride (10 mg) at 100°C until no evolution of hydrogen gas was noticed. Ethylene carbonate (**1**) (2.8 g, 33 mmol) was then added to the solution, and the mixture was heated at 145—155°C until the evolution of carbon dioxide gas ceased (about 7 hr). The DMF was then evaporated *in vacuo*, the resultant sirup was extracted with chloroform (100 ml), and the extract was washed with water (30 ml × 2). The organic layer was concentrated and distilled. Yield, 2.4 g; 89%. Bp 89—92°C/0.04 mmHg (lit.[3] 118°C/10 mmHg). IR (NaCl): 3355, 1080 (OH), and 1246 (Ph-O-C) cm^{-1}. NMR ($CDCl_3$, TMS): δ 3.97 (m, -$\mathbf{CH_2}$-).

β-Hydroxyethyl p-*Nitrophenyl Ether*: The reaction of *p*-nitrophenol (7.0 g, 50 mmol) with **1** (4.4 g, 50 mmol) catalyzed by lithium hydride (10 mg) in DMF (5 ml) was carried out at 150°C for 6 hr; raw crystals similarly obtained were recrystallized from ethanol to give the product. Yield, 6.4 g; 90%. Mp 83—85°C. IR (KBr): 3230, 1076 (OH), 1273 (Ar-O-C), 1508, and 1344 (NO_2) cm^{-1}. NMR ($CDCl_3$, TMS): δ 4.00 (2H, A_2B_2 type J=4 Hz, -$\mathbf{CH_2}$OH) and 4.20 (2H, Ar-O-$\mathbf{CH_2}$-).

Found: C, 52.39; H, 5.01; N, 7.70%. Calcd for $C_8H_9O_4N$: C, 52.40; H, 4.95; N, 7.65%.

β-Hydroxyethyl o-*Phenylcarbamoylphenoxy Ether*: The reaction of salicylanilide (2.1 g, 10 mmol) with **1** (1.0 g, 11 mmol) in DMF (10 ml) catalyzed by lithium hydride (5 mg) was carried out at 145°C for 2.5 hr. Yield, 2.2 g; 86%. Mp 109—112°C (from methanol). IR (KBr): 3310, 1075 (OH), 1240 (Ar-O-C), and 1642 (-CO-NH-) cm^{-1}. NMR (DMSO-d_6, DSS): δ 4.20 (2H, A_2B_2 type J=5 Hz, -$\mathbf{CH_2}$-OH) and 4.60 (2H, Ar-O-$\mathbf{CH_2}$).

Found: C, 70.24; H, 5.70; N, 5.36%. Calcd for $C_{15}H_{15}O_3N$: C, 70.02; H, 5.88; N, 5.44%.

β-Hydroxyethyl β-Naphthyl Ether: The reaction of *β*-naphthol (2.9 g, 20 mmol) with **1** (2.0 g, 22 mmol) in DMF (5 ml) catalyzed by lithium hydride (5 mg) was carried out at 145°C for 2 hr. Mp 72—74°C {from benzene–petroleum ether (1 : 1); lit.[3] 76.7°C}. IR (KBr): 3325, 1085 (OH), and 1253 (Ar-O-C) cm^{-1}. NMR ($CDCl_3$, TMS): δ 4.02 (2H, A_2B_2 type J=4 Hz, -$\mathbf{CH_2}$OH) and 4.20 (2H, Ar-O-$\mathbf{CH_2}$-).

Reaction of **1** *with 2,4-Dinitrophenol.* a) The reaction of **1** (2.7 g, 30 mmol) with 2,4-dinitrophenol (5.4 g, 30 mmol) was carried out at 150°C by the use of lithium hydride (10 mg). The evolution of gases ceased after about 3 hr. The resultant mixture was dissolved in chloroform (100 ml), and the extract was successively washed with 1M aqueous hydrochloric acid (40 ml) and water (40 ml × 2). The concentration of the organic layer *in vacuo* after drying with anhydrous calcium chloride recovered 2,4-dinitrophenol (5.0 g, 93%). b) When sodium hydride (50% in oil) (0.5 g, 10 mmol) was used in place of lithium hydride in the above reaction, 2,4-dinitrophenol (5.1 g, 94%) was recovered. c) When sodium hydride (50% in oil) (1.4 g, 30 mmol) was used in the above reaction, the phenol (5.0 g, 93%) was also recovered.

Preparation of Aryl β-Hydroxyethyl Ethers Catalyzed by Tetraethylammonium Halides. *β-Hydroxyethyl Phenyl Ether*: A mixture of phenol (1.88 g, 22 mmol), **1** (1.94 g, 22 mmol), and tetraethylammonium iodide (1.0 g, 0.36 mmol) was heated at 145°C. The evolution of carbon dioxide gas ceased after about 4 hr. The resultant mixture was dissolved in chloroform (100 ml) and then washed with water (20 ml). The concentration of the organic layer after drying with anhydrous calcium chloride and subsequent distillation gave the product (2.62 g, 95%). Bp 116°C/12.5 mmHg.

β-Hydroxyethyl p-*Nitrophenyl Ether*: A mixture of *p*-nitrophenol (2.8 g, 20 mmol), **1** (2.0 g, 22 mmol), and tetraethylammonium iodide (1.0 g, 0.36 mmol) was heated at 150°C for 4 hr. The resultant mixture was dissolved in benzene (50 ml), and then the precipitated tetraethylammonium iodide was removed by filtration. The filtrate was evaporated *in vacuo* to dryness to give crude, pale yellow crystals, which were subsequently recrystallized from ethanol. Yield, 3.26 g; 91%. Mp 83—85°C.

β-Hydroxyethyl o-*Nitrophenyl Ether*: A mixture of *o*-nitrophenol (2.8 g, 20 mmol), **1** (1.94 g, 22 mmol), and tetraethylammonium iodide (1.0 g, 0.36 mmol) was heated at 130°C for 1 hr; the resultant mixture was treated in the same way as above and then distilled. Yield, 2.85 g; 78%. Bp 170—180°C/10—15 mmHg. IR (KBr): 3425, 1090 (OH), 1250 (Ar-O-C), 1522, and 1360 (NO_2) cm^{-1}. NMR ($CDCl_3$, TMS): δ 3.97 (2H, A_2B_2 type J=5 Hz, -$\mathbf{CH_2}$OH) and 4.25 (2H, Ar-O-$\mathbf{CH_2}$-).

Found: C, 52.50; H, 5.01; N, 7.56%. Calcd for $C_{15}H_{15}O_3N$: C, 52.46; H, 4.95; N, 7.65%.

β-Hydroxyethyl m-*Nitrophenyl Ether*: The reaction of *m*-nitrophenol (1.40 g, 10 mmol) with **1** (0.88 g, 10 mmol) was carried out in the presence of tetraethylammonium bromide (2.1 g, 10 mmol) in DMF (5 ml) at 170°C for 30 min. Raw crystals obtained in the same manner as above were recrystallized from methanol. Yield, 1.70 g; 93%. IR (KBr): 3250, 1050 (OH), 1240 (Ar-O-C), 1520, and 1345 (NO_2) cm^{-1}. NMR ($CDCl_3$, TMS): δ 4.03 (2H, A_2B_2 type J= 4 Hz, -$\mathbf{CH_2}$OH) and 4.71 (2H, Ar-O-$\mathbf{CH_2}$-).

Found: C, 52.22; H, 5.16; N, 7.56%. Calcd for $C_{15}H_{15}O_3N$: C, 52.46; H, 4.95; N, 7.65%.

β-Hydroxyethyl 2,4-Dinitrophenyl Ether: A mixture of 2,4-dinitrophenol (2.68 g, 20 mmol), **1** (1.94 g, 22 mmol), and tetraethylammonium iodide (1.78 g, 5 mmol) was heated at 140°C for 2.25 hr; the resultant mixture was treated in the same way as above to give raw crystals, which were then recrystallized from ethanol. Yield, 3.30 g; 73%. Mp 110.5—111°C. IR (KBr): 3200, 1070 (OH), 1280 (Ar-O-C), 1520, and 1350 (NO_2) cm^{-1}. NMR ($CDCl_3$, TMS): δ 3.85 (2H, A_2B_2 type J=5 Hz, -$\mathbf{CH_2}$OH), and 4.46 (2H, Ar-O-$\mathbf{CH_2}$-).

Found: C, 42.29; H, 3.77; N, 12.56%. Calcd for $C_{15}H_{14}O_5N_2$: C, 42.11; H, 3.53; N, 12.28%.

β-Hydroxyethyl p-*Methoxyphenyl Ether*: A mixture of *p*-methoxyphenol (3.7 g, 30 mmol) and **1** (2.7 g, 33 mmol) was heated together with tetraethylammonium bromide (2.1 g, 10 mmol) at 155—160°C for 2.5 hr; raw crystals obtained in the same way as above were then recrystallized from ethanol. Yield, 3.34 g; 88%. Mp 63—65°C. IR (KBr): 3300, 1070 (OH), and 1230 (Ar-O-C) cm^{-1}.

Found: C, 64.23; H, 7.19%. Calcd for $C_9H_{12}O_3$: C, 64.27; H, 7.19%.

β-Hydroxyethyl p-*Methylphenyl Ether*: A mixture of *p*-cresol (1.08 g, 10 mmol) and **1** (0.88 g, 10 mmol) in DMF (5 ml) was heated together with tetraethylammonium bromide (2.10 g, 10 mmol) at 170°C for 1.3 hr, and the resultant mixture was treated as above. The raw liquid thus obtained was distilled. Yield, 1.22 g; 80%. Bp 84—95°C/0.4 mmHg. IR (NaCl): 3300, 1070 (OH), and 1240 (Ar-O-C) cm^{-1}. NMR ($CDCl_3$, TMS): δ 3.90 (4H, Ar-O-**CH$_2$**-**CH$_2$**-OH).

Found: C, 71.24; H, 7.94%. Calcd for $C_9H_{12}O_2$: C, 71.01; H, 7.95%.

β-Hydroxyethyl β-Naphthyl Ether: The reaction of *β*-naphthol (2.88 g, 20 mmol) with **1** (1.94 g, 22 mmol) catalyzed by tetraethylammonium iodide (1.0 g, 0.36 mmol) was carried out at 130°C for 4 hr; the resultant mixture was treated as above to give raw crystals, which were then recrystallized from ethanol. Yield, 3.71 g; 98%. Mp 72—73°C.

2,2-Di-[p-*(β-hydroxyethyloxy)-phenyl*]*-propane*. A mixture of 2,2-di-(*p*-hydroxyphenyl)propane (2.3 g, 20 mmol) and **1** (1.94 g, 22 mmol) was heated together with tetraethylammonium iodide (1.28 g, 5 mmol) at 130°C for 6 hr; raw crystals obtained in the same way as above were then recrystallized from ethanol. Yield, 2.38 g; 77%. Mp 109—111°C (lit.[7] 110.5°C). IR (KBr): 3460, 1090 (OH), and 1250 (Ar-O-C) cm^{-1}. NMR ($CDCl_3$, TMS): δ 3.93 (2H, A_2B_2 type J=6 Hz, -**CH$_2$**OH), and 4.03 (2H, Ar-O-**CH$_2$**-).

The authors are grateful to the Ministry of Education, Japanese Government, for a Scientific Research Grant-in-Aid, and to the members of the Laboratory of Organic Elemental Analysis.

---

[7] E. Dyer and H. Scott, *J. Amer. Chem. Soc.*, **79**. 672 (1956).