

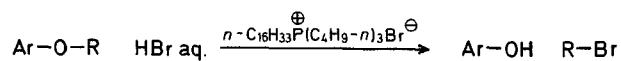
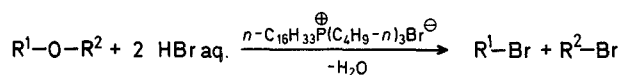
Cleavage of Dialkyl and Aryl Alkyl Ethers with Hydrobromic Acid in the Presence of Phase-Transfer Catalysts

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Standard methods to hydrolyse ethers require particularly drastic conditions, e.g. the use of boiling concentrated hydroiodic acid, or of a large excess of concentrated hydrobromic acid in acetic acid or acetic anhydride at reflux, or of pyridine hydrochloride at 200–220°. Cleavage of ethers by trimethylsilyl iodide has recently been reported².

We have found that dialkyl and aryl alkyl ethers can be advantageously cleaved by 47% hydrobromic acid in the presence of catalytic amounts of a phase-transfer agent in a heterogeneous aqueous-organic system.



Reactions were carried out by heating at 115°³ under vigorous stirring a heterogeneous mixture of substrate (1 mol), 47% hydrobromic acid (5–10 mol) and hexadecyltributylphosphonium bromide (0.1 mol). Under these conditions in all cases 90–95% conversions were obtained in 5–32 h (Table 1). Only alkyl bromides were formed from dialkyl ethers. Indeed in phase-transfer conditions even aqueous hydrochloric acid quantitatively converts alcohols into the corresponding chlorides⁴. In the case of aryl alkyl ethers the corresponding phenol and alkyl bromide were formed.

The best results were obtained with 5 and 10 mol of hydrobromic acid for aryl alkyl and dialkyl ethers, respectively (Table 2). For example, in the case of dialkyl ethers the reaction times were practically the same using 15 mol of hydrobromic acid, whereas they increased about 20 times with 2.5 mol of acid. The amounts of hydrobromic acid used favourably compare with those employed in classical methods (5–40 mol)¹.

The reaction rate is not affected by the nature of the onium salt, provided it is completely soluble in the organic phase⁵, e.g. hexadecyltributylphosphonium bromide, tetraoctylammonium bromide, and trioctylmethylammonium chloride, and increases with increasing amounts of catalyst (Table 2). In the absence of the latter the reaction is about 10–20

Table 1. Cleavage of Ethers with 47 % Hydrobromic Acid at 115°

Substrate R ¹	R ²	47% aq. HBr [mol]	Catalyst ^a [mol]	Time [h]	Yield [%] ^b of R ¹ Br	G.L.C. Conversion [%]
<i>n</i> -C ₄ H ₉	<i>n</i> -C ₄ H ₉	10	0.1	8	89	92
		10	0	87		93
<i>n</i> -C ₈ H ₁₇	<i>n</i> -C ₈ H ₁₇	10	0.1	5	91	92
		10	0	20		20
<i>n</i> -C ₆ H ₁₃ -CH(CH ₃)	<i>n</i> -C ₆ H ₁₃ -CH(CH ₃)	5	0.1	17	65	93
					+ octenes 22	
<i>n</i> -C ₁₆ H ₃₃	CH ₃	5	0	17		24
		5	0.1	3	88	91
		5	0	3		14

Ar	R	47% aq. HBr [mol]	Catalyst [mol]	Time [h]	Yield [%] ^b of Ar-OH R-Br	G.L.C. Conversion [%]
C ₆ H ₅	CH ₃	5	0.1	5	91	—
		5	0	22		92
C ₆ H ₅	<i>n</i> -C ₄ H ₉	5	0.1	24	90	85
		5	0	61		92
C ₆ H ₅	<i>n</i> -C ₈ H ₁₇	5	0.1	26	90	89
		5	0	30		7
4- <i>t</i> -C ₄ H ₉ -C ₆ H ₄	CH ₃	5	0.1	8	90	—
		5	0	40		92
4- <i>t</i> -C ₄ H ₉ -C ₆ H ₄	C ₂ H ₅	5	0.1	16	89	—
		5	0	66		60
4- <i>t</i> -C ₄ H ₉ -C ₆ H ₄	<i>n</i> -C ₄ H ₉	5	0.1	24	91	86
		5	0	71		22
4- <i>t</i> -C ₄ H ₉ -C ₆ H ₄	<i>n</i> -C ₈ H ₁₇	5	0.1	26	90	88
		5	0	67		21

^a Hexadecyltributylphosphonium bromide.^b Isolated products.**Table 2.** Effect of the Amount of Hydrobromic Acid and Catalyst^a

Substrate	47% Aqueous HBr [mol]	Cata- lyst ^b [mol]	Time [h]	G.L.C. Conver- sion [%]
<i>(n</i> -C ₈ H ₁₇) ₂ O	2.5	0.1	96	83
	3.5	0.1	53	89
	5	0.1	10	93
	10	0.1	5	92
	15	0.1	5	92
	10	0.05	12	91
	10	0.025	20	91
	10	0.01	91	91
	10	0	20	20
	C ₆ H ₅ -O-C ₈ H ₁₇ - <i>n</i>	1.5	0.1	96
3		0.1	53	90
5		0.1	26	92
15		0.1	25	90
5		0.05	54	88
5		0	30	7

^a At 115°.^b Hexadecyltributylphosphonium bromide.

times slower (Table 1). Attempts to use concentrated hydrochloric acid or hydrochloric acid and sodium bromide failed.

Di-*sec*-alkyl ethers react more slowly than primary ones, affording the *sec*-alkyl bromide together with a certain amount of alkenes (Table 1). In a series of 4-*t*-butylphenyl

Table 3. Cleavage of Phenyl *n*-Octyl Ether with 47 % Hydrobromic Acid in Acetic Acid^a at Reflux

47% Aqueous HBr [mol]	Time [h]	G.L.C. Conversion [%]
10	23	93
5	23	92
3	30	90
1.5	72	90

^a The ratio hydrobromic acid/acetic acid was 1/8 (v/v) in all cases.

alkyl ethers, all insoluble in the aqueous phase, a 92% conversion was obtained in 8, 16, 24, and 26 h for alkyl = methyl, ethyl, *n*-butyl, and *n*-octyl, respectively. These results, together with the dependance of the reaction rate on the amount of catalyst, indicate that the reaction occurs in the organic phase, probably according to a S_N2 mechanism.

For sake of comparison we cleaved phenyl *n*-octyl ether with 47 % hydrobromic acid in acetic acid at reflux. Under these conditions reaction times (Table 3) were similar to those found in the two-phase system, which however avoids the use and tedious elimination of solvents such as acetic acid or acetic anhydride.

Typical Procedure; Cleavage of Di-*n*-octyl Ether:

Di-*n*-octyl ether (12.1 g, 0.05 mol), 47 % aqueous hydrobromic acid (56 ml, 0.5 mol), and hexadecyltributylphosphonium bromide (2.5 g, 0.005 mol) are mixed in a flask equipped with a magnetic stirrer and reflux condenser, and heated at 115° (inner temperature)

b.p./torr	n_D^{20}	Lit. b.p./torr	Lit. n_D (temp.)
99°/760	1.4380	101.6°/760 ⁶	1.4373 (25°) ⁶
88°/18	1.4521	93°/20 ⁷	1.4520 (20°) ⁷
68°/10	1.4455	72°/14 ⁸	1.4442 (25°) ⁸
120–125°/760	1.4160	—	—
195°/18	1.4615	201°/19 ⁹	1.4620 (20°) ⁹

b.p./torr or m.p.	n_D^{20}	Lit. b.p./torr or m.p.	Lit. n_D (temp.)
39–40°	—	41° ¹⁰	—
97–98°	—	101° ¹¹	—

with stirring for 5 h. After this time G.L.C. analysis (SE 30, 3% over Chromosorb) showed a 92% conversion into 1-bromooctane. The organic layer is separated, dried with sodium sulfate, and distilled to give pure 1-bromooctane; yield: 17.5 g (91%); b.p. 88°/18 torr; n_D^{20} : 1.4521 (Lit. ⁷, b.p. 93°/20 torr; n_D^{20} : 1.4520). By treating the distillation residue with hexane, 2.3 g (92%) of pure phosphonium bromide are recovered, m.p. 54–56°. In the case of aryl alkyl ethers, aqueous alkaline extraction of the organic phase affords the corresponding phenol.

Cleavage of Phenyl *n*-Octyl Ether with 47% Hydrobromic Acid in Acetic Acid:

Phenyl *n*-octyl ether (10.3 g, 0.05 mol), 47% aqueous hydrobromic acid (27.8 ml, 0.25 mol), and acetic acid (220 ml) are heated under reflux for 23 h. After this time G.L.C. analysis (SE 30, 3% over Chromosorb) shows a 92% conversion into 1-bromooctane and phenol. The reaction mixture is diluted with water (750 ml), extracted with ether, and worked up to give phenol; yield: 4.0 g (85%); m.p. 39–40° (Lit. ¹⁰, 41°) and 1-bromooctane; yield: 8.1 g (84%); b.p. 88°/18 torr; n_D^{20} : 1.4518 (Lit. ⁷, b.p. 93°/20 torr; n_D^{20} : 1.4520).

Ethers:

Dibutyl, dioctyl and phenyl methyl ether were commercial products. Di-*sec*-octyl¹², hexadecyl methyl¹³, phenyl butyl¹⁴, phenyl octyl¹⁵, 4-*t*-butylphenyl methyl¹⁶, 4-*t*-butylphenyl ethyl¹⁷, 4-*t*-butylphenyl butyl ether¹⁷ were prepared according to literature methods; physical properties were in agreement with those reported.

4-*t*-Butylphenyl *n*-Octyl Ether:

4-*t*-Butylphenol (15.0 g, 0.1 mol), sodium hydroxide (4.4 g, 0.11 mol), water (40 ml), 1-chlorooctane (14.9 g, 0.1 mol), and hexadecyltributylphosphonium bromide (5.1 g, 0.01 mol) are stirred at 105° for 16 h according to the described procedure¹⁸; yield: 22.6 g (86%); b.p. 166–167°/8 torr; n_D^{27} : 1.4881.

C ₁₈ H ₃₀ O	calc.	C 82.38	H 11.52
(262.4)	found	82.45	11.48

¹H-N.M.R. (CDCl₃): δ = 0.89 (t, 3H, CH₃); 1.08–1.97 [m, 23H, *t*-C₄H₉ and (CH₂)₆]; 3.92 (t, 2H, CH₂O); 7.05 ppm (q, 4H_{arom}).

Received: February 27, 1978
(Revised form: May 18, 1978)

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