Synthetic Methods and Reactions; 95[1]. Ceric Ammonium Nitrate-Catalyzed Oxidative Cleavage of Alkyl and Silyl Ethers with Sodium Bromate

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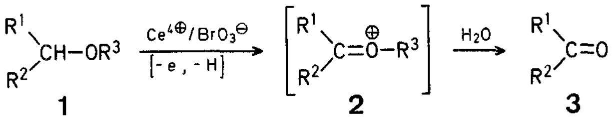
Ho[2] reported that benzylic alcohols can be oxidized conveniently to the corresponding carbonyl compounds using ceric ammonium nitrate and sodium bromate as a dual oxidant system. Our interest in the development of new and efficient methods for the cleavage of ethers, prompted us to investigate the reaction of alkyl and silyl ethers with this reagent. The oxidative cleavage of ethers is often a useful synthetic procedure and is usually carried out under rather forceful conditions such as with chromic acid/acetic acid[3], cerium(IV) sulfate in acetic acid[4], or silver oxide[5], which are of somewhat limited applicability. Trityl tetrafluoroborate[6], nitronium[7] and nitrosonium[8] salts can also be used to cleave ethers oxidatively via hydride transfer reactions. Recently in our laboratories, uranium hexafluoride, depleted of fissionable ^{235}U, has been effectively used to oxidatively cleave several alkyl and aralkyl ethers[9].

It was found, in the present study, that methyl, ethyl, trimethylsilyl, and *t*-butyldimethylsilyl ethers **1** readily undergo oxidative cleavage to afford the corresponding carbonyl compounds **3** when reacted with a molar equivalent of sodium bromate in the presence of a catalytic amount of ceric ammonium nitrate.



R^1 = alkyl, aryl;
R^2 = H, alkyl, aryl;
R^3 = CH_3, C_2H_5, $(H_3C)_3Si$, *t*-$C_4H_9Si(CH_3)_2$.

The reaction is quite general, being equally applicable to methyl, ethyl, trimethylsilyl, and *t*-butyldimethylsilyl alkyl (aralkyl) ethers. In the case of *t*-butyldimethylsilyl ethers, the product carbonyl compounds need to be separated from *t*-butyldimethylsilanol obtained as a by-product. This was successfully achieved by the formation of Girard T derivative of the carbonyl products[10]. Primary alkyl ethers reacted slower, when compared with secondary alkyl ethers under similar reaction conditions. The complete results are summarized in the Table.

In view of the high yields, simplicity, and mild reaction conditions, the presently described new oxidative cleavage of ethers should find use in organic synthesis.

Cerium(IV) Ion-Catalyzed Cleavage of Cyclohexyl Methyl Ether with Sodium Bromate; Typical Procedure:

A mixture of cyclohexyl methyl ether (1.14 g, 10 mmol), sodium bromate (1.51 g, 10 mmol), and ceric ammonium nitrate (55 mg, 0.1 mmol) in aqueous acetonitrile (7:3 v/v, 20 ml) is heated under a nitrogen atmosphere with good stirring to ~80 °C (oil bath) and maintained at this temperature for 12 h. The reaction mixture is then cooled to room temperature, diluted with water (50 ml), and taken up in ether (100 ml). The ether layer is washed with aqueous sodium hydrogen carbonate (50 ml), water (50 ml), and finally with brine (50 ml), and dried with sodium sulfate. Evaporation of ether from the dried extracts affords cyclohexanone, which is further purified by distillation; yield: 0.8 g (81%); b.p. 55 °C/20 torr; Lit.[11], b.p. 47 °C/15 torr.

Cerium(IV) Ion-Catalyzed Cleavage of Cyclohexyl *t*-Butyldimethylsilyl Ether with Sodium Bromate; Typical Procedure:

Using a mixture of cyclohexyl *t*-butyldimethylsilyl ether (2.14 g, 10 mmol), sodium bromate (1.51 g, 10 mmol), and ceric ammonium nitrate (55 mg, 0.1 mmol) in aqueous acetonitrile (7:3 v/v, 20 ml), the reaction is carried out as described above giving 1.9 g of the crude product contaminated with *t*-butyldimethylsilanol. The crude product is then dissolved in ethanol containing 10% acetic acid (20 ml) and heated for 1 h with Girard T[10] reagent (2.0 g, 12 mmol). The cooled solution is diluted with water (200 ml) and neutralized with aqueous 5% sodium hydroxide (~13 ml), keeping the solution, however, slightly acidic. It is then repeatedly extracted with ether (4 × 100 ml) to remove non-ketonic compounds. The aqueous layer containing the water-soluble hydrazone derivative is decomposed by the addition of concentrated hydrochloric acid (~3 ml) making it 0.5 normal in concentration. After the mixture has been allowed to stand for 1 h, the liberated cyclohexanone is extracted with ether (2 × 50 ml). Evaporation of the ether gives cyclohexanone whose I.R. spectrum is identical with that of an authentic sample; yield: 0.65 g (65%); m.p. of 2,4-dinitrophenylhydrazone, 159 °C; Lit.[11], 160 °C.

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Table. Oxidative Cleavage of Alkyl (Arylalkyl) Ethers **1** to Carbonyl Compounds **3** with $Ce^{4\oplus}/BrO_3^{\ominus}$ Reagent

R^1	R^2	R^3	Yield [%][a] of **3**	b.p. [°C]/torr	
				found	Lit.[11]
$-(CH_2)_5-$		CH_3	81	55°/20	47°/15
$-(CH_2)_5-$		C_2H_5	92	55°/20	
$-(CH_2)_5-$		$Si(CH_3)_3$	75	55–56°/20	
$-(CH_2)_5-$		$Si(CH_3)_2C_4H_9$-*t*	65[b]	—[b]	—[b]
n-C_3H_7	*n*-C_4H_9	CH_3	88	68–69°/26	70°/26
n-C_3H_7	*n*-C_4H_9	C_2H_5	95	65–68°/25	
n-C_8H_{17}	H	CH_3	60	77°/10	80–82°/13
n-C_7H_{15}	CH_3	$Si(CH_3)_3$	85	76–79°/12	75–77°/12
C_6H_5	H	CH_3	77	73–74°/25	62°/10
C_6H_5	H	$C_6H_5CH_2$	95	72–75°/25	
C_6H_5	*i*-C_3H_7	$Si(CH_3)_3$	84	103°/14	95–98°/10

[a] Yield of isolated product of >95% purity as determined by T.L.C. (silica plates using hexane), I.R. and ^{1}H-N.M.R. (absence of alkoxy or silyloxy protons) spectrometry.

[b] The product is isolated by Girard T derivative; m.p. of 2,4-dinitrophenylhydrazone, 159 °C; Lit.[11], 160 °C.

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