

Preparation of Di-*n*-alkyl Peroxides: Phase-Transfer Reaction of Potassium Superoxide with Primary Alkyl Bromides

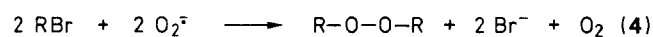
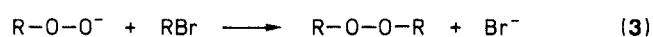
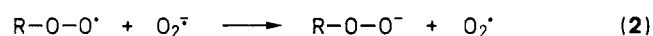
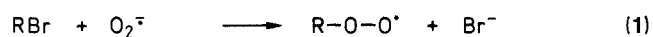
Thomas A. Foglia,* Leonard S. Silbert

U.S. Department of Agriculture, ARS, Eastern Regional Research Center, 600 East Mermaid Lane, Philadelphia, Pennsylvania 19118, USA

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Symmetrical saturated and unsaturated primary dialkyl peroxides **1** were prepared in a phase-transfer reaction by direct action of potassium superoxide, tetraethylammonium bromide and alkyl bromide in dimethylformamide solution. Applicability of the method to the preparation of unsymmetrical dialkyl peroxides was demonstrated by the example of butyl octyl peroxide (**2**). Yields generally exceeded 80 % for symmetrical dialkyl peroxides with total carbon numbers above 12 carbon atoms. Peroxide content of the isolated dialkyl peroxides generally exceeded 90 %.

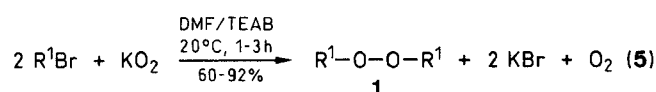
Methods of preparing dialkyl peroxides beyond six or seven carbon atoms per alkyl chain have been unsuccessful or of little utility.^{1,2} Within the past decade, a direct route by reaction of potassium superoxide with alkyl halide, tosylate or mesylate in anhydrous solvents (benzene, tetrahydrofuran, dimethyl sulfoxide, dimethylformamide)^{3,4} (eq. 1–4) in the presence of crown ethers has provided a potentially useful entry to symmetrical dialkyl peroxides. One team of workers³ has examined the reaction for a representative series of alkylating agents up to eight carbon atoms per chain. Another team⁴ independently reported the same reaction that included chain lengths extending to 18 carbon atoms per chain with formation of dialkyl peroxides in 40–65 % yields.



Potassium superoxide has a limited solubility in polar solvents and decomposes to molecular oxygen in hydroxylic solvents. Hence, increased solubility of superoxide is a key factor for a successful reaction with alkyl halide. In prior studies,^{3,4} improved solubility and enhanced reaction rates were attained by crown ether complexation of the inorganic potassium cation of potassium superoxide. The former workers^{3,4} reported their reaction for small (10–20 millimolar) quantities of reactants resulting in less than half gram quantities of product. Moreover, since crown ethers are relatively expensive reagents, their use for multigram or larger scale preparations may limit their application for peroxides.

In lieu of the potassium superoxide/crown ether combination, tetramethylammonium superoxide [(Me)₄N]O₂ could be used because of the metal-like properties of the tetramethylammonium cation⁵ and the higher solubility of this superoxide in polar solvents. However, preparation of this reagent from tetramethylammonium fluoride has the disadvantage of requiring liquid ammonia as solvent, although high purity and yields can be obtained.⁵

We recognized the use of tetramethylammonium superoxide as a promising alternative to potassium superoxide in dialkyl peroxide preparations. In the course of our studies of phase-transfer reactions, we realized a simple in situ preparation of the homologous tetraethylammonium superoxide from the reaction between potassium superoxide and tetraethylammonium bromide (TEAB) in anhydrous dimethylformamide (DMF). With subsequent admission of alkyl bromide, we have successfully prepared a homologous series of primary dialkyl peroxides in high yields and high dialkyl peroxygen content as presented in this paper Table 1, entries **1e** to **1i**. In addition, we have further demonstrated the feasibility of preparing secondary dialkyl peroxides as well as primary dialkyl peroxides by this route, Table 1, entry **1d**, but as expected for a secondary alkyl bromide the peroxide yield was low.



1 R¹		1 R¹	
a	Bu	f	<i>n</i> -C ₁₀ H ₂₁
b	CH ₂ =CH(CH ₂) ₃	g	<i>n</i> -C ₁₂ H ₂₅
c	<i>n</i> -C ₆ H ₁₃	h	<i>n</i> -C ₁₄ H ₂₇
d	CH ₃ (CH ₂) ₃ (CH ₃)CH	i	<i>n</i> -C ₁₆ H ₃₁
e	<i>n</i> -C ₈ H ₁₇		

In situ preparation of tetraethylammonium superoxide is obtained in 10 minutes as determined by aliquot titration for superoxide anion content by oxygen evolution and hydrogen peroxide titration. Remaining insoluble potassium peroxide salt is consumed as reaction with alkyl bromide progresses. The reaction was not examined for optimum ratio of reactants. However, preliminary examination showed excess potassium superoxide and tetraethylammonium bromide relative to alkyl bromide, i.e., 3.3:1.6:1, respectively, provided good conversion in 2–3 hours. Because of high conversions, alcohol and carbonyl byproducts previously reported by others are minor. However, about 5 % coproducts, as observed in both GLC and HPLC determinations, may be attributed to polar compounds derived from DMF by radical attack.

Reaction of 1-bromo-4-pentene with potassium peroxide in the phase-transfer process gives the expected dipent-4-enyl peroxide in 98 % purity by GLC in the isolated crude product, Table 1, entry **1b**. Characterization of the unsaturated peroxide (CH₂(a)=CH(b)CH₂(c)CH₂(d)CH₂(e)O)₂ was by ¹H NMR (CDCl₃, TMS): δ = (a) 5.1, q; (b) 5.8, m; (c) 2.15, q; (d) 1.7, m; (e) 4.0, t.

Table. Phase-Transfer Reaction of Potassium Superoxide/Tetraethylammonium Bromide with Alkyl Bromides^a

Compound	Carbon ^b No.	Yield ^c (%)	Peroxide ^d (%)	ROH ^e (%)	bp (°C)/Torr or mp (°C)	Molecular Formula ^f or Lit. Data	MS (70 eV) ^g <i>m/z</i> (%)
1a	8	45	97	—	55/12	61/20 ⁷	
1b	10	55	98	—	58–60/0.9	C ₁₀ H ₁₈ O ₂	170 (M ⁺ , 1), 101, 86, 69, 68 (100)
1c	12	55	93	5	60/0.4	59/0.2 ⁷	
1d	12	25	94	9	44–46/0.5	39–44/0.5 ⁷	
1e	16	73	90	4	82/0.5	76/0.2 ⁴	
1f	20	77	92	2	—	C ₂₀ H ₄₂ O ₂ ^h	314 (M ⁺ , 7), 173, 157, 141, 140 (100)
1g	24	88	97	1	24.5–26	C ₂₄ H ₅₀ O ₂	370 (M ⁺ , 6), 201, 185, 169, 140 (100)
1h	28	80	95	2	36–37	36.5 ⁴	
1i	32	92	95	3	46–47	47–48 ⁴	
2	12	45	94	—	58–60/0.4	C ₁₂ H ₂₆ O ₂	202 (M ⁺ , 4), 113, 112, 111, 73, 71 (100)

^a Molar ratio of reactants for all experiments was 1:3.3:1.6; RBr/potassium superoxide/TEAB. Reactions conducted in DMF at 5 ml/mmol of RBr at 5–10°C.

^b Total carbon No. of dialkyl peroxide.

^c Based on RBr as weight %.

^d Chromatographic values: Entries 1 to 4 and 10: GC, Entries 5 to 9: HPLC. See Ref. 6 and text.

^e In addition, aldehyde and R₂O were formed (± 3%).

^f Satisfactory microanalyses obtained for compounds **1b**, **1f**, **1g** and **2**: C ± 0.30%, H ± 0.15%.

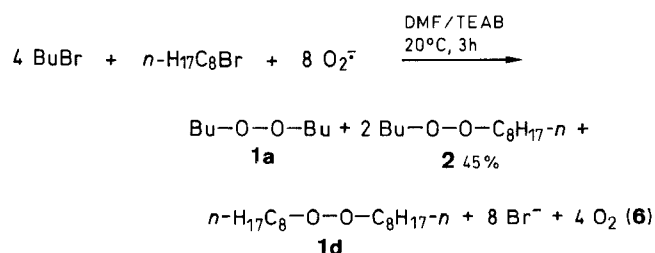
^g Recorded on a Hewlett-Packard 5995 Spectrometer.

^h Didecyl peroxide purified by chromatography on silica gel with hexane; CH₂Cl₂; 95:5 (v/v).⁴

The unsaturated peroxide compares well with that obtained by the crown ether method⁴ whereby it is shown that no cyclic product, **I**, arises by any intramolecular free radical cyclization.



The reaction is not limited to symmetrical dialkyl peroxides since unsymmetrical peroxides can be obtained but involves a separation problem. We considered the feasibility of deriving an unsymmetrical member by reaction of equimolar amounts of two alkyl bromides of size sufficiently different to effect simple separation of the three expected peroxides (eq. 6). They are expected to appear in the ratio of 1:2:1 since reactions R¹OO·/R²Br and R²OO·/R¹Br are equivalent and result in the same unsymmetrical R¹OOR². In the chosen example of the coreactants butyl bromide/octyl bromide, dibutyl peroxide is readily removed in vacuo and the remaining two peroxides are separated by distillation, Table 1, entry 2.



GLC analyses of dialkyl peroxides up to carbon number 16 were performed on a Hewlett Packard Model 5830 A gas chromatograph

with capillary inlet 18835B, a fused silica capillary column (12 m × 0.2 mm × 0.33 μm film thickness of methyl silicon OV 101) using He as carrier gas in temperature programming from 50°C to 180°C at 10°C/min and FI detector. HPLC analyses of dialkyl peroxides exceeding carbon number 12 were performed on Hewlett Packard 1090LC with Altex Ultrasphere ODS (5 μ particle size), column 4.6 mm I.D. × 25 cm, Tracor 945 FID-LC detector and a HP 3393 A integrator. Separations were made on the basis of total carbon number using a mobile phase of acetone/MeCN (70:30, v/v) isocratically at a flow rate of 1 mL/min.⁶

Didodecyl Peroxide: Typical Procedure:

Potassium superoxide (2.35 g; 0.0330 mol) was weighed into an Erlenmeyer flask under N₂ in a dry box. The flask was removed for addition of DMF (60 mL) and TEAB (3.36 g; 0.016 mol), loosely capped with a polyethylene stopper and stirred 10 min to facilitate major dissolution of the solids. Complete solution was not necessary as the solids dissolve in the course of reaction. Dodecyl bromide (2.49 g = 2.40 mL; 0.010 mol) was admitted to the mixture which was stirred 2 to 3 h at 20°C. Cold sat. NaCl (50 mL) and hexane (100 mL) were cautiously added to control the exotherm and oxygen evolution arising from hydrolysis of excess KO₂. On transference of the mixture to a separatory funnel, the hexane layer contained suspended salts above the aqueous salt layer. The aqueous layer was transferred to a second separatory funnel. The hexane solution in the first separatory funnel, after H₂O washing (50 mL), separated into three layers: the upper hexane, the lower aqueous and a middle milky aqueous layer. The aqueous layers from the two separatory funnels were combined, re-extracted with hexane (50 mL) and the hexane and middle layers combined. The latter layers were washed with H₂O (3 × 50 mL) (note: In the work-up of tetradecyl and hexadecyl peroxides, Et₂O (50 mL) was added to the hexane-middle layer combination and H₂O washed (6 × 50 mL). The hexane solution and any insoluble layer remaining were dried (Na₂SO₄), filtered, the salts washed with hexane and the organic solution evaporated on a rotary evaporator; yield: 1.61 g (87%). The crude product was crystallized from acetone (5 mL/g) at 0°C to give didodecyl peroxide (**1g**); 1.45 g (70%).

Butyl Octyl Peroxide (2):

Potassium superoxide (4.7 g; 0.066 mol) was placed into a round bottom flask (500 mL) along with DMF (75 mL) and TEAB (6.72 g; 0.032 mol). The mixture was stirred magnetically at 20 °C for 10 min at which time an equimolar mixture of butyl bromide (1.38 g; 0.010 mol) and octyl bromide (1.94 g; 0.010 mol) in DMF (25 mL) was added over a 30 min period at 20 °C. The mixture was stirred for an additional 1.5 h at which time cold sat. NaCl (50 mL) and hexane (100 mL) were added. The mixture was worked-up as described above for dodecyl peroxide with the exception that the bulk of the hexane solvent was removed by distillation. The crude dialkyl peroxide residue was fractionated by vacuum distillation to give dibutyl peroxide (**1a**), 0.2 g (53 %), butyl octyl peroxide (**2**), 0.66 g (45 %) and dioctyl peroxide (**1e**) 0.45 g (71 %).

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