***cis*- and *trans-tert*-Butyl 2,3-Oxo-1,4-dihydrobenzoate (5).** To a stirring solution of 2.00 g (11.1 mmol) of **4** in 20 mL of $CH_2Cl_2$ at 0 °C was added a solution of 2.26 g (11.1 mmol) of 85% *m*-chloroperbenzoic acid in 30 mL of $CH_2Cl_2$. After the addition was complete (0.5 h), the solution was stirred at 0 °C for an additional 0.5 h after which it was warmed to room temperature and stirred for 17 h. The solution was washed with three 25-mL portions of saturated aqueous $Na_2CO_3$ and 25 mL of saturated aqueous NaCl and dried ($K_2CO_3$). Filtration and evaporation under vacuum gave 2.08 g of a pale yellow oil. Distillation gave, after a small forerun, 1.40 g (67%) of *cis*- and *trans*-**5** as a colorless oil, bp 55–57 °C (0.2 Torr). GLC analysis (6 ft × 0.25 in, 15% SE-30, 130 °C) of the distillate showed the presence of the two isomers in a ratio of 1:1 with retention times of 11.8 (A) and 14.2 min (B). Preparative GLC provided pure samples of both isomers.

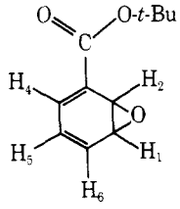
Isomer A: IR ($CCl_4$) 3055, 1730, 1370, 1288, 1258, 1150 $cm^{-1}$; NMR ($CCl_4$) δ 1.40 (s, 9 H), 2.4–2.6 (m, 2 H), 3.0–3.6 (m, 3 H), 5.4–5.6 ppm (m, 2 H).

Anal. Calcd for $C_{11}H_{16}O_3$: C, 67.32; H, 8.22. Found: C, 67.06; H, 8.25.

Isomer B: IR ($CCl_4$) 3042, 1737, 1365, 1280, 1255, 1152 $cm^{-1}$; NMR ($CCl_4$) δ 1.50 (s, 9 H), 2.3–2.5 (m, 2 H), 3.0–3.6 (m, 3 H), 5.4–5.6 ppm (m, 2 H).

Anal. Calcd for $C_{11}H_{16}O_3$: C, 67.32; H, 8.22. Found: C, 67.13; H, 8.30.

**3-Carbo-*tert*-butoxybenzene Oxide (2).** To a solution of 11.32 g (57.7 mmol) of *cis*- and *trans*-**5** in 100 mL of $CCl_4$ was added 12.30 g (69.2 mmol) of finely ground *N*-bromosuccinimide. The suspension was stirred under reflux and irradiated with an ultraviolet lamp until the bromination was complete. The mixture was cooled to room temperature, filtered, and evaporated under vacuum to give 15.6 g (98%) of allylic bromide as a viscous yellow oil. The crude bromide was dissolved in 100 mL of diethyl ether and 7.30 g (72.1 mmol) of triethylamine was added in one portion. A crystalline salt precipitated immediately. The mixture was filtered to remove the salt; the filtrate was diluted with 100 mL of diethyl ether and washed with three 150-mL portions of water followed by repeated washings with 200-mL portions of 5% aqueous NaOH until the aqueous wash was colorless. The ether solution was dried ($K_2CO_3$), filtered, and evaporated under reduced pressure to give 11.1 g of a dark, viscous oil. Distillation through a short-path still afforded 3.87 g (35%) of **2** as a bright yellow oil: bp 60–65 °C (]/]5 Torr); IR ($CCl_4$) 1708, 1670, 1628, 1365, 1280, 1160 $cm^{-1}$; UV max ($CH_3OH$) 286 nm (ε 3100); UV max (isooctane) 283 nm (ε 4100); mass spectrum *m/e* 194 (8), 177 (8), 162 (15), 138 (24), 123 (17), 121 (17), 105 (23), 104 (32), 57 (33), 56 (26), 55 (23), 44 (45), 43 (44), 41 (100); NMR (220 MHz, $CCl_4$).[10]




| | δ, ppm | *J*, Hz |
|---|---|---|
| $H_1$ | 4.29 | $J_{1,2}$ = 2.75; $J_{1,5}$ = 1.65; $J_{1,6}$ = 4 |
| $H_2$ | 4.91 | $J_{2,4}$ = 2 |
| $H_4$ | 6.90 | $J_{4,5}$ = 7.05; $J_{4,6}$ = 1.3 |
| $H_5$ | 6.26 | $J_{5,6}$ = 8.45 |
| $H_6$ | 6.34 | |
| $(CH_3)_3C$ | 1.59 | |

Benzene oxide **2** formed a 1:1 adduct in 65% yield with maleic anhydride in benzene. It was recrystallized from benzene as white flakes: mp 176–177 °C; IR ($CHCl_3$) 1860, 1790, 1730 $cm^{-1}$; NMR ($CDCl_3$) δ 1.60 (s, 9 H), 3.3–3.9 (m, 5 H), 5.8–6.6 ppm (m, 2 H).

Anal. Calcd for $C_{15}H_{16}O_6$: C, 61.64; H, 5.52. Found: C, 61.90; H, 5.38.

**Acid-Catalyzed Aromatization of 2.** A solution of 100 mg of **2** in a mixture of 2 mL of $CF_3CO_2H$ and 2 mL of water was stirred at room temperature. The solution was evaporated to dryness under reduced pressure, and the white, crystalline residue was dissolved in 1 mL of acetone. To the acetone solution was added 100 μL of *N*-trimethylsilyltrifluoroacetamide, and the resulting solution was analyzed by GLC (6 ft × 2 mm, 10% SE-30). The ratio of silylated *m*- and *o*-hydroxybenzoic acids was found to be 1:1.7 by comparison with authentic samples.

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**Registry No.**—**2**, 61812-51-9; **2** maleic anhydride adduct, 61812-48-4; **4**, 61812-52-0; **5**, 61812-53-1; maleic anhydride, 108-31-6.

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(10) We thank Dr. H. J. C. Yeh, National Institute of Arthritis, Metabolism and Digestive Diseases, Bethesda, Md., for the spectrum.

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# A Convenient Method for the α-Carbethoxylation of Alkylnitriles

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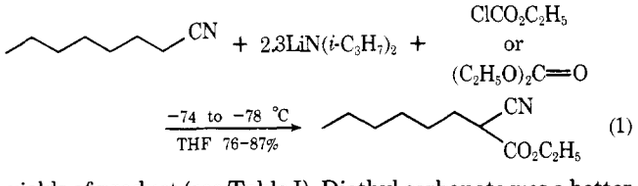
While carbethoxyl groups have been introduced in a number of instances into the α positions of acetonitriles substituted by phenyl groups,[2-4] only few examples are recorded when the acetonitriles are substituted by alkyl groups. With sodium ethoxide in diethyl carbonate[4] the yields are moderate and several hours heating at the boiling point and distillation of the ethanol produced are required to drive the reactions to products. Significant amounts of starting material are still recovered. For example, with this procedure capronitrile gives ethyl α-cyanocaproate in 54% yield along with starting material in 31% yield. An alternate procedure used by Hauser and Levine[5] to carbethoxylate acetonitrile with diethyl carbonate and sodium amide in refluxing ether gave ethyl cyanoacetate in only 40% yield and failed when extended to octanonitrile, octanamide forming instead in 30% yield after hydrolysis of the amidine intermediate.

Because alkylacetonitriles were recently monoalkylated[6] and benzeneselenylated[7] by way of the alkylacetonitrile anions formed using hindered dialkylamide bases, I attempted to carbethoxylate them analogously with diethyl carbonate or ethyl chloroformate. Using octanonitrile to optimize the conditions, it was found that 2.3 molar equiv of lithium diisopropylamide in tetrahydrofuran (THF) at −74 to −78 °C followed by 1.02–1.05 molar equiv of carbethoxylating agent gave high yields of ethyl hexylcyanoacetate (76–87%) after distillation (eq 1). Sodium hexamethyldisilamide gave lower



(1)

yields of product (see Table I). Diethyl carbonate was a better reagent to use than ethyl chloroformate, as the latter produced small amounts of ethyl *N,N*-diisopropylcarbamate as a side

**Table I. Carbethoxylation of Octanonitrile**

| Base | Molar equiv base | Carbethoxylating agent | Rxn temp, °C | % yield | % GC purity |
|---|---|---|---|---|---|
| $NaN[Si(CH_3)_3]_2$ | 2.5 | $(C_2H_5O)_2C{=}O$ | RT | 11 | 99 |
| $NaN[Si(CH_3)_3]_2$ | 2.3 | $ClCO_2C_2H_5$ | RT | 21 | 99 |
| $NaN[Si(CH_3)_3]_2$ | 2.1 | $ClCO_2C_2H_5$ | −74 | 49 | 87 |
| $LiN(i\text{-}Pr)_2$ | 2.3 | $ClCO_2C_2H_5$ | −74 | 85–87 | 98 |
| $LiN(i\text{-}Pr)_2$ | 2.3 | $(C_2H_5O)_2C{=}O$ | −74 | 76 | 99 |

**Table II. Carbethoxylation of Alkylacetonitriles**

| Registry no. | Nitrile | Molar equiv LDA | Molar equiv diethyl carbonate | Rxn temp, °C | % yield | % VPC purity | Bp, °C (mm) |
|---|---|---|---|---|---|---|---|
| 625-28-5 | Isovaleronitrile | 2.4 | 1.02 | −78 | 56 | 95 | 122–123 (41)[b] |
| 628-73-9 | Capronitrile | 2.3 | 1.05 | −78 | 76 | 97 | 119–120 (20)[c] |
| 5732-87-6 | Cyclopentylacetonitrile | 2.0 | 1.05 | −78 | 79 | 95 | 137–138 (19)[d] |
| 4435-14-7 | Cyclohexylacetonitrile | 2.3 | 1.05 | −78 | 86 | 97 | 147–148 (13)[e] |
| 638-65-3 | Stearonitrile | 2.3 | 1.05 | −15[a] | 81 | | 167–174 (0.15)[f] |

[a] Stearonitrile is insoluble in THF at −78 °C. [b] Lit.[4] 111–113 °C (22 mm). [c] Lit.[4] 128–129 °C (23 mm). [d] Lit. 135–138 °C (17 mm),[9a] 129 °C (12 mm).[9b] [e] Lit. 146–148 °C (12 mm).[10] [f] Mp 36–37.5 °C, lit.[4] bp 167–180 °C (2 mm), lit.[4] mp 14–18 °C.

product, which could only be removed by careful fractional distillation.

The method was extended to other alkylacetonitriles and the yields of pure, distilled carbethoxylated product were excellent (Table II).

The α-carbethoxylation method was not devised to replace more classical approaches to these compounds such as cyanoacetate displacement of alkyl halides or Knoevenagel condensation–reduction sequences, but rather to provide a new alternative when such methods fail or cannot be applied in a synthesis of a more complex molecule.

## Experimental Section

**Ethyl Hexylcyanoacetate.** To a flame-dried, $N_2$-flushed, three-necked 200-mL round-bottomed flask equipped with magnetic stirrer, $N_2$ inlet, stopper, and serum cap were added 4.75 g (47 mmol) of diisopropylamine and 40 mL of dry THF (freshly distilled from $LiAlH_4$). The solution was cooled to −74 °C (dry ice–2-propanol bath) and 29 mL of 1.6 N *n*-butyllithium in hexane (46 mmol, Foote Mineral Co., Exton, Pa.) was syringed in. The solution was stirred for 10 min at −74 °C and warmed to room temperature during 20 min. After cooling to −74 °C a solution of 2.50 g (20 mmol) of octanonitrile in 15 mL of THF was syringed in during 10 min, and the mixture was allowed to stir for 0.5 h at −74 °C and 0.5 h while it warmed to room temperature. The anion solution was then cooled to −74 °C and a 10-mL solution of 2.48 g (21 mmol) of diethyl carbonate in THF was syringed in during 10 min and allowed to stir for 2.5 h at −74 °C. The reaction was quenched with 10 mL of saturated $NH_4Cl$. Ether (75 mL) and water (20 mL) were added, and the layers separated. The organic layer was washed successively with 3 × 30 mL of 10% HCl, 3 × 30 mL of $H_2O$, and 30 mL of brine, and was dried over $MgSO_4$. Filtration and removal of solvent gave 3.86 g of a fragrant yellow oil, which upon fractional distillation (69–71 °C, 0.04 mm) gave 2.97 g of ethyl hexylcyanoacetate, analyzed to be 99% pure by GLC (10 ft × 0.125 in. column of 20% Apiezon L on 60/80 Chromosorb W, injector temperature 240 °C, column temperature 170 °C, detector temperature 280 °C). Lit. 149–150 °C (19 mm),[8a] 136–138 °C (14 mm).[8b] NMR ($CCl_4$) τ 5.69 (q, $J$ = 7 Hz, 1.93 H), 6.54 (t, $J$ = 7 Hz, 0.91 H), 8.05 (m, 2.50 H), 8.65 (m, 10.81 H), 9.10 (br t, 2.84 H). There are peaks in the IR spectrum (neat sample) at 2250 and 1750 $cm^{-1}$.

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**Registry No.**—Ethyl isopropylcyanoacetate, 3213-49-8; ethyl butylcyanoacetate, 7391-39-1; ethyl cyclopentylcyanoacetate, 61788-30-5; ethyl cyclohexylcyanoacetate, 3213-50-1; ethyl hexadecylcyanoacetate, 61788-31-6; octanonitrile, 124-12-9; diethyl carbonate, 105-58-8; ethyl hexylcyanoacetate, 26526-76-1; ethyl chloroformate, 541-41-3.

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# Application of Complex Formation to the Conformational Analysis of Thioxanthene Sulfoxides, Thianthrene Disulfoxides, and Phenoxathiin Sulfoxide Using Infrared Spectroscopy[1]

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The S–O stretching frequency of sulfoxides normally occurs at about 1050 $cm^{-1}$.[2] This rather intense vibration is not particularly influenced by the nature of the alkyl or aryl groups bonded to sulfur.[2] Consequently, this vibration has