mL of dry tetrahydrofuran. The resulting dense white precipitate was stirred at 20 °C for 6 h, after which the ether was removed by slow distillation and replaced with 30 mL of THF. Stirring at gentle reflux was continued for 36 h with little change in appearance. The mixture was then cooled, diluted with 100 mL of water, and extracted with three 25-mL portions of pentane. The combined extracts were washed with water, dried over $MgSO_4$, and concentrated on the steam bath under atmospheric pressure. Passage of the residue through 40 g of basic alumina (Woelm, activity grade I) with pentane, followed by short-path distillation, afforded 0.85 g (42%) of diene **7** as a colorless oil with a pinene-like odor: bp 174–176 °C (740 mm); homogeneous by GLC (90 °C on a 6 mm × 2 m 15% Carbowax–Chromosorb W column); IR (neat) 1645, 1375, 895 cm^{-1}; UV λ 220 nm (ϵ 3600, sh); ^1H NMR δ 4.87, 4.57 (m, 2 $=CH_2$, collapsed to 2 d, $J = 2$ Hz, by irradiation at δ 1.76), 2.0 (m, 4 H, 2 $CH_2C=$), 1.76 (m, 3 H, $CH_3C=CH_2$), 1.7–1.4 (m, 4 H, CH_2CH_2), 1.62 (m, 3 H, $CH_3C=$); ^{13}C NMR δ 147.66 (s), 134.25 (s), 126.30 (s), 112.04 (t) ($=CH_2$), 31.38 (t), 29.44 (t), 23.31 (t) (2 CH_2), 22.22 (q), 20.34 (q); mass spectrum (inlet temperature 154 °C), *m/e* (relative intensity) 136 (M^+, 68), 121 (76), 108 (8), 107 (32), 93 (100), 79 (60), 67 (20), 41 (24), 28 (28). Anal. Calcd for $C_{10}H_{16}$: C, 88.16; H, 11.84. Found: C, 87.79; H, 11.79.

Addition of 136 mg (1.0 mmol) of **7** in 1 mL of THF to 128 mg (1.0 mmol) of freshly sublimed tetracyanoethylene in 1 mL of THF at 22 °C gave an immediate purple color which faded after 5 min to light yellow. After 8 h the solvent was evaporated and the light tan residue passed through 10 g of silica gel with 50 mL of pentane–ether (5:1). Crystallization of the product at 0 °C from pentane–ether (1:1) gave 120 mg (45%) of coarse, colorless plates, mp 115–117 °C. Anal. Calcd for $C_{16}H_{16}N_4$: C, 72.70; H, 6.10; N, 21.20. Found: C, 73.01; H, 6.00; N, 21.50.

Under the same conditions, neither **2** nor **3** gave any color change with tetracyanoethylene, and on standing at 20–25 °C only slow reaction, leading to a mixture of products, could be detected by TLC.

Acknowledgment. I am indebted to Professor R. S. Givens for use of his photochemical apparatus and thank him, together with Professors R. G. Carlson, G. W. Everett, and J. Wolinsky, for generous advice and assistance. This work was supported in part by the National Science Foundation (CHE-7823856).

Registry No. **1**, 481-06-1; **2**, 23811-40-7; **3**, 76480-14-3; **7**, 76480-15-4; 1-acetyl-2-methylcyclohexene, 2047-97-4; tetracyanoethylene, 670-54-2; 4,8a-dimethyl-1,1,2,2-tetracyano-1,2,3,5,6,7,8,8a-octahydronaphthalene, 76480-16-5.

Diastereoselection in the Decarbalkoxylation Reaction. Effect of Nonbonded Ring Oxygens in the Reactions of Geminal Diesters

Harold D. Banks

Department of Chemistry, University of Bridgeport,
Bridgeport, Connecticut 06602

Received October 27, 1980

In connection with our interest in diastereoselective reactions of geminal carboxylic acids[1] and their derivatives, we have investigated the extremely useful decarbalkoxylation method of Krapcho and co-workers.[2] Of particular interest was the possibility that nonbonding electron pairs might produce a dramatic change in the stereoselectivity of the reaction. To test this possibility, the anancomeric compounds, 5,5-bis(carboethoxy)-2-isopropyl-1,3-dioxane, **1**, and diethyl 4-*tert*-butylcyclohexane-1,1-dicarboxylate, **4**, were synthesized and decarboethoxylated.

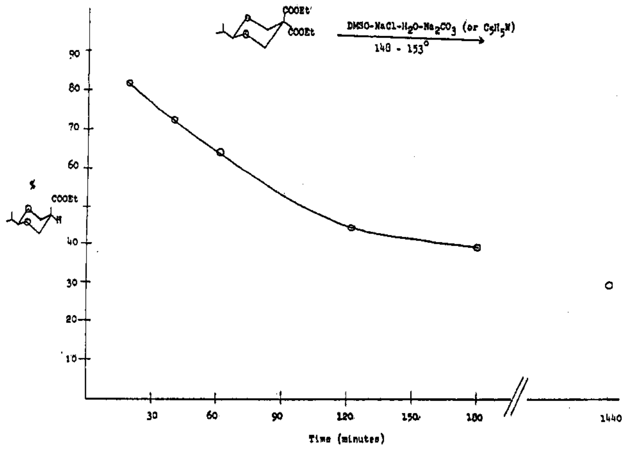


Figure 1.

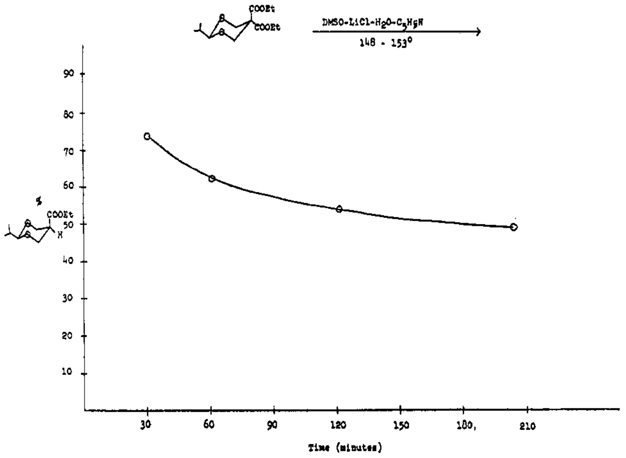


Figure 2.

Table I. Decarbalkoxylation of Geminal Diesters

diester	solvent	product composition, %
1	Me_2SO	86.6 ± 0.5 **2**
	DMF	86.9 ± 0.5 **2**
1 ($R_2 = R_3 = COOCH_3$)	Me_2SO	86.7 ± 0.5 **2**
4	Me_2SO	53.2 ± 0.2 **5**
	DMF	52.9 ± 0.2 **5**

1, X = O; $R_1 = CH(CH_3)_2$; $R_2 = R_3 = COOC_2H_5$

4, X = CH_2; $R_1 = C(CH_3)_3$; $R_2 = R_3 = COOC_2H_5$

2, X = O; $R_1 = CH(CH_3)_2$; $R_2 = COOC_2H_5$; $R_3 = H$

3, X = O; $R_1 = CH(CH_3)_2$; $R_2 = H$; $R_3 = COOC_2H_5$

5, X = CH_2; $R_1 = C(CH_3)_3$; $R_2 = COOC_2H_5$; $R_3 = H$

6, X = CH_2; $R_1 = C(CH_3)_3$; $R_2 = H$; $R_3 = COOC_2H_5$

Heating **1** with NaCl in wet Me_2SO at 148–153 °C resulted in the evolution of CO_2. The relative concentrations of **2** and **3** were not invariant as a function of time; the initial high preference for the axial isomer disappeared at long reaction times, with the thermodynamically more

---

[1] (a) Banks, H. D. *J. Org. Chem.* **1973**, *38*, 4084. (b) Banks, H. D.; Jacobs, W. **1975**, *40*, 790.

[2] (a) Krapcho, A. P.; Lovey, A. J. *Tetrahedron Lett.* **1973**, 957. (b) Krapcho, A. P.; Jahngen, E. G. E., Jr.; Lovey, A. J.; Short, F. W. *Ibid.* **1974**, 1091. (c) Krapcho, A. P.; Weimaster, J. F.; Eldridge, J. M.; Jahngen, E. G. E., Jr.; Lovey, A. J.; Stevens, W. P. *J. Org. Chem.* **1978**, *43*, 138. (d) Krapcho, A. P.; Weimaster, J. F. *Ibid.* **1980**, *45*, 4105. I thank Professor Krapcho for providing me with the results of his research on the stereochemistry of this reaction prior to publication.

0022-3263/81/1946-1743$01.25/0

stable trans isomer, **3**,[3] becoming the major product.[4] To eliminate the possibility that adventitious acid was responsible for equilibration of the products, Na_2CO_3[2c] and pyridine were added in separate experiments. Equilibration occurred even in the presence of these acid scavengers (Figure 1).

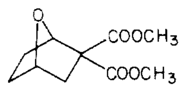
Homogeneous reaction conditions were obtained when LiCl was substituted for NaCl. In the presence of pyridine at 148–153 °C, the relative concentration of **3** increased as a function of time (Figure 2). When the reaction temperature was lowered to 135 °C, the product composition was independent of reaction yield. These homogeneous conditions were used in all subsequent experiments. The results are given in Table I.

While decarbalkoxylation of **1** was highly stereoselective, the reaction of **4** was nonstereoselective. Use of the corresponding dimethyl ester of **1** ($R_2 = R_3 = COOCH_3$) produced no significant change. The solvents Me_2SO and DMF gave identical results within experimental error.

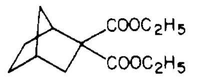
Several mechanisms have been proposed for the decarbalkoxylation reaction. Krapcho and Lovey[2a] postulated that the reaction occurs by means of attack of the chloride ion at the acyl position of one of the carbalkoxy functions, followed by the loss of ethyl chloroformate, formation of a carbanion, and capture of a proton by this carbanion. Alternatively, attack by chloride ion could occur at one of the ethyl functions, leading to formation of the carboxylate salt of the half-ester, with subsequent decarboxylation of this species (the B_{Al} 2 mechanism). Liotta and Cook[5] and Krapcho and co-workers,[2b] having demonstrated that certain diesters did not require chloride ion, suggested that the mechanism in these cases was simply a hydrolysis of one of the carbalkoxy functions followed by decarboxylation of the resulting half-ester.

The carbanion mechanism appears to be the most likely for the compounds investigated in this study. The hydrolysis mechanism cannot operate for **1**, which fails to undergo the reaction in the absence of chloride ion. While our results do not allow us to eliminate the B_{Al} 2 mechanism, the carbanion generated by treatment of **2** and **3** with lithium diisopropylamide gave 81.3% **2** and 18.7% **3** when quenched with D_2O under conditions that resulted in over 95% deuterium incorporation by ^1H NMR analysis; these results are quite close to those for the decarbalkoxylation reaction and suggest a common intermediate.

To determine if ring oxygens would produce similar effects in other systems, the oxygen heterobicycle **7** was synthesized (see the Experimental Section). Unlike the 1,3-dioxane system in which the axial nonbonding electron pairs approach a parallel orientation with respect to the carbanionic MO, the syn axial nonbonding electron pair of the bridge oxygen of **7** is found in an orbital which is virtually perpendicular to its carbanionic MO. Decarbomethoxylation of **7** gave 22.7% *exo*- and 77.3% *endo*-2-(carbomethoxy)-7-oxabicyclo[2.2.1]heptane. Comparison of this result with that of Krapcho[6] for 2,2-bis(carboethoxy)bicyclo[2.2.1]heptane, **8**, which produced a 3.0/7.0 ratio of the exo/endo monoesters, indicates that the effect of the nonbonding electron pair on the course of this reaction is a subtle one.



7



8

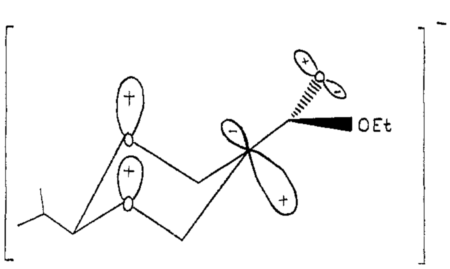


Figure 3.

One explanation of the diastereoselection in the 1,3-dioxane system is that electrostatic repulsion of the π cloud of the oxallylic system by the nonbonding electron pairs on the ring oxygens is responsible for the results. This would lead to an accumulation of electron density below the ring, and attack by acid would be predominantly from the lower face, generating the cis isomer. This approach, however, fails to explain the similarity of results for **7** and **8**; in this case the electrostatic repulsion argument would lead to the erroneous prediction of an excess of the exo isomer in the reaction of **7** relative to **8**, due to more proton attack from the lower or endo direction.

A satisfactory explanation of the results is an extension of the treatment of Klein,[7] who postulated that the stereochemistry of the protonation and hydroboration reactions of methylenecyclohexane is due to hyperconjugative interaction of the β C–C bonds with the exocyclic π electrons of the methylene group, giving rise to a frontier orbital (HOMO) in which there are considerable antibonding interactions on the upper face of the molecule, producing an accumulation of electron density on the lower face. Attack of an electrophilic species occurs predominantly from the equatorial direction. Extending Klein's treatment to the carbanionic species produced in the decarboethoxylation of **4** for which the HOMO is the NBMO of the oxoallylic system, which is unperturbed by the C–C bonding orbitals of the ring carbons, leads to the correct prediction of no diastereoselection.

Application of Klein's treatment to the decarboethoxylation of **1** leads to the correct prediction that attack on the intermediate carbanion should be preferentially from the equatorial direction. The HOMO of this carbanion has antibonding interactions on its upper face with the axial nonbonding electron pairs on the ring oxygens, producing an accumulation of electron density below the plane of the intermediate (Figure 3). The nearly perpendicular geometry[8] of the syn axial nonbonding electron pair of **7** relative to the carbanionic MO produces little if any hyperconjugative interaction. One would thus predict a result similar to that of the parent compound, **8**.[9]

The observation that **2** is formed 6.5 times faster than **3** in the decarbethoxylation of **1** is, to the best of our knowledge, the first observation of pronounced diaster-

---

(3) Kaloustian, M. K.; Dennis, N.; Mager, S.; Evans, S. A.; Alucia, F.; Eliel, E. L. *J. Am. Chem. Soc.* **1976**, *98*, 956. The equilibrium constants were measured for 5-(carbomethoxy)-2-isopropyl-1,3-dioxane in diethyl ether and acetonitrile. It is reasonable to assume that the trans isomer of the 5-carboethoxy derivative will also be the more stable.

(4) Dekmezian, A. H.; Kaloustian, M. K. *Synth. Commun.* **1979**, *9*, 431. Decarboethoxylation of **1** with NaCl in wet Me_2SO at reflux for 7 h gave a ratio of **2**/**3** of *ca.* 1/3.

(5) Liotta, C. L.; Cook, F. L. *Tetrahedron Lett.* **1974**, 1095.

(6) Krapcho, A. P. private communication.

(7) (a) Klein, J. *Tetrahedron Lett.* **1973**, 4307. (b) Klein, J. *Tetrahedron* **1974**, *30*, 3349.

(8) For a discussion of the effect of the geometric orientation of oxygen nonbonding orbitals on adjacent carbocationic centers, see: Meyer, W. P.; Martin, J. C. *J. Am. Chem. Soc.* **1976**, *98*, 1231.

(9) The slight preference for exo attack in the carbanion produced from **7** relative to that from **9** parallels the somewhat greater stability of exo-2 substituents in the 7-oxabicyclo[2.2.1]heptanyl systems studied by Ouellette, Rosenblum, and Booth (*J. Org. Chem.* 1 968, *33*, 4302) relative to the bicyclo[2.2.1]heptanyl systems.

J. Org. Chem. **1981**, *46*, 1745–1747

eoselection at the 5-position of 1,3-diheterocyclohexanes. Other workers have found diastereoselection at the 2-position of six-membered heterocycles. Eliel and Nader[10] found a preponderance of axial attack by alkylmagnesium halides on the carbocation formed at the 2-position of 1,3-dioxanes. Anancomeric 1,3-dithianes gave equatorial 2-substituted compounds upon treatment with DCl, CH_3I, or carbonyl compounds.[11]

Experimental Section

2-Isopropyl-5,5-bis(carboethoxy)-1,3-dioxane was prepared by following the procedure of Eliel and Banks.[16] 2-Isopropyl-5,5-bis(carbomethoxy)-1,3-dioxane was prepared in a similar manner except that dimethyl malonate was substituted for diethyl malonate.

Diethyl 4-*tert*-Butylcyclohexane-1,1-dicarboxylate. 4-*tert*-Butylcyclohexanecarboxylic acid was prepared by following the procedure of Stolow.[12] The acid (11.5 g, 62.4 mmol) was mixed with thionyl chloride (10.5 mL, 144 mmol) and allowed to stand at room temperature for 15 min; the reaction mixture was then refluxed for 15 min. The excess thionyl chloride was removed under reduced pressure. Pyridine (20 mL) was added, followed by the dropwise addition of absolute ethanol (20 mL, 348 mmol). After 0.5 h of reflux, the reaction mixture was poured into an ice–water mixture and extracted three times with 50-mL portions of diethyl ether. The combined ethereal extracts were washed with saturated aqueous $NaHCO_3$ and saturated NaCl and were dried over anhydrous $MgSO_4$. Filtration and concentration on the rotary evaporator gave 9.72 g (73.5%) of ethyl 4-*tert*-butylcyclohexanecarboxylate, bp 98–104 °C (1.4 mm) [lit.[13] (cis) bp 102–103 °C (9 mm), (trans) bp 106–107 °C (10 mm)].

Ethyl 4-*tert*-butylcyclohexanecarboxylate (8.00 g, 37.7 mmol) was converted to 4-*tert*-butyl-1-(carboethoxy)cyclohexanecarboxylic acid (6.54 g 67.3%) by following the procedure of Reffers.[14] This half-ester was then treated with thionyl chloride as above, followed by ethanol and pyridine. The product was isolated in 54.0% yield (3.91 g), bp 90–91 °C (0.08 mm) [lit.[15] bp 132 °C (2.5 mm)].

7-Oxa-2,2-bis(carbomethoxy)bicyclo[2.2.1]heptane. A magnetically stirred solution of 10 mL of anhydrous Et_2O, 40 mL of CH_2Cl_2, 45.1 mL (43.1 g, 500 mmol) of methyl acrylate, and 35.8 mL (33.5 g, 492 mmol) of furan was treated with small portions of a total of 0.6 g of $AlCl_3$ over a 10-min period. The reaction vessel was fitted with a reflux condenser, placed in a water bath at 23 °C, and allowed to stand for 72 h. A total of 25 mL of H_2O was added in small portions. The dark brown reaction mixture changed to a light brown after being stirred for 2 h and was then filtered through a fritted disk. The two-phase system was separated and the organic layer was dried over a mixture of anhydrous $MgSO_4$ and Na_2CO_3. The dry solution was filtered and concentrated under reduced pressure. A portion (22.43 g) of the above residue was dissolved in 250 mL of 95% ethanol, and 100 mg of 10% Pd/C was added. Hydrogenation was effected by using a Parr apparatus with an initial pressure of 47 psi. After removal of the catalyst and collection of a low-boiling fraction (1.0 mL), a fraction was collected: 17.4 g (77.6%); bp 92–94 °C (6.2 torr); ^1H NMR[17] (CCl_4) δ 1.29–2.10 (m, 6 H), 2.3–3.02 (m, 1 H), 3.14 (s, 1 H), 4.36–4.79 (m, 2 H).

By the procedure of Reffers et al,[14] diisopropylamine (3.0 g, 4.2 mL, 30.0 mmol) in 30 mL of dry tetrahydrofuran (THF), 15 mL of 2.3 M *n*-butyllithium, and 7-oxa-2-(carbomethoxy)bicyclo[2.2.1]heptane (4.00 g, 25.6 mmol) in 20 mL of THF were used to prepare 7-oxa-2-carboxy-2-(carbomethoxy)bicyclo[2.2.1]heptane. This half-ester was treated with 2 mL of $SOCl_2$ and the magnetically stirred mixture was heated to the boiling point. The hot reaction product was concentrated with an aspirator and cooled in an ice–water bath, and 2 mL of pyridine and methanol were added. After standing for 8 h at room temperature, the reaction mixture was poured into ice–water, extracted three times with a total of 25 mL of Et_2O, dried over $MgSO_4$, filtered, and distilled to give 1.0 g (18.2%) of product: bp 57–61 °C (0.15 torr); ^1H NMR (CCl_4) δ 1.30–1.44 (m, 6 H), 2.13–2.97 (m, 3 H), 3.59 (s, 3 H), 4.36–4.72 (m, 2 H).

Decarbalkoxylations. These reactions were conducted either in sealed ampoules in a constant-temperature bath (±0.1 °C) or in round-bottomed flasks equipped with condensers and $CaCl_2$ drying tubes in silicone oil baths (±1 °C). Typical procedures follow.

1. Decarboethoxylation of 2-Isopropyl-5,5-bis(carboethoxy)-1,3-dioxane. A mixture of 80.64 mg (1.902 mmol) of LiCl, 54.9 mg (3.053 mmol) of H_2O, 383.0 mg (1.398 mmol) of 2-isopropyl-5,5-bis(carboethoxy)-1,3-dioxane, 152.3 mg (0.8948 mmol), and 5 μL of pyridine was dissolved in 2.00 mL of dimethyl sulfoxide. Samples of 200 μL of this solution were sealed into small ampules constructed from 6-mm glass tubing and were then placed into a silicone oil bath maintained at 135.0 ±0.1 °C. Ampules were withdrawn periodically, cooled, and opened. A Pasteur pipet was used to transfer the contents of the ampule to a vial containing 2 mL of 5% aqueous $KHCO_3$. The mixture was extracted three times with 1-mL portions of Et_2O. The combined ethereal extracts were dried over a mixture of anhydrous $MgSO_4$ and Na_2CO_3. The dried solution was analyzed by GLC [6 ft × 0.25 in 20% FFAP on Chromasorb W, 80–100 mesh, He flow 100 mL/min, program mode 180 (4 min), 180–210 (3 min), 210 °C (4 min)].

2. Decarboethoxylation of Diethyl 4-*tert*-Butylcyclohexane-1,1-dicarboxylate. A mixture of LiCl (40.9 mg, 01965 mmol), H_2O (46.1 mg, 2.56 mmol), diphenyl ether (102.7 mg, 0.603 mmol, internal standard), 5 μL of pyridine, and 1.00 mL of dimethyl sulfoxide was added to a 25-mL flask equipped with a magnetic stirring bar, condenser, and $CaCl_2$ drying tube. The mixture was heated to 135 ±1 °C by means of a silicone oil bath. By means of a syringe, 209.6 mg (0.738 mmol) of 4-*tert*-butyl-1,1-bis(carboethoxy)cyclohexane was added at such a rate that thermal equilibrium was maintained. Samples were removed periodically and quenched by addition to 1 mL of 5% aqueous Na_2CO_3. The resulting mixture was worked up and analyzed as above.

Control experiments demonstrated that the product composition was unaffected by the workup procedure.

Registry No. 1, 35113-48-5; 1 (R_2, R_3 = $COOCH_3$), 76480-24-5; **2**, 70708-55-3; **3**, 70708-56-4; **4**, 53695-41-3; **5**, 7214-36-0; **6**, 7214-35-9; **7**, 76480-25-6; 4-*tert*-butylcyclohexanecarboxylic acid, 5451-55-8; 4-*tert*-butyl-1-(carboethoxy)cyclohexanecarboxylic acid, 76480-26-7; methyl acrylate, 96-33-3; furan, 110-00-9; *endo*-7-oxa-2-(carbomethoxy)bicyclo[2.2.1]heptane, 17791-35-4; *exo*-7-oxa-2-(carbomethoxy)bicyclo[2.2.1]heptane, 17791-34-3; 7-oxa-2-carboxy-2-(carbomethoxy)bicyclo[2.2.1]heptane, 76480-27-8.

---

[10] Eliel, E. L.; Nader, F. W. *J. Am. Chem. Soc.* **1970**, *92*, 584.

[11] (a) Eliel, E. L.; Hartmann, A. A.; Abatjoulou, A. G. *J. Am. Chem. Soc.* **1972**, *94*, 4786. (b) Eliel, E. L. *Tetrahedron* **1974**, *30*, 1503.

[12] Stolow, R. D. *J. Am. Chem. Soc.* **1959**, **81**, 5818.

[13] Eliel, E. L.; Haubenstock, H.; Acharya, R. V. *J. Am. Chem. Soc.* **1961**, *83*, 2351.

[14] Reffers, S.; Wynberg, H.; Strating, J. *Tetrahedron Lett.* **1971**, 3001.

[15] Brown, D. R.; Leviston, P. G.; McKenna, J.; McKenna, J. M.; Melia, R. A.; Pratt, J. C.; Hutley, B. G. *J. Chem. Soc., Perkin Trans. 2* **1976**, 838.

[16] Eliel, E. L.; Banks, H. D. *J. Am. Chem. Soc.* **1972**, *94*, 171.

[17] Ouellette, R. J.; Rosenblum, A.; Booth, G. *J. Org. Chem.* **1968**, *33*, 4302.

Phase Transfer Catalyzed Hydrolysis of Thioacetals Using Pyridinium Hydrobromide Perbromide

Gordon S. Bates* and James O'Doherty[1]

Department of Chemistry, University of British Columbia, Vancouver, Canada V6T 1Y6

Received September 25, 1980

In connection with some ongoing studies, we required a mild, general method for the hydrolysis of various α-thioketalized aldehydes,[2] carboxylic acids,[3] and esters[4] to

---

[1] Research assistant, Summer 1980.

0022-3263/81/1946-1745$01.25/0