Preparation of the Diacid of 2.—The exo anhydride (**2**), 5.0 g (0.0196 mol), was dissolved in 500 ml of boiling 1% aqueous potassium hydroxide, filtered, and cooled to room temperature. The solution was adjusted to a pH of 4 with 6 *N* hydrochloric acid. The resulting mixture was filtered, washed with water, and air-dried, giving 4.5 g (84%) of a colorless solid, mp 242–244° (sealed tube). This substance was identical with the product of the attempted iodolactonization of **2**.

Zinc Reduction of the Iodolactone (5).—Exactly 1.0 g (0.0025 mol) of the iodolactone (**5**) was dissolved in 250 ml of glacial acetic acid. Excess zinc dust (0.64 g, 0.076 g-atom) was added, and the suspension was stirred for 10 hr. The unconsumed zinc was removed and the filtrate diluted with water to the cloud point. The solution was heated until homogeneous, cooled, and then filtered. The resulting white crystals were washed with cold glacial acetic acid and air-dried giving 0.25 g (39%) of the endo anhydride (**1**), mp 193–195°.

Half-Esters.—A 0.21-g sample of the exo anhydride, mp 175–177°, was heated in methanol until all of the solid dissolved. Evaporation of the 10 ml of solvent to dryness gave 0.25 g of the exo half-ester: mp 169–172°; pmr ($CDCl_3$) 1.77 (s, 6 CH_3), 3.10 (d, 2, $J = 1$ Hz), 3.38 (s, 3, OCH_3), 3.32 (d, 2, $J = 1$ Hz), and 7.20 (m, 4, ArH).

Anal. Calcd for $C_{17}H_{18}O_4$: C, 71.31; H, 6.34. Found: C, 71.19; H, 6.27.

The higher melting endo adduct was similarly converted into a half-ester, mp 187–189° (lit.[5] mp 184–185°). The pmr of this half-ester was similar to that of the exo isomer, but no coupling between the bridge and bridgehead protons was observed and the integration suggested the acidic proton might lie in the aromatic region: pmr ($CDCl_3$) 1.83 (s, 6) 3.00 (s, 2), 3.64 (s, 3), 3.92 (s, 2), 7.18 (m, 4.6).

The half-esters were dissolved in 5 ml of 5% sodium carbonate and treated with an iodine stock solution.[10] The exo half-ester (0.18 g) did not decolorize the first four drops of iodine, and 0.12 g was recovered unchanged. When 0.37 g of the endo half-ester, mp 187–189°, was similarly treated, the iodine was immediately decolorized and a precipitate formed: yield 0.13 g; mp 105–110° dec; pmr ($CDCl_3$) 1.83 (s, 3), 2.35 (s, 3), 2.95 (m, 2), 3.7 (m, 1), 3.80 (s, 3), 4.17 (d, 1, $J = 1$ Hz), 7.34 (m, 4, ArH).

Anal. Calcd for $C_{17}H_{17}IO_4$: C, 49.53; H, 4.16. Found: C, 49.31; H, 3.99.

A 2-g sample of the endo anhydride was heated in 40 ml of 5% sodium carbonate until solution was effected. Cooling, acidification, and drying gave 2.10 g of a solid; 1 g of this acid was added to 75 ml of 0.1 *N* sodium bicarbonate. This solution was diluted with 75 ml of water and filtered. Bromine was added dropwise to the filtrate until the bromine color persisted. After 30 min the solution was acidified, decolorized with a trace of sodium bisulfite, and filtered, yield 0.90 g, mp 215–218°. Recrystallization from ethanol did not improve the product: pmr (acetone-d_6) 1.61 (s, 3), 2.05 (s, 4), 2.93 (m, 2), 4.01 (m, 2), 7.36 (m, 4); ir 1770 cm^{-1} (C=O, lactone).

Anal. Calcd for $C_{16}H_{15}BrO_4$: C, 54.70; H, 4.27. Found: C, 54.49; H, 4.19.

A solution of 0.35 g of this bromolactone acid was treated with an ethereal solution of diazomethane. The product was recrystallized from ethanol and gave 0.20 g of solid, mp 191–193°. A mixture of this solid and a sample of the methyl bromolactone (lit.[5] mp 191.5–192°) prepared by the method of Yates and Eaton[5] melted without depression.

Preparation of 3.—A mixture of 3.9 g of a 2,3-dimethylnaphthalene, 2.5 g of maleic anhydride, and 3.4 g of aluminum chloride in 400 ml of methylene chloride was allowed to react at room temperature. After decomposition of the complex with acid, 10% sodium carbonate was used to make the solution basic and extract a yellow acid. Acidification, filtration, and recrystallization from acetic acid gave 0.70 g of **3**: mp 188–189°; pmr (dimethyl sulfoxide-d_6) 2.40 (s, 6), 6.68 (d, 1, $J = 16$ Hz), 7.61 and 7.83 (4), 8.00 (d, 1, $J = 16$ Hz), 8.50 (s, 1); ir (KBr) 1760, 1690 (C=O, acid), 1670 cm^{-1} (C=O, ketone). The analytical sample melted at 190–191° to give a red liquid.

Anal. Calcd for $C_{16}H_{14}O_3$: C, 75.59; H, 5.51. Found: C, 75.35; H, 5.47.

Hydrogenation of 0.25 g of the acid over 10% palladium on charcoal gave 0.16 g of white crystals, mp 182–183 dec (lit.[9] mp 179–180°). Authentic material was prepared by the method or Morten and Senders, but the use of methylene chloride in place of nitrobenzene as solvent for the aluminum chloride, 2,3-dimethylnaphthalene, and succinic anhydride gave much less tar and the product melted at 183–184° dec. A mixture of this material and that from the hydrogenation melted at 183–184° dec, and the products had identical spectra.

Analysis of the material left from the extraction of **3** showed a 33% yield of **1** and **2** in which the ratio of **1** to **2** was 2:1.

Registry No.—**1**, 36736-37-5; **1** half-ester iodide, 36808-03-4; **1** bromolactone, 36808-04-5; **2**, 36736-38-6; **2** diacid, 36808-06-7; **2** half-ester, 36807-55-3; **3**, 36807-56-4; **5**, 36807-57-5; **6**, 36803-78-8.

Acknowledgment.—This investigation was supported in Missouri through Contract No. DA 18-108-CML-6601 and DA 18-035-AMC-382A from the U. S. Army Research and Development Laboratories, Edgewood Arsenal, Maryland.

The Utilization of Magnesium Enolates in the Michael Reaction

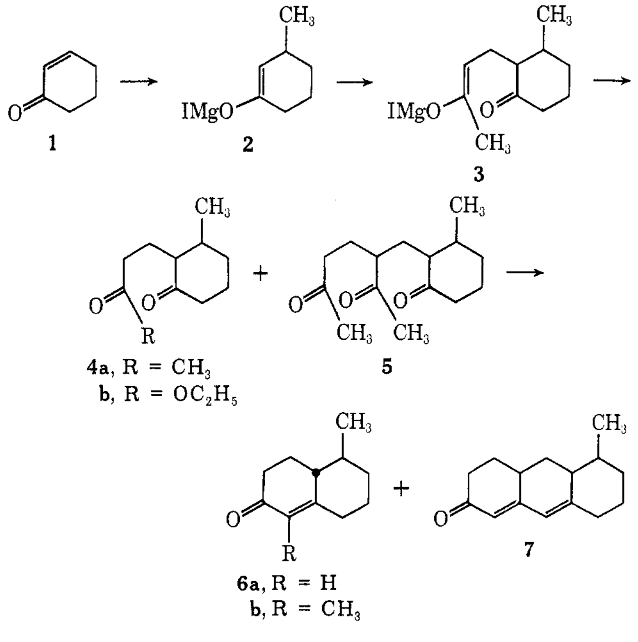
RICHARD A. KRETCHMER,* EDWARD D. MIHELICH,[1] AND JOHN J. WALDRON

Department of Chemistry, Illinois Institute of Technology, Chicago, Illinois 60616

Received July 11, 1972

The Michael reaction of magnesium enolates has recently been demonstrated to be a potential side reaction in the conjugate addition of Grignard reagents to α,β-unsaturated ketones.[2] We wish to report the application of this observation to the stereospecific synthesis of 2,3-disubstituted cyclohexanones and 1,5-substituted $\Delta^{1,9}$-octal-2-one derivatives.

SCHEME I



---

[10] C. S. Rondestvedt, Jr., and C. D. Ver Nooy, *J. Amer. Chem. Soc.*, **77**, 4878 (1955).

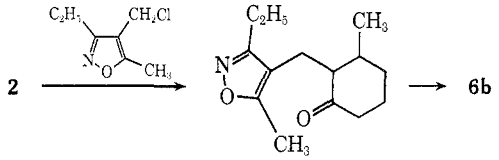
[1] National Science Foundation Undergraduate Research Participant, Summer 1972.

[2] R. A. Kretchmer, *J. Org. Chem.*, **37**, 2744 (1972); (b) R. A. Kretchmer, *ibid.*, **37**, 2747 (1972); (c) E. P. Kohler and W. D. Peterson, *J. Amer. Chem. Soc.*, **55**, 1073 (1933).

An ether solution of magnesium enolate **2** was generated by the cuprous chloride catalyzed addition of methylmagnesium iodide to 2-cyclohexenone (**1**) (Scheme I). Addition of methyl vinyl ketone then afforded a crude product which was treated with KOH in aqueous methanol to give **6a** in 11% overall yield. In addition, dienone **7** was also isolated in 14% yield. The relatively low yield of **6a** presumably reflects the fact that the initially formed Michael adduct **3** may react further with methyl vinyl ketone to give products such as **5** instead of **4a**. The formation of dienone **7**, which would result from base-catalyzed cyclization of **5**, appears to confirm this latter process.

Reaction of magnesium enolate **2** with ethyl vinyl ketone followed by base treatment afforded **6b** in 14% overall yield. The structure of **6b** was confirmed by alternate synthesis. This was accomplished by alkylation of **2**[3] with 5-methyl-3-ethyl-4-chloromethylisoxazole[4] in the presence of hexamethylphosphoramide to give **8**, which was converted to **6b** by Stork's annelation procedure.[5]

In addition, the Michael reaction of **2** with ethyl acrylate was found to afford a 17% yield of keto ester **4b**. Although the yields of **4b**, **6a**, and **6b** are modest, this is mitigated by the stereospecificity, speed, and simplicity of the reaction sequence.



8

Experimental Section[6]

Preparation of 5-Methyl-$\Delta^{1,9}$-octal-2-one (6a).—A solution of methylmagnesium iodide was prepared under nitrogen by dropwise addition of a solution of 13.068 g (92.1 mmol) of methyl iodide in 150 ml of anhydrous ether into a flask containing 2.143 g (0.0881 g-atom) of magnesium turnings over a period of 25 min with stirring at ice-bath temperature. After the addition was completed, stirring was continued at room temperature for 2 hr. The mixture was then cooled to ice-bath temperature and 0.411 g (4.15 mmol) of cuprous chloride was added. A solution of 7.711 g (80.2 mmol) of 2-cyclohexenone (**1**) in 150 ml of anhydrous ether was next added dropwise over a period of 1.3 hr, with stirring and at ice-bath temperature. When addition was completed, a solution of 5.623 g (80.2 mmol) of methyl vinyl ketone in 30 ml of anhydrous ether was added rapidly in one portion. After stirring at room temperature for 1.5 hr, the mixture was treated with 200 ml of saturated NH_4Cl solution. The ether layer was separated and washed six times with 100-ml portions of water and once with 100 ml of saturated NaCl solution, and concentrated *in vacuo* to give 11.7 g of amber oil, ir (neat) 1706 cm^{-1}.

The crude product was dissolved in 300 ml of methanol and 15 ml of 45% aqueous KOH. The resulting mixture was refluxed under nitrogen for 20 hr. After cooling, the mixture was diluted with 300 ml of water and extracted with ether. The ether extract was washed with water, dilute HCl, and saturated NaCl solution, and dried. Concentration *in vacuo* followed by distillation through a 10-cm Vigreux column afforded 1.456 g (11%) of enone **6a** as a colorless oil, bp 84–86° (0.5 mm) [lit.[3a] bp 71–76° (0.1 mm)], which was identified by spectroscopic comparison with an authentic sample.[3a] The 2,4-dinitrophenylhydrazone had mp 190.5–192.5° and was undepressed upon admixture with that prepared from authentic 5-methyl-$\Delta^{1,9}$-octal-2-one.[3a]

The fractional distillation also afforded 2.401 g (14%) of dienone **7** as a yellow solid, bp 100–125° (0.5 mm). Material from a similar reaction was recrystallized twice from ether–hexane to give the analytical sample as a pale yellow solid: mp 102.0–103.5°; uv max (EtOH) 293 nm (ϵ 29,000); ir (CCl_4) 1662 (α,β-γ,δ-unsaturated C=O), 1622 (C=C), and 1588 cm^{-1} (C=C); nmr (CCl_4) δ 1.04 (3 H, br, W_H = 4.7 Hz, $CHCH_3$), 5.60 (1 H, br, W_H = 4.9 Hz, vinyl CH), and 5.97 (1 H, br, W_H = 5.3 Hz, vinyl CH); mass spectrum (70 eV) *m/e* 216 (M^+).

Anal. Calcd for $C_{15}H_{20}O$: C, 83.28; H, 9.32. Found: C, 83.38; H, 9.47.

Preparation of 1,5-Dimethyl-$\Delta^{1,9}$-octal-2-one (6b). A. From 2-Cyclohexenone by Isoxazole Annelation.—A solution of methylmagnesium iodide in 400 ml of ether was prepared by reaction between 28.703 g (0.202 mol) of methyl iodide and 5.140 g (0.211 g-atom) of magnesium turnings. To this was added 0.551 g (5.6 mmol) of cuprous chloride and the mixture was cooled at ice bath temperature. A solution of 17.697 g (0.184 mol) of 2-cyclohexenone (**1**) in 400 ml of ether was then added dropwise, over a period of 3 hr, with mechanical stirring, and under nitrogen. When addition was complete, a solution of 30.804 g (0.193 mol) of 5-methyl-3-ethyl-4-chloromethylisoxazole,[4] bp 109.0–111.0° (13 mm), in 90 ml of hexamethylphosphoramide was added. The resulting mixture was stirred at ice-bath temperature for 1 hr and at room temperature for an additional 14 hr. The mixture was then treated with 400 ml of saturated NH_4Cl solution. The ether layer was separated, washed five times with 200-ml portions of water and once with 200 ml of saturated NaCl solution, and dried. Concentration *in vacuo* followed by distillation through a 10-cm Vigreux column afforded 17.739 g (41%) of keto isoxazole **8** as a pale yellow oil: bp 134–143° (0.15–0.25 mm); ir (neat) 1709 (C=O) and 1633 cm^{-1} (isoxazole).

The keto isoxazole **8** was dissolved in 200 ml of absolute ethanol and stirred under a hydrogen atmosphere with 19 g of W-4 Raney nickel[7] for 16 hr. An additional 17 g of W-4 Raney nickel[7] was then added and stirring under hydrogen was continued for 12 hr (the reaction was followed by monitoring the disappearance of isoxazole absorption at 223 nm in the uv). Catalyst was filtered off, and the filtrate was concentrated *in vacuo*. The residual amber resin was dissolved in 250 ml of absolute methanol. After the solution was purged with nitrogen, 40.0 g of sodium methoxide was added, and the mixture was heated at reflux under nitrogen for 6 hr. The mixture was then diluted with 350 ml of water, and refluxing under nitrogen was continued for an additional 10 hr. After cooling, the mixture was diluted with 500 ml of water and extracted four times with 250-ml portions of ether. The combined ether extracts were washed three times with 250-ml portions of water and once with 250 ml of saturated NaCl solution, and dried. Concentration *in vacuo* followed by distillation through a 10-cm Vigreux column afforded 9.643 g (29% overall) of enone **6b** as a pale yellow liquid: bp 75–83° (0.10–0.15 mm); ir (neat) 1668 (C=O) and 1615 cm^{-1} (C=C); uv max (EtOH) 247 nm; nmr (CCl_4) δ 1.05 (3 H, br, $CHCH_3$) and 1.69 (3 H, s, vinyl CH_3). The 2,4-dinitrophenylhydrazone, after three recrystallizations from ethanol, had mp 192.5–193.5°.

Anal. Calcd for $C_{18}H_{22}N_4O_4$: C, 60.32; H, 6.19; N, 15.63. Found: C, 60.47; H, 6.19; N, 15.62.

B. From 2-Cyclohexenone and Ethyl Vinyl Ketone.—A solution of magnesium enolate **2** was prepared in ether solution by cuprous chloride catalyzed reaction between 88.1 mmol[8] of methylmagnesium iodide and 7.711 g (80.2 mmol) of 2-cyclohexenone (**1**) as described above in the preparation of **6a**. To this was added 6.750 g (80.2 mmol) of ethyl vinyl ketone in one portion, at ice-bath temperature, and the mixture was allowed to stir at room temperature for 1 hr. The resulting mixture was

---

(3) (a) R. A. Kretchmer and W. M. Schafer, *J. Org. Chem.*, in press; (b) G. Stork, G. L. Nelson, F. Rouessac, and O. Gringore, *J. Amer. Chem. Soc.*, **93**, 3091 (1971); (c) G. Stork, *Pure Appl. Chem.*, **17**, 383 (1968).

(4) J. E. McMurry, Ph.D. Thesis, Columbia University, New York, N. Y., 1967.

(5) (a) G. Stork, S. Danishefsky, and M. Ohashi, *J. Amer. Chem. Soc.*, **89**, 5459 (1967); (b) G. Stork and J. E. McMurry, *ibid.*, **89**, 5463 (1967); (c) G. Stork and J. E. McMurry, *ibid.*, **89**, 5464 (1967).

(6) Melting points are uncorrected. Magnesium sulfate was employed as a drying agent. The infrared spectra were determined with either a Beckman IR-8 or a Perkin-Elmer 257 infrared spectrophotometer. Nmr spectra were determined with either a Varian A-60 or T-60 spectrometer using tetramethylsilane as internal standard. Uv spectra were determined on a Cary Model 11PM spectrophotometer. The mass spectra were obtained with a Varian MAT CH7 mass spectrometer. Microanalyses were performed by M-H-W Laboratories, Garden City, Mich.

(7) A. A. Pavlic and H. Adkins, *J. Amer. Chem. Soc.*, **68**, 1471 (1946).

(8) Calculated on the basis of the amount of magnesium employed.

then treated with 200 ml of saturated NH_4Cl solution. The ether layer was separated, washed six times with 75-ml portions of water and once with 75 ml of saturated NaCl, and dried. Concentration *in vacuo* afforded 13.5 g of oil which was dissolved in 250 ml of anhydrous methanol. To this was added a solution of 30 g of NaOH in 350 ml of water, and the resulting mixture was heated at reflux under nitrogen for 16 hr. After cooling, the mixture was extracted with ether. The ether extract was washed with water, 3 *M* HCl, and saturated NaCl solution, and then dried. Concentration *in vacuo* followed by distillation through a 10-cm Vigreux column afforded 1.985 g (14%) of **6b** as a colorless liquid, bp 97–117° (0.6–0.65 mm). This material was characterized by conversion to the 2,4-dinitrophenylhydrazone derivative, which, after recystallization from ethanol–ethyl acetate had mp 194.0–195.5°, undepressed on admixture with material prepared *via* the isoxazole route above.

Preparation of Keto Ester 4b.—An ether solution of magnesium enolate 2 was prepared under nitrogen by cuprous chloride catalyzed reaction between 89.9 mmol[8] of methylmagnesium iodide and 8.04 g (83.6 mmol) of 2-cyclohexenone (1), as described above in the preparation of **6a**. A solution of 8.37 g (83.6 mmol) of ethyl acrylate in 50 ml of ether was then added in one portion at ice-bath temperature, and the mixture was allowed to stir at room temperature under nitrogen for 30 min. The resulting mixture was next treated with dilute aqueous HCl. The ether layer was separated, washed five times with 100-ml portions of water and once with 100 ml of saturated NaCl solution, and dried. Concentration *in vacuo* afforded 15.19 g of amber oil which was distilled through a 10-cm Vigreux column to give 0.45 g (5%) of 3-methylcyclohexanone, bp 25° (0.25 mm), which was identified by spectroscopic comparison with an authentic sample.

The fractional distillation also afforded 2.94 g (17%) of keto ester **4b** as a pale yellow liquid, bp 88–93° (0.1–0.35 mm). Redistillation afforded the analytical sample as a colorless liquid: bp 100–102° (0.45–0.55 mm); ir (neat) 1711 (ketone C=O) and 1735 cm^{-1} (ester C=O); mass spectrum (70 eV) *m/e* 212 (M^+).

Anal. Calcd for $C_{12}H_{20}O_3$: C, 67.89; H, 9.50. Found: C, 67.94; H, 9.41.

Registry No.—**4b,** 36794-99-7; **6a** DNPH, 36795-00-3; **6b,** 32456-17-0; **6b** DNPH, 36795-02-5; **7,** 36795-03-6; **8,** 36795-04-7; 3-methylcyclohexanone, 591-24-2.

Rotational Isomerism in β,β-Dichlorovinyl Carbonyl Compounds

JAMES B. ELLERN[1] AND HARRY B. GRAY*

Contribution No. 4517 from the
Arthur Amos Noyes Laboratory of Chemical Physics,
California Institute of Technology, Pasadena, California 91109

Received July 27, 1972

In connection with a synthetic effort, we have prepared several of the title compounds, $Cl_2C{=}CHCOX$, where X = H (**1**), Cl (**2**), CH_3 (**3**), and OCH_3 (**4**).[2] These compounds show two bands in the carbonyl-stretching frequency region of their ir spectra. The studies of Dabrowski and coworkers on the related mono-β-chlorovinyl compounds[3a–c] suggest that this phenomenon is due to s-cis,s-trans[4] isomerism about the olefin–carbonyl bond.

Infrared absorption bands in the 1500–1800-cm^{-1} region and nmr chemical shifts are set out in Table I. Inspection of the ir data suggests that the higher frequency carbonyl band (A) should be assigned to the s-cis forms of the compounds and the lower one (B) to the s-trans form. As one would expect the relative intensity of band A (s-cis) increases with the size of X. Also, the relative strength of band B is usually apparently greater in the more polar solvent.[3b,c] The ketone **3** appears to be a particularly good example. There are four well-resolved double bond stretching bands in CCl_4 and C_2Cl_4; it is tempting to assign the two outer bands to the s-cis form and the two inner ones to the s-trans.[3b] But this simple picture is complicated when one considers all the data, especially for the ketone. In this compound, the relative intensity of band A to band B is in the order $CH_3CN > CH_2Cl_2 > CHCl_3 > CCl_4$, C_2Cl_4. Similarly, a careful inspection of the ester **4** spectra indicates band B is probably actually more intense in CH_3CN. In addition, there are more than two bands in the C=C region for all the compounds.[5] The discussion below considers these facts.

In the aldehyde **1**, band B is much more intense than band A and is relatively stronger in CH_3CN. Since this is the least sterically hindered compound and the s-trans form is electronically favored,[3b] band A is assigned to $\nu_{C=O}$ (s-cis) and band B to $\nu_{C=O}$ (s-trans). The strongest C=C band, 1585 cm^{-1}, is assigned to $\nu_{C=C}$ (s-trans). These s-trans bands are near those found in the s-trans monochlorovinyl aldehyde (1692 and 1588).[3a] The s-cis C=C band is probably overlaid by the s-trans one; both the other bands between 1500 and 1600 cm^{-1} seem too strong to go with the weak s-cis C=O band.

In the acid chloride **2** the two well-resolved C=O bands are of comparable intensity. The relative intensity of band B is markedly greater in CH_3CN. These two bands are therefore assigned as for the aldehyde. Both shoulders on the very strong C=C band increase as band B increases, but, since it is difficult to judge intensities for these closely spaced absorptions, we are reluctant to assign any of them definitely to one conformer or the other.

The ketone **3** departs from the pattern of **1** and **2**. Bands A and B are well separated and of comparable intensity as in **2**, but the relative strength of band B *falls* with increasing solvent polarity. Both the highest and lowest band in the C=C region show the same behavior relative to the strongest C=C band. The Noack criterion, *viz.*, that $\nu_{C=O}$ in s-cis shifts less than that of $\nu_{C=O}$ in s-trans in going from CCl_4 to $CHCl_3$,[6] is no help in this case except that it may suggest that the conformers in this case are not very close to s-cis and s-trans. A quasi-s-trans rotamer must be considerably skewed from planarity in **3** due to interference between the methyl and the nearer β-chlorine.[7]

---

[1] NSF Predoctoral Fellow, 1966–1970.

[2] Our interest in these compounds stems from our discovery that they react with certain secondary amines to yield directly aminoethynyl carbonyl compounds: ethynylogous amides, "push-pull" acetylenes. *Cf.* H.-J. Gais, K. Hafner, and M. Neuenschwander, *Helv. Chim. Acta*, **52**, 2641 (1969). These results will be communicated shortly.

[3] (a) J. Terpinski and J. Dabrowski, *Bull. Akad. Pol. Sci., Ser. Sci. Chim.*, **17**, 355 (1969); (b) J. Dabrowski and K. Kamienska-Trela, *Bull. Chem. Soc. Jap.*, **39**, 2565 (1966); (c) J. Dabrowski and J. Terpinski, *J. Org. Chem.*, **31**, 2159 (1966).

[4] We recognize that both conformations may deviate from planarity; *cf.* A. J. Bowles, W. O. George, and W. F. Maddams, *J. Chem. Soc. B*, 810 (1969), and D. D. Faulk and A. Fry, *J. Org. Chem.*, **35**, 365 (1970).

[5] Factors other than rotational isomerism that may cause band splitting (*e.g.*, Fermi resonance) are discussed in ref 3b and c and references cited therein; see also ref 8.

[6] K. Noack, *Spectrochim. Acta*, **18**, 1625 (1962).

[7] (a) A sketch made to scale using reasonable values for bond lengths and contact radii (values from Pauling[7b]) or the use of models shows this; (b) L. Pauling, "The Nature of the Chemical Bond," 3rd ed, Cornell University Press, Ithaca, N. Y., 1960.