TABLE I

REACTION OF 2 WITH AMMONIA IN ETHANOL

Time	Temp, °C	Sample composition, % 1	2	3	Unidentified
2 weeks	25	7.2	11.1	81.9	0
4 hr	100	5.2	29.9	65.0	0
4 hr	150	11.8	14.3	73.9	0
8 hr	150	6.8	0	84.4	8.8
12 hr	150	7.7	0	89.6	2.7

then cyclized to [2-^{14}C]-6,7-dimethoxy-4-ethylquinazoline by heating the formamido compound in a sealed tube with ethanol and ammonia at 150° for 12 hr. The residue from the reaction was recrystallized from acetone to give (in two crops) the product in 63% yield. The two crops were combined with unlabeled material by recrystallization. The total ^{14}C content was 6.41 mCi, which, allowing for the material recovery, amounts to 56.4% incorporation of the [^{14}C]formic acid.

Experimental Section

6,7-Dimethoxy-4-ethylquinazoline (3). Ammonium Formate Method.—A 100-ml three-necked flask equipped with a magnetic stirrer, gas inlet tube, thermometer, and condenser was charged with 25.2 g (0.4 mol) of ammonium formate. The ammonium formate was heated to 125° with stirring. Then 2.37 g (0.01 mol) of 2 (*vide infra*) was added; the addition of ammonia gas below the surface at a moderate rate was started immediately. Periodically, 0.1-ml samples were withdrawn, diluted with 5 ml of water, adjusted to pH 9 with NH_4OH, and extracted with $CHCl_3$ (5 ml). The extracts were analyzed by glc;[5] the results are presented in Figure 1. After 6 hr of reaction, the mixture was poured into water, made basic with NH_4OH, and extracted with $CHCl_3$. The extract was dried ($MgSO_4$) and evaporated *in vacuo* to give a yellow solid. The solid was recrystallized from acetone–hexane to give 1.5 g (69%) of white product, mp 149–150.5°.

6,7-Dimethoxy-4-ethylquinazoline (3). Ammonia in Ethanol Method.—A solution of 0.5 g (2.11 mmol) of 2 in 75 ml of absolute EtOH was saturated with ammonia at 0° in a steel cylinder of 100-ml capacity. The bomb was sealed and heated to temperature and held there for a specified time. After the reaction period the cylinder was cooled and opened, and the solution was analyzed by glc without further treatment.[5] The results of several runs are presented in Table I. The solution was then evaporated to dryness, and the residue was recrystallized from acetone–hexane to give white crystalline material.

2′-Formamido[^{14}C]-4′,5′-dimethoxypropiophenone.—A 100-ml three-necked flask equipped with a mechanical stirrer, thermometer, and addition funnel was charged with 2.30 g (11.0 mmol) of 2 and 0.515 g of 97% formic acid (11.0 mmol of anhydrous HCO_2H). Then 23.5 mCi of [^{14}C]formic acid (specific activity 60 mCi/mmol) was transferred to the flask with 30 ml of CH_2Cl_2. A solution of 2.44 g (11.83 mmol) of dicyclohexylcarbodiimide in 30 ml of CH_2Cl_2 was added over 5 min, during which time the temperature was maintained at 20–25° with an ice bath. The mixture was stirred at room temperature for 1 hr, and then the dicyclohexylurea was filtered, rinsed with CH_2Cl_2, and air dried to give 2.5 g (100% of theory) of white material. The combined filtrates were evaporated *in vacuo*, and the residue was recrystallized from 15 ml of MeOH. The material was filtered, rinsed with MeOH, and air dried to give 2.16 g (82.8%) of slightly yellow material, mp 125–130°. The material was carried directly to the next step.

[2-^{14}C]-6,7-Dimethoxy-4-ethylquinazoline.—A cylindrical stainless steel pressure vessel of 100-ml capacity was charged with 2.16 g (9.12 mmol) of 2′-formamido[^{14}C]-4′,5′-dimethoxypropiophenone and 75 ml of absolute EtOH. The mixture was cooled and saturated with NH_3. The vessel was sealed and heated at 150° for 12 hr; it was then cooled and opened. The content was evaporated *in vacuo* to dryness. The residue was taken up in 75 ml of hot acetone, treated with Darco G-60 charcoal, and concentrated *in vacuo* to 25 ml. The solution was cooled, and the precipitate was filtered, rinsed with cold acetone (2 × 3 ml), and air dried to give 0.96 g of material. The combined filtrates were treated with charcoal and evaporated *in vacuo*. The residue was recrystallized from 5 ml of acetone to give 0.26 g of product. The two crops (total 1.22 g, 63%) were combined with 1.225 g of 3, and the whole was dissolved in 30 ml of acetone. The solution was concentrated to 20 ml and cooled. The solid was filtered and air dried to give 2.275 g of off-white solid (92.9% recovery), mp 149–150°, specific activity 2.82 μCi/mg.[6] The thin layer radiochromatogram showed one spot.[7]

Anal. Calcd for $C_{12}H_{14}N_2O_2$: C, 66.04; H, 6.47; N, 12.83. Found: C, 65.83; H, 6.46; N, 12.86.

Registry No.—2, 34314-99-3; 3, 4015-32-1; 2′-formamido[^{14}C]-4′,5′-dimethoxypropiophenone, 34314-79-9; [2-^{14}C]-6,7-dimethoxy-4-ethylquinazoline, 34315-01-0.

Acknowledgments.—I am indebted to Dr. J. A. LaBudde and his group for the tlc and activity count, and to Mr. C. Combs and his group for the elemental analysis.

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[5] The glc analyses were made using 1.2 m × 6 mm dual glass columns packed with 3.8 wt % UC W-98 on 80/100 mesh Diatoport S; the oven temperature was programmed from 150 to 250° at 10°/min. The flow rates in ml/min were He, 40; H_2, 20; and air, 300; and the detector was a dual flame-ionization model. The retention times (in min) were **4**, 4.55; **5**, 5.90; and **6**, 5.30; respectively. All the components were assumed to have the same response; and, consequently, the area per cent is taken as mole per cent composition of the sample.

[6] The radioactivity of the samples was determined in a Packard Tri-Carb liquid scintillation counter in a counting solution of 2.5-diphenyloxazole (7 g/l.) and naphthalene (100 g/l. in *p*-dioxane).

[7] The tlc was run by spotting the sample from chloroform on Eastman No. 6060 silica gel tlc sheet and eluting with 50:50 Skelly F/acetone. The eluted strips were scanned with a Varian Aerograph Berthold radioscanner which showed a single radioactive peak.

Stereoselective Synthesis of Racemic Grandisol

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Grandisol (**1a**) is one of the four components of the boll weevil sex pheromone and has been previously synthesized nonselectively[1] and stereoselectively.[2] We now report another stereoselective synthesis which provides gram quantities of pure **1a**.

Since ethylene undergoes 2 + 2 cycloaddition in the required cis manner to negatively substituted cyclohexenones[3] which are photochemically activated, we attempted the addition of ethylene to 5,6-dihydro-4-methyl-2*H*-pyran-2-one[4] (**2**).

Indeed, when **2** was irradiated in benzene saturated and continuously swept with ethylene, the bicyclic lactone, 6-methyl-3-oxabicyclo[4.2.0]octan-2-one (**3**), was the major product. The reaction proceeds *via* a

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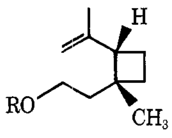
[1] (a) J. H. Tumlinson, D. D. Hardee, R. C. Gueldner, A. C. Thompson, P. A. Hedin, and J. P. Minyard, *Science*, **166**, 1010 (1969); (b) J. H. Tumlinson, R. C. Gueldner, D. D. Hardee, A. C. Thompson, P. A. Hedin, and J. P. Minyard, *J. Org. Chem.*, **36**, 2616 (1971).

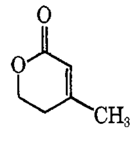
[2] R. L. Zurflüh, L. L. Dunham, V. L. Spain, and J. B. Siddall, *J. Amer. Chem. Soc.*, **92**, 425 (1970).

[3] W. C. Agosta and W. W. Lowrance, Jr., *Tetrahedron Lett.*, 3053 (1969). We are grateful to W. C. Agosta for providing a preprint.

[4] (a) A. L. Remizov and G. A. Tsetkova, *Chem. Abstr.*, **65**, 614*a* (1966); (b) Cornforth, *et al.*, *Tetrahedron*, **5**, 311 (1959).



1a, R = H
b, R = CH$_3$CO



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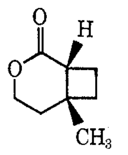

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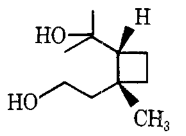

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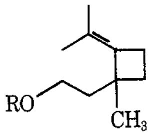
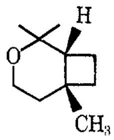


5a, R = CH$_3$CO
b, R = H



6

triplet state of **2** with a triplet energy (E_t) of 69–74 kcal since it is photosensitized by acetophenone (E_t = 74[5]) but not by benzophenone (E_t = 69[5]).

The addition of the lactone **3** to excess methyllithium (to minimize epimerization, catalyzed by lithium alkoxide, of the intermediate methyl ketone resulting from the addition of 1 equiv of methyllithium) at 0° resulted in the formation of the cis diol[1b] **4**, mp 87–87.5°. The minor amount of the trans diol[1b] (12–15%) also formed did not crystallize and was easily removed from the cis diol by recrystallization. Selective removal of the tertiary hydroxyl group of **4** in refluxing acetic anhydride yielded two isomeric acetates, **1b** and **5a**, in a 2:1 ratio (90% yield).

Other methods of dehydration of the diol (neutral and acidic alumina in refluxing toluene, pyridine–POCl$_3$) produced the ether[2] **6** predominantly and gave a less favorable ratio of **1a**:**5b** than the acetic anhydride method. Preliminary esterification of the primary hydroxyl group in pyridine–acetic anhydride prevented the formation of the ether but gave a 45:55 and a 50:50 ratio of **1b**:**5a** using pyridine–POCl$_3$ and dimethyl sulfoxide (160°), respectively.

Thermal decomposition of isomer **1b** occurred to the extent of about 50% when the mixture of isomeric acetates **1b** and **5a** was distilled. Prior reduction of the acetates with lithium aluminum hydride and then distillation to separate the corresponding isomeric alcohols **1a** and **5b** prevented decomposition during distillation. The ir and pmr spectra of synthetic **1a** are identical with those of the natural product. In laboratory bioassays, synthetic **1a** elicited the same response as the natural material.

Experimental Section

Melting points were determined in an oil bath and are uncorrected. Infrared spectra were run in CCl$_4$ solution on a Beckman IR-5A spectrophotometer. Infrared peaks are reported as wavenumbers. The uv spectrum was recorded on a Beckman DK-2A spectrophotometer. All proton magnetic resonance spectra were run in CCl$_4$ on a Varian A-60 spectrometer. Chemical shifts are reported as δ (parts per million) relative to tetramethylsilane as an internal standard at 60 MHz. Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, Tenn.

5,6-Dihydro-4-methyl-2*H*-pyran-2-one (**2**).—Mevalonic acid lactone was prepared and dehydrated to **2** by the method of Remizov and Tsetkova.[4a] Using the method of Cornforth, *et al.*,[4b] to prepare mevalonic acid lactone, Engel and Byerley, Midwest Research Institute, Kansas City, Mo., prepared lactone **2** in 80% overall yield from 4 acetoxy-2-butanone. The pmr spectrum of **2** showed resonances at δ 1.92 (broad s, 3, olefinic CH$_3$), 2.32 (broad t, 2, J = 6 Hz, CH$_2$), 4.22 (t, 2, J = 6 Hz, CH$_2$O), 5.57 (m, 1, C=CH); ir 1720 cm^{-1} (C=O); uv 210 nm (ε 10,000).

6-Methyl-3-oxabicyclo[4.2.0]octan-2-one (**3**).—In a typical run a 3.8% solution of **2** with acetophenone (1.4%) in benzene saturated and continuously swept with ethylene was irradiated with a 450-W medium-pressure mercury-vapor lamp without filter. The reaction time varied from 12 to 48 hr for 90% consumption of **2** (by glpc analysis[6a]) according to the distillation cut of **2** being used. At the end of the irradiation period the benzene was removed by distillation and the residue was extracted with pentane to isolate **2**, acetophenone, and mainly the bicyclic lactone **3**. After distillation of several combined runs, **3** was isolated in 56% yield. Glpc analysis[6b] indicated 5–12% of another component with a retention time very close to that of **3**. The pmr spectrum of **3** showed resonances at δ 1.25 (s, 3, CH$_3$), 1.55–2.90 (complex multiplets), 4.10–4.50 (complex multiplet, 2, CH$_2$O), and most importantly no olefinic H; ir spectrum 2950, 1730 (C=O), 1385 (CH$_3$), 1265, 1075 cm^{-1}. An analytical sample was prepared by preparative glpc.[6c]

Anal. Calcd for $C_8H_{12}O_2$: C, 68.54; H, 8.63. Found: C, 68.60; H, 8.53.

***cis*-α-(2-Methyl-2-β-hydroxyethylcyclobutyl)-α-methylethanol** (**4**).—Under nitrogen 27.7 g (0.198 mol) of **3** was added during 1 hr, with stirring to an ice-cooled flask containing 410 ml (0.82 mol) of a 2 *M* methyllithium solution in ether. The mixture was stirred for another 1.75 hr and the excess methyllithium was decomposed with a saturated aqueous solution of ammonium chloride. After removal of the ether layer, the aqueous layer was further extracted with chloroform. The combined ether–chloroform fractions were concentrated *in vacuo*, and benzene was added and removed three times by distillaton to dry the diol product. A residue remained which weighed 34.3 g (theory 34.02 g) and when recrystallized from 50 ml of cyclohexane weighed 23.4 g and melted at 87–88.5°. A second recrystallization from cyclohexane did not change the melting point but yielded an odorless product, 22 g (65%), identical with the diol **4** prepared by the earlier method.[1b]

***cis*-2-Isopropenyl-1-methylcyclobutaneethanol Acetate** (**1b**).—A mixture of 29.0 g (0.168 mol) of diol **4** and 100 ml of acetic anhydride was refluxed and stirred for 4 hr. The excess anhydride was removed at 40 mm and the mixture of acetates remaining was quickly distilled, bp 89–94° (10 mm). The mixed acetates **1b** (67%) and **5a** (33%) were separated by distillation in an annular spinning band still. **5a** had bp 89.4° (9.2 mm); pmr spectrum δ 1.11 (s, 3, CH$_3$), 1.36 (broad s, 3, olefinic CH$_3$), 1.45 (m, 2, CH$_2$), 1.54–1.78 (m, 4, two CH$_2$, cyclobutane ring), 1.82 (s, 3, OCOCH$_3$), 2.31 (broad t, 2, J = 7 Hz, OCH$_2$CH$_2$), 3.92 (t, 2, J = 7 Hz, OCH$_2$); ir 1725 (C=O), 1383 (tertiary CH$_3$), 1358 cm^{-1} (olefinic CH$_3$). **1b** had bp 90.5° (8.0 mm); pmr spectrum δ 1.17 (s, 3, CH$_3$), 1.64 (s, 3, vinyl CH$_3$), 1.3–2.2 (broad m, 6, three CH$_2$), 1.92 (s, 3, OCOCH$_3$), 2.53 (broad t, 1, J = 8 Hz, methinyl H), 3.96 (t, 2, J = 7.5 Hz, OCH$_2$), 4.57 and 4.76 (broad s, 2, C=CH$_2$), ir 1730 (C=O), 1635 (C=CH$_2$), 1360 (olefinic CH$_3$), 887 cm^{-1} (C=CH$_2$). Under the conditions of the distillation [pot temperature 125° (8.0–9.5 mm), 55 hr], about 50% of isomer **1b** underwent thermal degradation. The yield of pure **5a** was 8.6 g (26%) and of **1b** was 9.2 g (28%).

Anal. Calcd for $C_{12}H_{20}O_2$: C, 73.43; H, 10.27. Found: for **1b**: C, 73.17; H, 10.13. Found for **5a**: C, 73.32; H, 10.38.

***cis*-2-Isopropenyl-1-methylcyclobutaneethanol** (**1a**) **and 2-Isopropylidene-1-methylcyclobutaneethanol** (**5b**).—Lithium aluminum hydride (3 g) was refluxed for 0.5 hr in 120 ml of dry ether. The mixture was cooled to 0° and the mixed acetates **1b** and **5a**, 9.2 g (0.047 mol) in 40 ml of dry ether, were added dropwise. The mixture was refluxed for 1 hr and cooled to 0°, and the excess hydride was decomposed with aqueous 10% sodium hydroxide. The white solids were removed by filtration, and the ether was dried over sodium sulfate and removed by distillation.

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(5) N. J. Turro, "Molecular Photochemistry," W. A. Benjamin, New York, N. Y., 1965.

(6) Gas chromatographic columns used were as follows: (a) 6 ft × 0.125 in. 20% Apiezon L on silanized 60/80 mesh Chromosorb W; (b) 12 ft × 0.125 in. 15% XE-60 on Gas-Chrom Q (60/80 mesh); (c) 15 ft × 0.25 in. 20% Apeizon L on silanized Gas-Chrom P (60/80 mesh). Mention of a commercial or proprietary product in this paper does not constitute an endorsement of this product by the USDA.

The undesired isomer **5b** was carefully removed by distillation on an annular spinning band still: bp 68° (1.0 mm); pmr spectrum δ 1.19 (s, 3, CH_3), 1.45 (broad s, 3, vinyl CH_3), 1.56 (m, 3, vinyl CH_3), 1.72–2.19 (m, 4, two CH_2), 2.42 (broad t, 2, J = 6 Hz, $HOCH_2\mathbf{CH_2}$), 3.57 (t, 2, J = 7.5 Hz, $HOC\mathbf{H_2}CH_2$), 3.77 (s, 1, $\mathbf{H}OCH_2CH_2$); ir spectrum 3300 (broad OH), 1350 cm^{-1} (sharp, olefinic CH_3). The desired isomer **1a** boiled at 73° (1.0 mm) and had spectra identical with those of the natural material.

Registry No.—1a, 28117-21-7; **1b,** 34502-18-6; **3,** 33194-47-7; **4,** 34566-68-2; **5a,** 34502-20-0; **5b,** 34502-21-1.

Diphenylacetylene from the Decomposition of 2,2-Diphenyl-1-tosylazoethylene[1]

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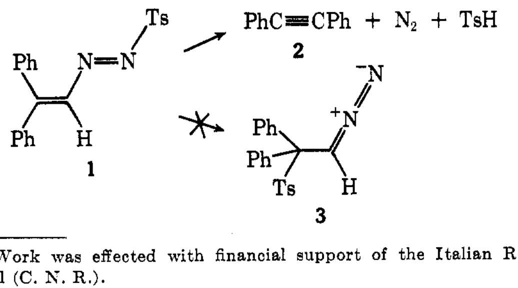
During the last few years we have investigated the chemistry of azoalkenes. In some reactions (1:4 additions,[2a] isomerizations[2b]) the S–N bond of tosylazoalkenes is retained, whereas in other cases (cycloadditions,[3] reactions with alcohols[4]) this bond is cleaved.

Earlier we reported the thermal degradation, at 90° in benzene and at 25° in chloroform, of aryl-substituted tosylazoalkenes having a vinylic proton on the carbon β to the azo group.[5] One degradation path apparently involves the formation of a vinylic carbonium ion which loses a proton from the adjacent carbon forming a triple bond as well as another principal path in which the tosylazoalkene rearranges to the corresponding α-tosyldiazo derivative which then undergoes acid-catalyzed decomposition.[5]

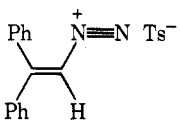
In order to extend our earlier studies, we have examined the thermal decomposition of 2,2-diphenyl-1-tosylazoethylene (**1**) which does not possess a proton on the vinylic carbon adjacent to the azo group.

In benzene at 90° and in chloroform[6] at 25°, **1** gives diphenylacetylene (**2**) as the main product (85–90%), nitrogen, and *p*-toluenesulfinic acid, without formation of 2-tosyl-2,2-diphenyl-1-diazoethane (**3**) or the decomposition products expected from **3** (Chart I).

Chart I



Although the detailed mechanism for the decomposition of **1** has not been established, it seems likely that the azoalkene gives rise to the diazonium ion pair **4** which may rearrange to **2** either in a concerted manner or through the formation of a vinylic carbonium ion[7–12] **5** or a divalent intermediate[9,13,14] **6**.



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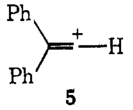

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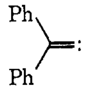

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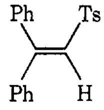
However, all attempts to trap intermediates such as **5** and **6** were unsuccessful. For example, compounds **7–9** (expected by-products from the carbonium ion **5**) were not detected in the reaction mixture.



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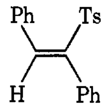

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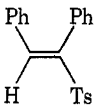

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Introduction of cyclohexene did not afford any carbenoid adducts. Thus if **5** or **6** are intermediates they are too short lived to undergo any intermolecular reactions.

Experimental Section

Melting points are uncorrected. Spectra were recorded on Beckman IR-5A, Unicam SP-800, and Minimar Jeolco spectrometers. Nmr spectra were recorded using TMS as internal standard. Microanalyses were performed using C, H, N Analyzer Model 185 of Hewlett-Packard Co. Diphenylacetaldehyde and tosylhydrazine are commercial materials. Analytical-grade solvents were purified by standard methods and distilled through a Vigreux column before use.

2,2-Diphenyl-1-tosylazoethylene (1).—Diphenylacetaldehyde (5.0 g, 2.5×10^{-2} mol) was dissolved in 200 ml of diethyl ether, and 4.0 g (2.5×10^{-2} mol) of bromide was added dropwise. The ethereal solution obtained was shaken with an aqueous solution of sodium carbonate and then washed several times with water. The ethereal solution was dried (Na_2SO_4), and the ether was evaporated. Part (2.0 g, 7.2×10^{-3} mol) of the crude 2-bromo-2,2-diphenylacetaldehyde was dissolved in 200 ml of ether, and 1.3 g (7.2×10^{-3} mol) of tosylhydrazine was added with magnetic stirring. When the solution turned red it was shaken with a saturated aqueous solution of sodium carbonate and then washed several times with water, dried (Na_2SO_4), filtered, and concentrated under reduced pressure at room temperature until precipitation of a yellow-orange product occurred. The crystals of 1 were collected, washed with *n*-hexane, and dried (yield 65%): mp 82° dec; uv max (Et_2O) 348 mμ (ε 20,400); ir (KBr) 3000 (vw), 1580 (m), 1550 (w), 1480 (w), 1440 (m), 1415 (s), 1335 (vs). 1290 (w), 1250 (w), 1210 (vw), 1185 (m), 1160 (vs), 1120 (vs), 1080 (vs), 1025 (w), 1015 (w), 985 (m), 928 (w), 878 (m), 830 (s), 810 (s); nmr (C_6D_6) δ 7.60 (s, 1, vinylic proton), 1.85 (s, 3, methyl of tosyl group).

Anal. Calcd for $C_{21}H_{18}N_2O_2S$: C, 69.61; H, 4.97; N, 7.73. Found: C, 69.57; H, 5.00; N, 7.75.

Decomposition of 2,2-Diphenyl-1-tosylazoethylene (1). **Route**

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[1] Work was effected with financial support of the Italian Research Council (C. N. R.).

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[3] W. Barbieri, L. Bernardi, P. Masi, L. Caglioti, and G. Rosini, *Tetrahedron Lett.*, 1343 (1970); W. Barbieri, L. Bernardi, P. Masi, A. Vigevani, L. Caglioti, and G. Rosini, *Tetrahedron*, in press.

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[5] G. Rosini and R. Ranza, *J. Org. Chem.*, **36**, 1915 (1971).

[6] Methanol-free chloroform was used.

[7] M. S. Newman, and A. E. Weinberg, *J. Amer. Chem. Soc.*, **78**, 4654 (1956).

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