The substrate was 3-azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose, obtained in 40% yield from 1,2:5,6-di-*O*-isopropylidene-3-*O*-(*p*-tolysulfonyl)-α-D-glucofuranose by nucleophilic displacement with sodium azide in hexamethylphosphoramide.[3] Synthesis of this azide was recently reported by this laboratory[4] using dimethylformamide as the solvent for the tolysulfonyloxy displacement. The disadvantage of the method was the 15 days required for disappearance of the starting material. In hexamethylphosphoramide, however, the reaction time is reduced to 18 hr. After extracting the products from the reaction mixture, silica gel column chromatography separates the azide from an olefinic by-product, 3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*erythro*-hex-3-enofuranose.

When a benzene solution of the azide is exposed to ultraviolet radiation for 18 hr, the starting material completely disappears, as indicated by the absence of azide absorption at 2150 cm^{-1}. The syrup obtained after concentration of the reaction mixture is refluxed with aqueous ether to convert the photoproduct, presumably the imine, to the ketone hydrate, isolated in 34% yield. The hydrate is a crystalline compound,[5] whereas the ketone, 1,2:5,6-di-*O*-isopropylidene-α-D-*ribo*-hexofuran-3-ulose, is a syrup.

An authentic sample of the ketone was prepared according to the method of Sowa and Thomas,[6] by oxidation of 1,2:5,6-di-*O*-isopropylidene-α-D-glucofuranose with methyl sulfoxide in the presence of acetic anhydride. This ketone on conversion to the hydrate was identical with the photoproduct derivative.

Experimental Section

Irradiations with unfiltered ultraviolet light were conducted using a Hanovia 200-W low-pressure mercury lamp (654A36) inserted into a water cooled quartz immersion well. Melting points were measured on a Fisher-Johns apparatus and are corrected. Infrared spectra were obtained with a Perkin-Elmer Model 337 spectrophotometer.

3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose.—To a solution of 1,2:5,6-di-*O*-isopropylidene-3-*O*-(*p*-tolysulfonyl)-α-D-glucofuranose (4.14 g, 0.01 mol) in 50 ml of hexamethylphosphoramide heated to 120° is added, with stirring, sodium azide (5.2 g, 0.08 mol). After 18 hr the reaction mixture is cooled to 25° and transferred with the aid of 25 ml of water to a Friedrich liquid–liquid extractor and extracted with 250 ml of hexane. After 12 hr, the hexane extract is washed 4 times with 250-ml portions of water to remove the small remaining quantity of hexamethylphosphoramide. The hexane extract is dried over anhydrous sodium sulfate and filtered. The filtrate is concentrated to a syrup and chromatographed over a silica gel column (4 × 65 cm) using benzene–ethyl acetate (20:1 v/v) as eluent. Only two carbohydrate components are present in the reaction mixture and in the column eluate as determined by thin layer chromatography using benzene–ethyl acetate (6:1 v/v) as irrigant. The column fractions containing the faster moving olefin component are combined and concentrated to a syrup, whereupon the residue spontaneously crystallized (0.75 g, 31%). It is recrystallized from hexane to give 3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-*erythro*-hex-3-enofuranose, mp 51° (lit.[7] mp 51°). The ir spectrum in Nujol shows a strong olefinic band at 1650 cm^{-1}. The slower moving azide fractions from the column are then collected and concentrated to a syrup. This is dissolved in 10 ml of hexane and left at 0° for 24 hr, whereupon 3-azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose crystallizes as long needles: mp 38–39°; $[\alpha]^{25}D$ +72° (*c* 1.0, chloroform); yield 1.14 g (40%).

Photolysis of 3-azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranose.—The above azide (4.85 g) in 1 l. of benzene was irradiated 18 hr after which the solution was concentrated and refluxed with aqueous ether (50 ml). After concentrating to dryness, the syrup was applied to a silica gel column and eluted with chloroform–acetone (15:1 v/v). Progress was followed by tlc and the fraction containing the ketone hydrate crystallized from ether–hexane: mp 113–114°; $[\alpha]^{25}D$ +45° (*c* 1.0, chloroform); yield 1.6 g (34%). R_f and ir values and mixture melting point were identical with those of an authentic sample. Elemental analysis agreed with calculated values.

Registry No.—3-Azido-3-deoxy-1,2:5,6-di-*O*-isopropylidene-α-D-allofuranonse, 21870-78-0.

(3) Y. Ali and A. C. Richardson, *J. Chem. Soc.*, 1764 (1968).
(4) U. G. Nayak and R. L. Whistler, *J. Org. Chem.*, **34**, 3819 (1969).
(5) P. J. Beynon, P. M. Collins, P. T. Doganges, and W. G. Overend, *J. Chem. Soc.*, 1131 (1966).
(6) W. Sowa and G. H. S. Thomas, *Can. J. Chem.*, **44**, 836 (1966).
(7) K. Freudenberg and F. Brauns, *Ber.*, 3233 (1922).

Synthesis of N-Carbobenzoxyamino Acid and Peptide Pentafluorophenyl Esters as Intermediates in Peptide Synthesis

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Recently we have shown that peptide bond formation, by use of active esters in the presence of triethylamine under conditions where oxazolones are not known to form, led to racemization *via* α-hydrogen abstraction.[1] Kinetic studies demonstrated the superiority of the pentafluorophenyl ester in the synthesis of peptides, where racemization by α-hydrogen abstraction can occur. N-Carbobenzoxy-S-benzyl-L-cysteine active esters were studied as to their relative rates of racemization and coupling, and it was found that the pentafluorophenyl ester could be coupled in better than 90% yield in 5 min with virtually no racemization.[2] Previous work had shown that there is no racemization when N-carbobenzoxyglycyl-L-phenylalanine pentafluorophenyl ester is coupled with glycine ethyl ester in the Anderson test.[3] The high reactivity of the pentafluorophenyl esters[2] indicates that these compounds can be used in the synthesis of peptide active esters in a variation of the mixed anhydride procedure. Thus a N-protected amino acid pentafluorophenyl ester can be coupled with a slowly reacting amino acid active ester, such as *p*-nitrophenyl ester, to yield N-protected dipeptide active ester.[2b] This variation of the "backing-off procedure"[4] can be helpful in preparing optically pure intermediates for high-molecular-weight sequential polypeptides. Peptide pentafluorophenyl esters can be prepared either by the "pentafluorophenol complex"[5] or through the mixed anhydride procedure;[6]

(1) (a) J. Jovacs, G. L. Mayers, R. H. Johnson, and U. R. Ghatak, *Chem. Commun.*, 1066 (1968); (b) Symposium Monograph of The First American Peptide Symposium, Yale University, 1968 (in press).
(2) (a) J. Kovacs, G. L. Mayers, R. H. Johnson, R. E. Cover, and U. R. Ghatak, *Chem. Commun.*, 53 (1970); (b) J. Kovacs, G. L. Mayers, R. H. Johnson, R. E. Cover, and U. R. Ghatak, *J. Org. Chem.*, **35**, 1810 (1970).
(3) L. Kisfaludy and J. Kovacs, Proceedings of the 8th European Peptide Symposium, Noordwijh, 1966, Macmillan, New York, N. Y., 1967.
(4) M. Goodman and K. C. Steuben, *J. Amer. Chem. Soc.*, **81**, 3980 (1959).
(5) J. Kovacs, L. Kisfaludy, and M. Q. Ceprini, *ibid.*, **89**, 183 (1967).
(6) (a) J. R. Vaughn, Jr., *ibid.*, **73**, 3547 (1951); (b) T. Wieland and H. Bernhard, *Justus Liebigs Ann. Chem.*, **572**, 190 (1951); (c) R. A. Boissonnas, *Helv. Chim. Acta*, **34**, 874 (1951).

TABLE I

N-CARBOBENZOXYAMINO ACID PENTAFLUOROPHENYL ESTERS

PFPOH ester	Registry no.	Method of prep- aration	Purification solvent	Mp, °C	$[\alpha]^{22}D$, deg	Formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
Z-Ala	25516-39-6	B	Hexane	84.0–85.0	−22.41 (*c* 2.12, EtOAc)	$C_{17}H_{12}NO_4F_5$	52.45	3.11	3.60	52.48	3.52	3.87
Z-Val	25529-25-3	A	EtOH–H_2O	50–51.5	−12.30 (*c* 2.00, EtOAc)	$C_{19}H_{16}NO_4F_5$	54.70	3.80	3.40	54.96	4.11	3.72
Z-DL-Val	17543-46-3		EtOH–H_2O	88–90						54.9	4.00	3.50
Z-Lys | Z	25529-27-5	A	$CHCl_3$–hexane	105–107	8.58 (*c* 2.25, EtOAc)	$C_{23}H_{25}N_2O_6F_5$	57.93	4.34	4.83	58.10	4.46	5.29
Z-Try	17543-50-9	A	$CHCl_3$–hexane	124–125	−26.4 (*c* 2.05, EtOAc)	$C_{25}H_{17}N_2O_4F_5$	59.53	3.40	5.55	60.02	3.38	5.94
Z-Met	17543-51-0	A	EtOH	104–106	−18.7 (*c* 2.00, EtOAc)	$C_{19}H_{16}NO_4SF_5$	50.78	3.59	3.12	50.41	3.94	3.20
Z-Phe	17543-49-6	A	EtOH	98–100	−26.67 (*c* 2.00, EtOAc)	$C_{23}H_{16}NO_4F_5$	59.40	3.60	3.00	59.54	3.71	3.26
Z-Ser	25529-31-1	A	EtOH	142.5–143.5	−16.25 (*c* 2.00, EtOAc)	$C_{17}H_{12}NO_5F_5$	50.38	3.00	3.46	50.33	3.11	3.49
Z-DL-Ser	17543-47-4		EtOH	140.5–141						50.50	3.20	3.70
Z-Pro	17543-45-2	B	Hexane–C_6H_6	Oil	−55.05 (*c* 2.00, EtOAc)	$C_{19}H_{14}NO_4F_5$	54.95	3.39	3.37	55.20	3.70	3.60
Z-Leu	25529-34-4	B	Hexane	Oil	−17.7 (*c* 2.00, EtOAc)	$C_{20}H_{18}NO_4F_5$	55.68	4.20	3.25	55.69	4.39	3.30
Z-Glu | O-Bu-*t*	25529-35-5	B	Hexane–C_6H_6	85–87	−16.5 (*c* 2.03, EtOAc)	$C_{23}H_{22}NO_6F_5$	54.87	4.41	2.99	54.73	4.54	2.78
Z-Ileu	25529-36-6	B	Hexane–C_6H_6	Oil	−13.5 (*c* 2.00, EtOAc)	$C_{20}H_{18}NO_4F_5$	55.68	4.20	3.25	55.53	4.15	3.12
Z-Glu | NH_2	17543-48-5	A	EtOH–H_2O	116–118	−10.94 (*c* 2.01, EtOAc)	$C_{19}H_{15}N_2O_6F_5$	51.20	3.40	6.30	51.59	3.68	6.55
Z-Asp-BZL	17543-13-4	A	EtOH	95.5–96	−9.85 (*c* 2.01, EtOAc)	$C_{25}H_{18}NO_6F_5$	57.37	3.46	2.68	57.10	3.52	2.83
Z-Arg | NO_2	17543-52-1	A	EtOH	98–99	−12.6 (*c* 2.15, EtOAc)	$C_{20}H_{18}N_5O_6F_5$	46.30	3.50	13.50	46.66	3.90	13.57
Z-Gly	16748-79-1	A	EtOH–H_2O	86–87		$C_{16}H_{10}NO_4F_5$	51.25	2.70	3.70	51.43	2.80	3.99
Z-Cys | BZL	25529-39-9	A	EtOAc–pentane	85–86	−25.6 (*c* 2.00, EtOAc) −40.0 (*c* 2.05 THF) −24.95 (*c* 2.00, $CHCl_3$)	$C_{24}H_{18}NO_4SF_5$	56.36	3.55	2.74	56.40	3.61	2.84
Z-Asp-O-*t*-Bu	25529-40-2	B	Hexane–C_6H_6	76.5–77.5	−43.1 (*c* 2.00, $CHCl_3$)	$C_{22}H_{20}NO_6F_5$	53.99	4.22	2.93	53.12	4.04	3.16

thus N-carbobenzoxyglycine was coupled with S-benzyl-L-cysteine pentafluorophenyl ester to give the corresponding dipeptide active ester. Such peptide pentafluorophenyl esters are very important for the synthesis of sequential polypeptides.[2]

The above considerations suggested the merit of reporting the preparation of several important N-carbobenzoxy-L-amino acid pentafluorophenyl esters. Similar to the pentachlorophenyl esters,[7] N-carbobenzoxyamino acid pentafluorophenyl esters were most conveniently prepared by the use of dicyclohexylcarbodiimide. Several of the pentafluorophenyl ester derivatives were difficult to prepare in a pure state since these esters are low melting, very soluble in all organic solvents, and hydrolyze in the presence of water. However, this does not reduce their usefulness in peptide synthesis since the crude ester can be used in coupling to give the corresponding optically pure peptides in high yield.[8] To obtain the latter esters analytically pure, the synthesis and purification had to be carried out using anhydrous reagents and solvents in an inert atmosphere. Table I summarizes the reaction conditions for the preparation of N-carbobenzoxyamino acid pentafluorophenyl esters with the corresponding physical constants and analysis.

Experimental Section

Melting points were taken on a Thomas–Hoover melting point apparatus in open capillaries and are uncorrected. Optical rotations were determined on a Rudolph spectropolarimeter Model 80. Infrared spectra were taken on a Beckman IR-8. Elemental analysis were performed by Schwartzkopt Microanalytical Laboratory, Woodside, N. Y., or Alfred Bernhardt Mikroanalytisches Laboratorium, West Germany.

Reagents.—Hexane (reagent grade) was treated with sulfuric acid and passed through a column of basic alumina (Woelm aluminum oxide activity grade I). Ethyl acetate (reagent grade) was placed over anhydrous potassium carbonate for several days, filtered, and distilled from phosphorus pentoxide. Chloroform (reagent grade) was washed with sulfuric acid, six times with half its volume of water, dried over anhydrous calcium chloride for at least 24 hr, filtered, and distilled from phosphorous pentoxide. Benzene (thiophene free, Fisher Scientific) was distilled from sodium. Silica gel (Merck) (0.05–0.20 mm) was heated at least 4 hr at 100° and cooled in an inert anhydrous atmosphere before use. Pentafluorophenol was obtained from Aldrich and used as supplied.

Synthesis of Amino Acid Pentafluorophenyl Esters. Method A.—An N-protected amino acid (10 mmol) and pentafluorophenol (10 mmol) were dissolved in 75 ml of ethyl acetate and the solution was cooled to 0°. Dicyclohexylcarbodiimide (10 mmol), dissolved in 10 ml of ethylacetate, was added, and the reaction mixture was stirred at 0°. After 1 hr the dicyclohexylurea was removed by filtration and the solvent was removed *in vacuo*. The resulting N-protected amino acid pentafluorophenyl ester was recrystallized from the appropriate solvent. The recrystallization solvent and physical data are reported in Table I.

Method B.—The synthesis described in method A and the isolation of the pentafluorophenyl ester was carried out in an inert atmosphere using anhydrous solvents. Since these esters were difficult to purify by recrystallization because of their high solubility in organic solvents, it was necessary to purify them for analysis by column chromatography in silica gel. To avoid hydrolysis during the chromatography the silica gel and all glassware were heated in the oven at 100° for at least 4 hr and then quickly removed to an inert atmosphere to cool. After removal of the dicyclohexylurea by filtration and removal of the solvent *in vacuo*, the residue was dissolved in 5 ml of hexane and placed on the silica gel column. The column was prepared with 20 g of silica gel suspended in hexane (13 × 2 cm). The eluates were collected and monitored by thin layer chromatography. Fractions that contained the pentafluorophenyl ester were combined and evaporated to dryness. The solid residues were triturated with pentane and filtered. All samples prepared in this manner gave one spot on thin layer chromatography and were shipped under nitrogen for analysis.

N-Carbobenzoxyglycyl-L-phenylalanine Pentafluorophenyl Ester.—To a solution of dicyclohexylcarbodiimide (0.206 g, 1

(7) J. Kovacs, M. Q. Ceprini, C. A. Duprez, and G. N. Schmit, *J. Org. Chem.*, **32**, 3696 (1967).

(8) For example, crude N-carbobenzoxy-nitro-arginine pentafluorophenyl ester can be coupled to valyl-tyrosyl-isoleucyl-histidyl-prolyl phenylalanine methyl or *t*-butyl ester in 90% yield: unpublished work of U. R. Ghatak and V. R. Giannasio.

mmol) in 4 ml of ethyl acetate, pentafluorophenol (0.558 g, 3 mmol) in 4 ml of ethyl acetate was added at 0°, and after 5 min N-Carbobenzoxyglycyl-phenylalanine (0.356 g, 1 mmol) in 20 ml of ethyl acetate was added. After the reaction mixture was stirred for 1 hr at 0°, the dicyclohexylurea was filtered and the mother liquor evaporated to dryness. The resulting oil was dissolved in ethyl acetate and residual dicyclohexylurea was filtered. After removal of the solvent *in vacuo*, the dipeptide active ester was obtained in 92% yield (0.482 g), mp 96–98°. For analysis it was crystallized from ethanol–water: mp 96–98°, $[\alpha]^{23}D$ −10.5° (*c* 1.0, $CHCl_3$). This compound prepared by the "backing-off" procedure gave the same physical constants.

Anal. Calcd for $C_{25}H_{19}N_2O_5F_5$: C, 57.47; H, 3.67; N, 5.36. Found: C, 57.23; H, 3.86; N, 5.69.

N-Carbobenzoxyglycyl-S-benzyl-L-cysteine Pentafluorophenyl Ester.—N-Carbobenzoxyglycine (1.045 g, 5 mmol) was dissolved in 13 ml of ethyl acetate containing (0.55 ml, 5 mmol) N-methyl morpholine, and isobutyl chloroformate (0.7 ml, 5.3 mmol) was added at −20°. After stirring the reaction mixture at −20° for 15 min, *S*-benzyl-L-cysteine pentafluorophenyl ester hydrobromide (2.289 g, 5 mmol), which had been prepared in the usual manner from the corresponding N-carbobenzoxy derivative, and triethylamine (0.7 ml, 5 mmol) were added. After stirring the reaction mixture for 30 min at −20° and 1 hr at 0°, it was diluted with 13 ml of ethyl acetate and washed with 13 ml of 1 *N* hydrochloric acid, 15 ml of 5% sodium bicarbonate solution, twice with 20 ml of 1 *N* hydrochloric acid, thrice with 20 ml of water, and dried over anhydrous sodium sulfate. The solvent was removed *in vacuo* and the oily residue (3.39 g, 60%) was dissolved in ether and placed in the freezer. The crystalline product was filtered and washed with ether and pentane, yield 2.50 g (44%), mp 74–80°. Recrystallization from ether–pentane raised the mp to 84–85°, $[\alpha]^{22}D$ −30.74° (*c* 2.04, ethyl acetate).

Anal. Calcd for $C_{26}H_{21}O_5N_2SF_5$: C, 54.93; H, 3.72; N, 4.93; S, 5.64. Found: C, 54.73; H, 3.75; N, 5.20; S, 6.04.

Registry No.—N-Carbobenzoxyglycyl-L-phenylalanine pentafluorophenyl ester, 14131-93-2; N-carbobenzoxyglycyl-S-benzyl-L-cysteine pentafluorophenyl ester, 25529-42-4.

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Reduction of Olefins Using Sodium–Hexamethylphosphoramide–*t*-Butyl Alcohol[1]

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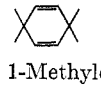
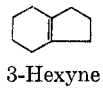
Nonconjugated alkenes and polyalkylated aromatic compounds are resistant to reduction by dissolving metals in liquid ammonia.[3–6] Solutions of lithium in certain alkylamines reduce some nonconjugated monoolefins and alkylbenzenes, but reaction is slow and yields are variable.[7] During the course of other work, we found that solutions of sodium hexamethylphosphoramide (HMPA) containing *t*-butyl alcohol were capable of effecting reduction of hexamethylbenzene not only to 1,2,3,4,5,6-hexamethylcyclohexa-1,4-diene, but also to the corresponding hexamethylcyclohexene and -hexane.[8,9] The observation of the latter products suggested that HMPA–sodium–*t*-butyl alcohol might be effective in reducing other unactivated alkenes. Here we wish to describe experiments indicating that this reducing mixture provides a convenient and general method of saturating even tetraalkyl substituted carbon–carbon bonds.[11]

Table I lists the yields of products detected on reaction of several representative unsaturated compounds with ~2–4 equiv of sodium in HMPA–*t*-butyl alcohol at room temperature over periods of 6–24 hr. The yields of reduced product in these reactions are generally high. The relatively low yields observed for the reduction of norbornene and 3,3,6,6-cyclohexa-1,4-diene represent isolated yields, and should be considered minimum values: with attention to detail during the work-up procedures, it should be possible to increase these numbers significantly. Similarly, the conversion

TABLE I

REDUCTION OF OLEFINS WITH SODIUM–HEXAMETHYLPHOSPHORAMIDE–*t*-BUTYL ALCOHOL

Starting material	Product	Yield, %[a]
1-Hexene	*n*-Hexane	98
Methylenecyclohexane	Methylcyclohexane	100
trans-3-Hexene	*n*-Hexane	97
Cyclohexene	Cyclohexane	99
Norbornene	Norbornane	73[b]
		>40[b,c]
1-Methylcyclohexane	Methylcyclohexene	100
	*trans*-Decalin	91
	cis-Decalin	3
	*trans*-Hexahydroindan	(73)[d]
	cis-Hexahydroindan	(27)[d]
3-Hexyne	Hexane	79
	trans-3-Hexene	14
Norcarane	1-Methylcyclohexane	Trace[e]

[a] Unless noted otherwise, yields were determined by glpc using internal standard techniques. Products were identified by comparison of mass spectra with those of authentic samples. [b] Isolated yield. [c] No effort was made to maximize this yield (see Experimental Section). [d] Relative yields. [e] >95% norcarane was observed at the end of the reaction. 1-Methylcyclohexane (<1%) was identified by glpc retention time only.

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(2) National Science Foundation Trainee, 1965–1966; National Institutes of Health Predoctoral Fellow, 1966–1969.

(3) A. J. Birch, *Quart. Rev. (London)*, **4**, 69 (1950); A. J. Birch and H. Smith, *ibid.*, **12**, 17 (1958).

(4) H. O. House, "Modern Synthetic Reactions," W. A. Benjamin, New York, N. Y., 1965, Chapter 3.

(5) T. J. King, *J. Chem. Soc.*, 898 (1951).

(6) H. Boer and P. M. Duinker, *Recl. Trav. Chim. Pays-Bas*, **77**, 346 (1958); J. D. Brooks, R. A. Durie, and H. Silberman, *Aust. J. Chem.*, **17**, 55 (1964).

(7) For examples, see (a) R. A. Benkeser, C. Arnold, R. F. Lambert, and O. H. Thomas, *J. Amer. Chem. Soc.*, **77**, 6042 (1955); (b) R. A. Benkeser, R. E. Robinson, D. M. Sauve, and O. H. Thomas, *ibid.*, **77**, 3230 (1955); (c) R. A. Benkeser, *et al.*, *J. Org. Chem.*, **29**, 1313 (1964); (d) R. A. Benkeser, M. L. Burrous, J. J. Hazdra, and E. M. Kaiser, *ibid.*, **28**, 1094 (1963); (e) R. A. Benkeser, J. J. Hazdra, R. F. Lambert, and P. W. Ryan, *ibid.*, **24**, 854 (1959).

(8) G. M. Whitesides and W. J. Ehmann, *J. Amer. Chem. Soc.*, **91**, 3800 (1969).

(9) The initial stimulus to examine sodium–HMPA–*t*-butyl alcohol as a reducing system originated in studies of the reduction of α,β-unsaturated ketones carried out by Dr. Roger Giese and Professor H. O. House in this department.[10] We are indebted to Drs. Giese and House for advice concerning this system.

(10) K. W. Bowers, R. W. Giese, J. Grimshaw, H. O. House, N. H. Kolodny, K. Kronberger, and D. K. Roe, *J. Amer. Chem. Soc.*, **92**, 2783 (1970); H. O. House, R. W. Giese, K. Kronberger, J. P. Kaplan, and J. F. Simeone, *ibid.*, **92**, 2800 (1970).

(11) For reviews of HMPA as a solvent for reductions, see H. Normant, *Angew. Chem., Int. Ed. Engl.*, **6**, 1046 (1967); H. Normant, *Bull. Chim. Soc. Fr.*, 791 (1968); H. Normant, T. Cuvigny, J. Normant, and B. Angelo, *ibid.*, 1561 (1965); and ref 10.