Table III. Crystal and Experimental Data

molecular formula: $C_{28}H_{20}O_4$
molecular weight: 420.5
habit: monoclinic prisms
radiation: Cu Kα (graphite monochromator)
wavelength: 1.5418 Å
space group: $P2_1$ (No. 4)
cell dimensions (from least-squares refinement of plus/minus data)
a = 9.4212 (9) Å
b = 11.1806 (10) Å
c = 10.8498 (14) Å
β = 100.309 (11)°
V = 1124.4 Å^3
Z = 2
D_m = 1.22 (2) g cm^{-3}
D_x = 1.243 g cm^{-3}
crystal size: 0.3 × 0.2 × 0.2 mm^3
reflections: 2318 (304 unobserved: 1σ)
maximum (sin θ)/λ: 0.62 Å^{-1}
diffractometer: Enraf-Nonius CAD-4
least-squares weighting: after Peterson and Levy[20]
function minimized: $\Sigma w(F_o - F_c)^2$
Anisotropic temperature factor:
$\exp[-2\pi^2\Sigma_i\Sigma_j U_{ij}h_ih_ja_i^*a_j^*]$
Final R factor (observed reflections only): 3.3%

oil with benzene, cooling in ice, and filtration gave 0.33 g of tetraphenylethylene, identical with an authentic sample. Addition of hexane to the resulting mother liquor and cooling at −5 °C gave two crops of pale yellow solid (total 7.0 g, 51%). Recrystallization of this material from benzene–hexane gave pure 9,9-diphenylbicyclo[6.1.0]nonatriene as colorless prisms: mp 107–108 °C (5.9 g); NMR ($CDCl_3$) δ 7.19 (10 H, m), 6.06 (4 H, d, J = 3.1 Hz), 5.82 (2 H, s br), 3.35 (2 H, s, br); mass spectrum m/e 270 (P, 12), 181 (100).

X-ray Analysis of 12. Details of the experimental results are given in Table III. The X-ray intensity data were collected by standard techniques and Lorentz and polarization corrections were applied by local programs. No absorption corrections were made or deemed necessary. The space group, given the molecular formula, could not be assigned unambigously to either $P2_1$ or $P2_1/m$ but the intensity statistics suggested the lower symmetry. Assuming space group $P2_1$, the phase problem was attacked by using MULTAN[16,17] and a unique solution was obtained which showed most of the heavier atoms. Further refinement was routine and the final R factor of 3.3% confirmed the choice of space group. The nonhydrogen atoms were refined with anisotropic thermal parameters and the hydrogen atoms with isotropic parameters. The scattering factors used were those provided in XRAY 72[18] which was used for all calculations not mentioned explicitly. The atomic and thermal parameters are available on request from the authors. Figure 1 shows the molecule in its crystal conformation and Figure 2 the molecular packing.

After the final refinement, a reading of French and Wilson's paper[19] on the estimation of "unobserved" intensities suggested that the data might be useful as a test for the techniques described therein. Accordingly all F values were recalculated by using the equations given by French and Wilson and refined treating all reflections as observed. The R factor was somewhat higher, 3.9%, and the standard deviations of bond lengths marginally better. With the standard technique, which uses "unobserved" reflections only if they calculate higher than the cutoff level (here 1σ), the standard deviations ranged from 0.0025 to 0.0057 Å, and with values estimated by the French and Wilson technique, the range was 0.0024–0.0055 Å. It may be concluded that, for a crystal which has reasonably low thermal parameters and X-ray intensity data collected by modern diffractometric techniques, the standard method of treating "unobserved" intensities is entirely adequate.

Acknowledgment. The authors thank William Landis of NIH for the mass spectra on the compounds described and Dr. Herman Ziffer for providing access to the 220-MHz NMR spectrometer.

Registry No. 1, 262-89-5; 2, 71837-32-6; 4, 71837-33-7; 6, 71837-34-8; 7, 71837-35-9; 10, 71837-36-0; 11, 1924-29-4; 12, 1924-28-3; 13, 42788-51-2; 15, 71837-37-1; 16, 71837-38-2; dipotassium 1,2:5,6-dibenzocyclooctatetraenide, 71837-83-7; acetyl chloride, 75-36-5; acetone, 67-64-1; diphenyldichloromethane, 2051-90-3; tetraphenylethylene, 632-51-9; dilithium cyclooctatetraenide, 59391-85-4.

(16) Germain, G.; Main, P.; Woolfson, M. M. *Acta Crystallogr., Sect A* **1971**, *27*, 368.
(17) Main, P.; Woolfson, M. M.; Germain, G. "MULTAN-72, A Computer Program for the Automatic Solution of Crystal Structure"; Universities of York and Lourain, 1972.
(18) Stewart, J. M.; Kruger, G. J.; Ammon, H. L.; Dickinson, C.; Hall, S. R. "XRAY 72", Technical Report TR-192; Computer Center: University of Maryland, 1972.
(19) French, S.; Wilson, K. *Acta Crystallogr., Sect. B* **1978**, *34*, 517–25.

Stereochemistry of Cuprate Addition to 4-, 5-, and 6-Alkylcycloheptenones

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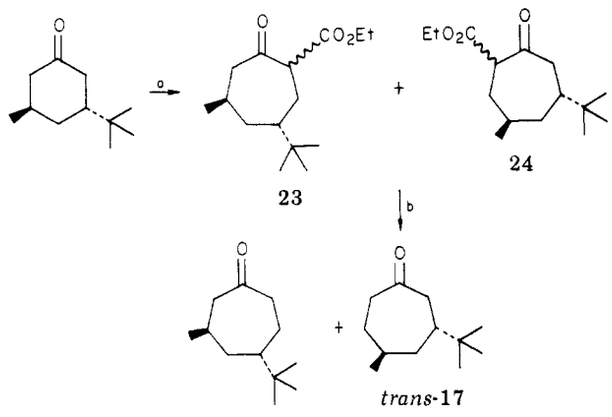
The reactions of cycloheptenones 1–7 with Me_2CuLi and $(t\text{-Bu})_2CuLi$ have been studied. Stereostructures of the resulting diastereomeric products have been determined by comparison with known compounds, by unambiguous synthesis, or by the use of ^{13}C NMR spectroscopy. Good stereoselectivity is observed in the reaction of Me_2CuLi with enones **2**, **4**, and **7** and in the reaction of $(t\text{-Bu})_2CuLi$ with enones **1**, **5**, and **6**.

During the course of our research to develop stereoselective syntheses of pseudoguaianolides, we became interested in the stereoselectivity of cuprate addition to substituted cycloheptenones. In principle, such a route might be used to establish the required relative stereostructure about the cycloheptane ring in guaianolides and pseudoguaianolides, provided suitably high stereoselectivity is realized. Although a large literature has accumulated describing the stereochemical outcome of 1,4-additions of organometallic reagents to a variety of substituted cyclohexenones,[1] no systematic study dealing with cycloheptenones has appeared. The facts that until recently substituted cycloheptenones have been difficult to prepare and that little is known regarding conformational preferences for cycloheptane rings may account for this lack of experimental investigation. In this paper, we describe the preparation of a number of monosubstituted

(1) See G. H. Posner, *Org. React.*, **19**, 1 (1972); see pp 18–22 and 31–43 for a review.

0022-3263/79/1944-4481$01.00/0

Chart I

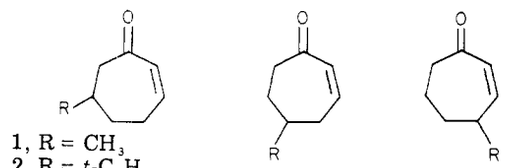


(a) N_2CHCO_2Et, $BF_3 \cdot OEt_2$; (b) H_3O^+, Δ

cycloheptenones and the stereochemistry of addition of several organometallic reagents to these enones.

Synthesis of Cycloheptenones

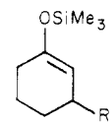
Cycloheptenones 1–3 were prepared from cyclohepta-2,6-dienone[2] by conjugate addition of an organometallic reagent. The known enones 4 and 5 were prepared as



1, R = CH_3
2, R = t-C_4H_9
3, R = CH_2=$C(CH_3)$

4, R = CH_3
5, R = t-C_4H_9

6, R = CH_3
7, R = t-C_4H_9



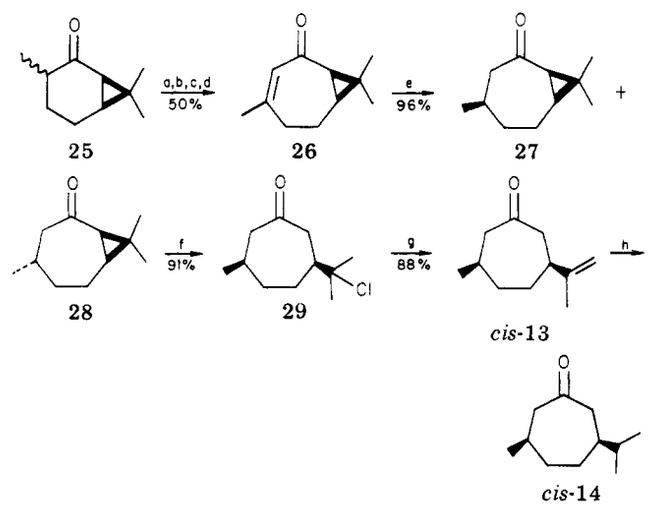
8, R = CH_3
9, R = t-C_4H_9

described by Saegusa and co-workers.[3] Compounds 6 and 7 were prepared by the Saegusa procedure[3] from silyl enol ethers 8[4] and 9, which are produced by silylation of the enolates obtained in the conjugate addition of the appropriate cuprate to cyclohexenone.

Conjugate Additions of Cuprate Reagents to Enones 1–7

Cuprate additions to enones 1–7 were carried out in the standard manner, employing either Me_2CuLi (prepared from commercial methyllithium and purified CuI) or (t-Bu)$_2$CuLi (prepared from commercial *tert*-butyllithium and the freshly recrystallized dimethyl sulfide complex of CuBr).[6] Reaction products were analyzed by ^{13}C NMR spectroscopy and (where possible) by gas chromatography. In all cases except two, both cis and trans diastereomeric products were produced. Diastereomer ratios were ascertained by comparison of peak heights of the ^{13}C NMR

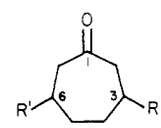
Chart II



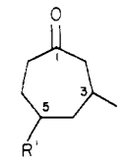
(a) Me_3SiCl, Et_3N, DMF; (b) CH_2I_2, Zn, CuCl, Et_2O; (c) $FeCl_3$, DMF, pyridine; (d) NaOAc, MeOH; (e) H_2, Pd/C, EtOH; (f) HCl, EtOH; (g) NaOAc, HOAc, 100 °C; (h) H_2, Pd/C

resonances of similar carbons in the two isomers. In most cases, we were able to assign specific resonances to the proper carbons using chemical shifts,[7] by analogy to previous assignments for related compounds, or the splitting pattern observed in the off-resonance decoupled spectrum. In all cases in which the two diastereomers are sufficiently resolved by GLC for a determination to be made, the GLC ratio was found to be identical, within experimental error, with the ^{13}C NMR derived ratio.

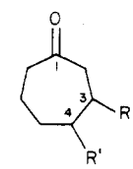
The assignment of stereostructure to the reaction products was accomplished primarily by ^{13}C NMR signal correlation. In some cases the spectra of authentic samples of known structure were available for comparison with the reaction product spectra. The spectrum of the minor diastereomer of the reaction products 15 was identical with



10, R = R′ = CH_3
11, R = CH_3; R′ = t-C_4H_9
12, R = R′ = t-C_4H_9
13, R = CH_2=$C(CH_3)$; R′ = CH_3
14, R = i-C_3H_7; R′ = CH_3



15, R = R′ = CH_3
16, R = CH_3; R′ = t-C_4H_9
17, R = t-C_4H_9; R′ = CH_3
18, R = R′ = t-C_4H_9



19, R = R′ = CH_3
20, R = CH_3; R′ = t-C_4H_9
21, R = t-C_4H_9; R′ = CH_3
22, R = R′ = t-C_4H_9

the published spectrum of *cis*-3,5-dimethylcycloheptanone.[8] Wolff-Kishner reduction of reaction products 19 affords a mixture of the known 1,2-dimethylcycloheptanes, ^{13}C NMR signals of which have been assigned

(2) E. W. Garbisch, *J. Org. Chem.*, **30**, 2109 (1965).
(3) (a) S. Murai, T. Aya, and N. Sonoda, *J. Org. Chem.*, **38**, 4354 (1973); (b) Y. Ito, S. Fujii, and T. Saegusa, *ibid.*, **41**, 2073 (1976). This reference, in which complete experimental details are not given, curiously refers to both 4 and 5 as "axial–equatorial mixtures". On the basis of our experience (see Experimental Section), the authors were probably dealing with a mixture of α,β- and β,γ-unsaturated enones in each case. It is not clear why this was not apparent from the IR spectra of their products.
(4) E. S. Binkley and C. H. Heathcock, *J. Org. Chem.*, **40**, 2156 (1975).
(5) G. H. Posner, *Org. React.*, **19**, 1 (1972); see page 110.
(6) H. O. House and J. M. Wilkins, *J. Org. Chem.*, **43**, 2443 (1978).
(7) J. B. Stothers, "Carbon-13 NMR Spectroscopy", Academic Press, New York, 1972.
(8) (a) J. D. Roberts and M. Christl, *J. Org. Chem.*, **37**, 3443 (1972); (b) J. D. Roberts, F. J. Weigert, J. I. Kroschwitz, and H. J. Reich, *J. Am. Chem. Soc.*, **92**, 1338 (1970).

Table I

enone	organomet reagent	reactn conditns[a]	product	purified yield, %	cis/trans composn
1	Me_2CuLi	A	10	85	50:50
1	$(t\text{-Bu})_2CuLi$	C	11	88	82:18
2	Me_2CuLi	A	11	84	20:80
2	$(t\text{-Bu})_2CuLi$	C	12	41	60:40
3	Me_2CuLi	A	13	98[b]	40:60
4	Me_2CuLi	B	15	74	10:90
4	$(t\text{-Bu})_2CuLi$	C	17	77	30:70
5	Me_2CuLi	D	16	83	30:70
5	Me_2CuLi	B	16	80	40:60
5	$(t\text{-Bu})_2CuLi$	C	18	65	85:15
6	Me_2CuLi	B	19	77	28:72
6	$(t\text{-Bu})_2CuLi$	C	21	38[c]	2:98
7	Me_2CuLi	D	20	70	3:97
7	$(t\text{-Bu})_2CuLi$	C	22	0	enolized[d]

[a] A, ether, 0 °C; B, THF, −15 °C; C, Me_2S, ether, −70 °C; D, ether, −15 °C. [b] Crude yield. [c] Purified yield, 55% conversion. [d] 75% recovered enone.

by Roberts and co-workers.[8]

The stereostructures of products **16** and **17** were determined by unambiguous synthesis from *trans*-3-*tert*-butyl-5-methylcyclohexanone[9] (Chart I). Ring expansion, via the β-keto esters **23** and **24**, affords a mixture of *trans*-**16** and *trans*-**17**. Products **13** were also identified by unambiguous synthesis, as summarized in Chart II. Saegusa ring expansion of (+)-carone[10] (**25**) to the bicyclic enone **26** proceeds without incident. Catalytic hydrogenation of **26** furnishes two diastereomeric ketones in a ratio of 95:5. Examination of molecular models shows clearly that the major isomer produced from this reaction must have the endo structure **27**. The mixture of **27** and **28** undergoes smooth ring opening upon treatment with ethanolic HCl to provide the crystalline chloro ketone **29**, which was transformed by standard methods into *cis*-**13** and then to *cis*-**14**.

Stereostructures for products **10**, **11**, **12**, **18**, **20**, and **21** were assigned by comparing the observed ^{13}C NMR spectra with calculated spectra. For products **20** and **21**, the spectra were calculated by adding appropriate α, β, and γ shift corrections for changing a methyl group to a *tert*-butyl group to the chemical shifts of the known isomers of **19**. Similar corrections were applied to the spectra of **15**, **16**, or **17** in order to predict the spectrum of the isomers of **18**. For **10**, **11**, and **12**, chemical shifts were predicted by applying the appropriate corrections to the known stereoisomers of **14**.[11]

Table I summarizes the results obtained in 14 conjugate additions which we examined. Table II contains the ^{13}C NMR chemical shifts of the 23 dialkylcycloheptanones produced from these reactions.

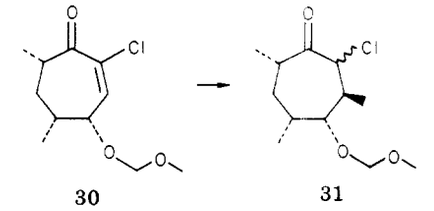
Discussion

Examination of Table I reveals that stereoselectivity ranges from excellent (**20**, **21**) through good (**1** → **11**, **2** → **11**, **15**, **18**) and fair (**16**, **17**, **19**) to poor (**10**, **12**). There are some puzzling aspects. For example, 6-methylcycloheptenone (**1**) reacts with $(t\text{-Bu})_2CuLi$ to give *cis*- and *trans*-**11** in a ratio of 4:1, while addition of Me_2CuLi to the corresponding *tert*-butyl enone **2** gives exactly the opposite ratio. A similar reversal is observed in reactions of the 5-alkylcycloheptenones. The methyl enone **4** reacts with Me_2CuLi and $(t\text{-Bu})_2CuLi$ to give predominantly the trans isomers of **15** and **17** (9:1 and 2.3:1, respectively). The *tert*-butyl analogue **5** also gives predominantly the trans isomer of **16** (2.3:1) with Me_2CuLi but the cis isomer of **18** (5.7:1) with $(t\text{-Bu})_2CuLi$.

Fortunately, we do observe some trends. First, the 4-alkyl enones **6** and **7** exhibit trans selectivity with both reagents, ranging from better than 49:1 in the addition of $(t\text{-Bu})_2CuLi$ to **6** down to only 2.6:1 in the addition of Me_2CuLi to this same enone. This high trans selectivity is probably steric in origin and is analogous to the trans selectivity which is observed in the addition of cuprates to 4-alkylcyclohexenones.[12] For the 5- and 6-alkylcycloheptenones, it is interesting that addition of $(t\text{-Bu})_2CuLi$ to a given enone always results in more cis adduct than addition of Me_2CuLi to the same enone.

The observed reversals of stereochemistry (vide supra) suggest that two distinct factors are at work. For the *tert*-butylcycloheptenones **5** and **7**, molecular models suggest that there is one lowest energy conformation in which the double bond and carbonyl group are coplanar. For these two compounds, it is possible that trans attack is favored on stereoelectronic grounds but that the trans face of the molecule is also more hindered than the cis. Thus, the smaller reagent Me_2CuLi gives predominantly trans stereochemistry, whereas $(t\text{-Bu})_2CuLi$ gives more cis product. For the methylcycloheptenones **1** and **4**, there appear to be at least two conformations of comparable energy, which complicates the picture to such an extent that we are unable to convincingly rationalize the observed results.

It is intriguing to note the recent synthesis of the Prelog–Djerassi lactone by Stork and Nair,[13] in which a cuprate reagent is added to cycloheptenone **30** to provide



30 **31**

intermediate **31** with high stereochemical purity. An examination of Table I shows that both the C_4-oxygen and

(9) This material is produced in 78% yield by the addition of $(t\text{-Bu})_2CuLi$ to 5-methylcyclohexenone. Only one stereoisomer is produced. It may confidently be assigned the trans stereochemistry on the basis of well-established precedent.[1]

(10) O. Wallach, *Justus Liebigs Ann. Chem.*, **279**, 366 (1894); I. M. Klotz, *J. Am. Chem. Soc.*, **66**, 88 (1944); W. G. Dauben, G. W. Shaffer, and E. J. Deving, *ibid.*, **92**, 6273 (1970).

(11) Full details for these correlations are contained in an appendix which is available as supplementary material.

(12) T. L. T. Ngoc and H. Rivière, *C. R. Hebd. Seances Acad. Sci., Ser. C*, **267**, 776 (1968); H. Rivière and J. Tostain, *Bull. Soc. Chim. Fr.*, 568 (1969).

(13) G. Stork and V. Nair, *J. Am. Chem. Soc.*, **101**, 1315 (1979).

Table II. ^{13}C NMR Chemical Shifts (ppm) of Dialkylcycloheptanones

compd	C-1	C-2	C-3	C-4	C-5	C-6	C-7	ring methyls	*t*-Bu methyls	quaternary
cis-10	212.1	50.8	29.2	33.9				20.9		
trans-10	212.1	51.7	31.1	37.9				23.7		
cis-11	213.0	49.6	28.6	35.4	25.7	45.4	44.8	20.3	26.8	33.2
trans-11	213.6	51.0	32.6	38.8	30.0	46.1	46.1	23.7	26.8	33.2
cis-12	[a]	45.4	44.4	26.8					27.0	33.5
trans-12	[a]	47.2	43.0	30.8					27.0	33.4
cis-13[b]	211.9	50.3	28.7	34.9	30.2	41.8	48.2	20.3[g]		
trans-13[c]	211.9	51.6	31.3	38.0	[a]	43.6	48.9	23.6		
cis-14[d]	213.0	50.6	28.9	32.2	29.2	40.8	47.0	21.0		
trans-14[e]	213.4	51.6	32.0	38.5	32.5	41.9	47.0	23.9		
cis-15[f]	213.5	51.7	30.6	47.9	35.5	32.2	42.5	23.8, 24.0		
trans-15	213.1	50.2	26.5	44.9[g]	29.8[h]	30.3[h]	40.7[g]	20.7, 21.1		
cis-16	214.1	51.6	31.7	40.4	50.7	24.7[g]	43.2	25.7[g]	27.2	33.3
trans-16	213.7	49.5	27.8	37.5	44.9[g]	24.7	43.3[g]	20.1	27.2	33.3
cis-17	213.9	45.1[g]	45.8[g]	39.9	36.1	31.6	41.9	24.0	26.8	[a]
trans-17	213.9	44.8	39.4[g]	36.4	29.6[h]	29.9[h]	39.6[g]	19.3	26.8	33.4
cis-18	215.3	45.8	46.1	33.8	51.6	32.4	42.1		27.0, 27.5	33.8
trans-18	213.3	45.0	41.4	29.3	43.5	22.6	43.3		27.1, 27.4	[a]
cis-19	213.9	48.5	33.4[g]	38.6	34.2[g]	21.3	43.7	16.3, 16.3		
trans-19	213.9	50.0	37.2[g]	41.6	36.3[g]	21.0	43.3	21.5, 21.5		
trans-20	213.3	46.5	28.4	54.7	26.2	22.1[g]	44.8	23.8[g]	27.1	34.3
cis-21[i]	[a]	38.3	46.4	28.7	34.2	20.6	43.5	17.9	27.2	[a]
trans-21	214.1	41.9	50.2	30.5	30.3	17.4	44.3	22.2	27.3	34.3

[a] Not observed. [b] Also 20.0,[g] 109.4, and 149.1. [c] Also 19.6, 109.0, and 148.5. [d] Also 19.1, 19.4, and 33.5. [e] Also 18.5, 18.9, and 34.9. [f] Reference 8a. [g,h] May be interchanged. [i] Tentative assignments.

the C_5-methyl should direct the incoming reagent to the opposite side of the molecule.

Experimental Section

Cuprous iodide was purified by the method of Kauffman and Teter.[14] Ether and tetrahydrofuran (THF) were distilled from $LiAlH_4$ or Na/benzophenone immediately prior to use. All cuprate reactions were conducted under a nitrogen atmosphere.

All boiling points are uncorrected. IR spectra were determined with a Perkin-Elmer Model 297 infrared recording spectrophotometer. ^1H NMR spectra were determined with a Varian Model T-60 or EM 390 NMR spectrometer. The chemical shift values are expressed in δ values relative to tetramethylsilane as an internal standard. Significant ^1H NMR data are tabulated in parentheses in the order (number of protons, multiplicity). ^{13}C NMR spectra were determined at 25.14 MHz on a Nicolet TT-23 spectrometer or at 45.28 MHz on the UCB 180 spectrometer. Chemical shifts are reported in ppm downfield from tetramethylsilane. Mass spectra were obtained with Atlas MS-12 and Consolidated 21-110B mass spectrometers. Mass spectra are given as m/e with relative intensities (percent of base peak) in parentheses. Ultraviolet spectra were measured on a Cary Model 118 ultraviolet spectrophotometer. Gas–liquid partition chromatography (GLC) analyses were performed on Varian Aerograph 920 and 940 analytical gas chromatographs. Preparative high-pressure liquid chromatography (LC) was conducted on a Waters Prep LC/System 500 using Porasil columns. Elemental analyses were performed by the Microanalytical Laboratory, operated by the College of Chemistry, University of California, Berkeley, CA.

6-Methylcyclohept-2-enone (1). Methylmagnesium iodide was prepared from 568 mg of magnesium turnings (23 mmol) and 1.44 mL of methyl iodide (23 mmol) in 20 mL of ether. The resulting solution was diluted with 40 mL of ether and cooled to 0 °C, and 160 mg of cuprous iodide (0.8 mmol) was added, followed by the dropwise addition of a solution of 2.0 g (18.5 mmol) of cyclohepta-2,6-dienone[2] in 40 mL of ether. The addition required 30 min. After addition was complete, the cooling bath was removed, and stirring was continued for 45 min, after which time the reaction mixture was slowly poured into 50 mL of rapidly stirring saturated NH_4Cl solution. A few milliliters of concentrated ammonia was added to facilitate dissolution of the copper salts. The phases were separated, and the aqueous phase was extracted with ether. The combined organic phase was washed with dilute ammonium hydroxide and saturated NaCl solution. After being dried over $MgSO_4$, the solvent was evaporated in vacuo to furnish 2.09 g (91%) of a yellow oil which was purified by high-pressure LC, eluting with 10% ether/hexane to obtain 1.04 g (45%) of pure enone 1: ^1H NMR (CCl_4) δ 6.48 (1 H, m), 5.79 (1 H, d, J = 12 Hz), 1.03 (3 H, d, J = 6 Hz); IR (neat) 2925, 1665 cm^{-1}; UV (95% EtOH) λ_{max} 228 nm (log ϵ 3.96); we were unable to obtain a satisfactory elemental analysis in repeated attempts; high-resolution mass spectrum m/e required for $C_8H_{12}O$ 124.0888, obsd 124.0891.

6-*tert*-Butylcyclohept-2-enone (2). Lithium *tert*-butylmethyl cuprate was prepared by first adding 34.5 mL of 1.8 M methyllithium in ether to a stirred suspension of cuprous iodide (11.9 g, 62.5 mmol) in 300 mL of dry ether at 0 °C. This yellow suspension was cooled to −60 °C, and 37.6 mL of *tert*-butyllithium (1.65 M in pentane) was added over a 45-min period. A solution of 6.10 g of cyclohepta-2,6-dienone[2] (56.5 mmol) in 50 mL of dry ether was then dropped into the cold (−60 °C) cuprate reagent over a 30-min period. The cooling bath was removed, and stirring was continued for 30 min. Workup was as described above for 1, with the exception that, after quenching with ammonium chloride, the whole mixture was filtered through Celite to remove the troublesome copper salts. The crude product was chromatographed on 200 g of silica (12% ether/hexane) to provide 3.97 g (42%) of pure enone 2: bp 63–65 °C (0.25 torr); ^1H NMR (CCl_4) δ 6.52 (1 H, m), 5.87 (1 H, d, J = 12 Hz), 0.95 (9 H, s); IR (neat) 2960, 1665, 1399, 1370 cm^{-1}; UV (95% EtOH) λ_{max} 229 nm (log ϵ 4.01). Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.53; H, 10.79.

6-Isopropenylcyclohept-2-enone (3). Isopropenylmagnesium bromide was prepared in 100 mL of dry THF from 1.35 g (55.6 mmol) of magnesium turnings and 7.28 g of isopropenyl bromide (60.2 mmol). The resulting solution was diluted with 100 mL of dry ether and cooled to −10 °C. Cuprous iodide (0.44 g, 2.3 mmol) was added, followed by 5.0 g of cyclohepta-2,6-dienone[2] (46.3 mmol) in 50 mL of ether over a 35-min period. After an additional 30 min, the reaction was worked up as described for the preparation of 1. The crude product (5.6 g, 80%) was distilled [short path, bp 61–65 °C (0.4 torr)] to afford 3.3 g (47%) of pure enone 3: ^1H NMR (CCl_4) δ 6.43 (1 H, m), 5.82 (1 H, d, J = 12 Hz), 4.68 (2 H, br s), 1.75 (3 H, br s); IR (neat) 2945, 1665 cm^{-1}; as with compound 1, we were unable to obtain satisfactory analytical values by combustion analysis; high-resolution mass spectrum, m/e required for $C_{10}H_{14}O$ 150.1045, obsd 150.1049; UV (95% EtOH) λ_{max} 228 nm (log ϵ 3.95).

5-Methylcyclohept-2-enone (4) and 5-*tert*-butylcyclohept-2-enone (5) were prepared as described by Saegusa and co-workers.[3] Compound 4, obtained in 51% overall yield from

(14) G. B. Kauffman and L. A. Teter, *Inorg. Synth.*, 7, 9 (1963).

4-methylcyclohexanone, was purified by column chromatography on silica gel: R_f 0.17 (hexanes/ether, 85:15); ^{1}H NMR (CCl_4) δ 6.42 (1 H, m), 5.84 (1 H, br d, J = 13 Hz), 1.02 (3 H, d, J = 5 Hz); IR (neat) 1662, 1452 cm^{-1}. Compound **5**, obtained in 42% overall yield from 4-*tert*-butylcyclohexanone, was purified by column chromatography on silica gel: R_f 0.17 (hexanes/ether, 85:15); ^{1}H NMR (CCl_4) δ 6.5 (1 H, m), 5.8 (1 H, br d, J = 13 Hz), 0.94 (9 H, s); IR (neat) 1660, 1360, 1392 cm^{-1}; UV (95% EtOH) λ_{max} 229 (log ϵ 4.01).

4-Methylcyclohept-2-enone (6). The procedure of Saegusa and co-workers[3b] was employed to prepare enone **6** from enol ether **8**.[4] Best yields are obtained if the intermediate 4-methyl-3-chlorocycloheptanone is dehydrochlorinated immediately after its preparation. A reflux period of 3 h is required for complete elimination. Crude **6** was purified by distillation [94–98 °C (7 torr)] to furnish 9.9 g (79.8 mmol, 66% from **8**) of pure enone **6**. The analytical sample was obtained by preparative GLC (8% SE-30, 10 ft × $^1/_4$ in., 130 °C): ^{1}H NMR (CCl_4) δ 6.20 (1 H, dd, J = 3, 12 Hz), 5.75 (1 H, dd, J = 1.5, 12 Hz), 1.09 (3 H, d, J = 9 Hz); IR (neat) 2930, 2860, 1658, 1450 cm^{-1}; mass spectrum, m/e (rel intensity) 124 (26), 96 (32), 81 (100), 68 (89), 67 (57), 39 (63). Anal. Calcd for $C_8H_{12}O$: C, 77.43; H, 9.68. Found: C, 77.16; H, 9.67.

4-*tert*-Butylcyclohept-2-enone (7). This material was prepared in a manner similar to that described for the preparation of **6**. The requisite silyl enol ether **9** was prepared from cyclohex-2-enone by the addition of *t*-BuMeCuLi,[5] followed by trapping of the enolate with chlorotrimethylsilane and triethylamine. After addition of cyclohexenone to the *t*-BuMeCuLi solution at −78 °C, the reaction mixture was centrifuged (−78 °C) and the supernatant decanted before the addition of Me_3SiCl and Et_3N. Compound **7** [bp 95–105 °C (bath temperature) (2.4 torr)] was obtained in 45% overall yield from cyclohexenone. An analytical sample was obtained by preparative GLC. Repeated attempts failed to achieve a satisfactory combustion analysis; however, the expected molecular formula was confirmed by high-resolution mass spectrometry. Furthermore, the IR, ^{1}H NMR, and mass spectra showed no evidence of contamination by other substances: ^{1}H NMR (CCl_4) δ 6.44 (1 H, dd, J = 4.5, 13 Hz), 5.87 (1 H, dd, J = 2.5, 13 Hz), 0.99 (9 H, s); IR (neat) 2960, 2760, 1670, 1394, 1368 cm^{-1}; UV (MeOH) λ_{max} 230 nm (log ϵ 4.03), 315 (1.73); mass spectrum, m/e (rel intensity) 166 (1.8), 110 (85), 95 (20), 57 (100); high-resolution mass spectrum, m/e required for $C_{11}H_{18}O$ 166.1358, obsd 166.1361.

General Procedure for the Addition of Cuprate Reagents to Cycloheptenones. Procedure A. The Me_2CuLi solution was prepared at 0 °C by adding 2.77 mL of 1.3 M methyllithium in ether (3.6 mmol) to a stirring suspension of 342 mg (1.8 mmol) of cuprous iodide in 15 mL of dry ether. The substrate (1.6 mmol) in 2 mL of ether was added dropwise over a 10-min period. After an additional 30 min at 0 °C, the reaction mixture was slowly poured into 50 mL of a rapidly stirring saturated ammonium chloride solution. A few milliliters of aqueous ammonia was added to facilitate dissolution of copper salts. The phases were separated, and the aqueous phase was extracted with ether. The combined organic layers were washed with dilute ammonia and brine and dried over $MgSO_4$. The solvent was removed in vacuo to provide the crude product.

Procedure B. The Me_2CuLi solution was prepared at −15 °C by adding 2.8 mL of 1.3 M methyllithium in ether (3.74 mmol) to a stirring suspension of 356 mg (1.87 mmol) of cuprous iodide in 22 mL of THF. The substrate (0.935 mmol) in 3 mL of THF was added dropwise over a 20-min period while the reaction temperature was maintained between −15 °C and −18 °C. After addition was complete, the cooling bath was removed, and the reaction mixture was allowed to warm to room temperature (approximately 30 min). The mixture was then poured into a mixture of 80 mL of ether and 80 mL of a 5:1 mixture of saturated ammonium chloride solution and concentrated aqueous ammonium hydroxide and cooled to 5 °C. The organic layer was further washed with saturated $NaHCO_3$ and brine, dried over $MgSO_4$, and concentrated in vacuo to obtain the crude product.

Procedure C. The $(t\text{-Bu})_2CuLi$ solution was prepared at −72 °C by adding 3.14 mL of 1.95 M *tert*-butyllithium in pentane (6.12 mmol) dropwise over a 30-min period to a stirring solution of 629 mg (3.06 mmol) of freshly recrystallized dimethyl sulfide–cuprous bromide complex[6] in a mixture of 5 mL of ether and 10 mL of dimethyl sulfide. The internal reaction temperature was carefully maintained below −70 °C throughout the addition. To the resulting orange solution was added dropwise a solution of 2.06 mmol of substrate in 2 mL of ether over a 10-min period. During the addition, the reaction temperature increased slightly but was maintained below −65 °C. The mixture was stirred at −60 °C to −70 °C for an additional 45 min and then was allowed to warm to 0 °C. The workup procedure was identical with that used for procedure B.

3,6-Dimethylcycloheptanones (10). Procedure A was followed with enone **1** to give 230 mg (100%) of a pale yellow oil, showing one spot on TLC (silica gel, 1:1 ether/hexane) and one peak by GLC (Carbowax 20M). Bulb-to-bulb distillation furnished 200 mg (85%) of material [bp 65 °C (bath temperature) (5 torr)] shown by ^{13}C NMR to be a 1:1 mixture of the cis and trans isomers: ^{1}H NMR (CCl_4) δ 1.03 (6 H, d, J = 6 Hz); IR (neat) 2950, 2920, 1695 cm^{-1}. Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 76.98; H, 11.42.

3-*tert*-Butyl-6-methylcycloheptanones (11). Procedure A was employed to convert 25.1 mmol of enone **2** into 4.46 g (98%) of an oil which was distilled by using a short-path still [bp 63–66 °C (bath temperature) (0.5 torr)] to afford 3.84 g (84%) of **11** as a 20:80 mixture of the cis and trans stereoisomers: ^{1}H NMR (CCl_4) δ 0.88 (9 H, s); IR (CCl_4) 2960, 2875, 1701, 1399, 1365 cm^{-1}. Anal. Calcd for $C_{12}H_{20}O$: C, 79.06; H, 12.16. Found: C, 79.27; H, 11.96.

Procedure C was followed to convert 1.61 mmol of enone **1** into 260 mg of pale yellow oil. The ^{13}C NMR spectrum of this material indicated that the same stereoisomers were present, in a cis/trans ratio of 82:18.

3,6-Di-*tert*-butylcycloheptanones (12). Procedure C was employed to convert 2.4 mmol of enone **2** into 390 mg (72%) of crystalline material. Chromatography on silica gel, eluting with 12:1 hexane/ether, provided 220 mg (41%) of compound **12** (mp 55.5–58.0 °C). The ^{13}C NMR spectrum of the purified material indicated the same cis/trans ratio as in the crude product (60:40). Repeated attempts to achieve separation of the stereoisomers by recrystallization were unsuccessful: ^{1}H NMR (CCl_4) δ 0.87 (18 H, s); IR (CCl_4) 2970, 2875, 1700, 1398, 1365 cm^{-1}. Anal. Calcd for $C_{15}H_{28}O$: C, 80.27; H, 12.55. Found: C, 80.31; H, 12.55.

3-Isopropenyl-6-methylcycloheptanones (13). Procedure A was employed to convert 3.3 mmol of enone **3** into 540 mg (98%) of pale yellow **13**. The crude product was shown to be of high purity by TLC (silica gel, 1:1 ether/hexane) and GLC (Carbowax 20M). An analytical sample was obtained by preparative GLC (10 ft × $^1/_4$ in., Carbowax 20M, 120 °C): ^{1}H NMR (CCl_4) δ 4.64 (2 H, br s), 1.70 (3 H, br s); IR (neat) 2925, 1700, 1642 cm^{-1}. Anal. Calcd for $C_{11}H_{16}O$: C, 79.46; H, 10.91. Found: C, 79.26; H, 10.93.

3,5-Dimethylcycloheptanones (15). Procedure B was employed with 0.76 mmol of enone **4**. The crude product was chromatographed on silica gel (12:1 hexane/ether) to furnish 73 mg (74%) of **15**, shown by ^{13}C NMR to be a 1:9 mixture of cis and trans stereoisomers. The ^{13}C NMR resonances of the minor component of this mixture were identical with those observed for an authentic sample of *cis*-3,5-dimethylcycloheptanone.[15] The major stereoisomer must therefore be the trans product: ^{1}H NMR (CCl_4) δ 0.97 (3 H, d, J = 7 Hz); IR (neat) 1695, 1455 cm^{-1}. Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.00; H, 11.38.

5-*tert*-Butyl-3-methylcycloheptanones (16). Procedure B was employed with 0.935 mmol of enone **5**. The crude product, 170 mg (100%) of a pale yellow oil, was purified by bulb-to-bulb distillation [110 °C (bath temperature) (2 torr)] to provide 136 mg (80%) of a colorless oil shown by ^{13}C NMR to be a 40:60 mixture of cis and trans stereoisomers. An analytical sample was obtained by GLC (8% SE-30, 5 ft × $^1/_4$ in., 150 °C): ^{1}H NMR (CCl_4) δ 1.02 (3 H, d, J = 7 Hz), 0.9 (9 H, s); IR (neat) 2950, 2860, 1703, 1398, 1365 cm^{-1}. Anal. Calcd for $C_{12}H_{22}O$: C, 79.06; H, 12.16. Found: C, 79.44; H, 11.92.

3-*tert*-Butyl-5-methylcycloheptanones (17). Procedure C was used with 0.98 mmol of enone **4**. The crude product was purified by silica gel chromatography, eluting with 10:1 hexane/ether, to obtain 138 mg (77%) of **17**. Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 192 °C, flow rate 0.5 mL/s) showed two isomers

(15) J. B. Hendrickson and R. K. Boeckman, Jr., *J. Org. Chem.*, **36**, 2315 (1971).

in a ratio of 30:70, with retention times of 6.1 and 6.8 min. ^{13}C NMR indicated that the cis and trans stereoisomers were present in a ratio of 30:70. An analytical sample was obtained by GLC: ^1H NMR (CCl_4) δ 0.96 (3 H, d, J = 7.5 Hz), 0.89 (9 H, s); IR (neat) 2960, 2875, 1702, 1397, 1363 cm^{-1}; mass spectrum, m/e (rel intensity) 182 (4.7), 129 (41), 111 (39), 57 (100); high-resolution mass spectrum, m/e required for $C_{12}H_{22}O$ 182.1671, obsd 182.1679.

Several attempts to obtain a satisfactory elemental analysis were unsuccessful. However, the IR, ^1H NMR, ^{13}C NMR, and mass spectra of the material exhibited no evidence of contamination.

3,4-Di-*tert*-butylcycloheptanones (18). Procedure C was employed with 2.06 mmol of enone **5**. The crude product was 420 mg (90%) of an oil, shown by ^{13}C NMR to be an 85:15 mixture of cis and trans isomers. Chromatography on silica gel (10:1 hexane/ether) provided 294 mg (65%) of pure **18**, of unchanged stereoisomer composition. An analytical sample was obtained by preparative GLC (8% SE-30, 5 ft × $^1/_4$ in., 200 °C): ^1H NMR (CCl_4) δ 0.91 (9 H, s), 0.88 (9 H, s); IR (neat) 2955, 2870, 1700, 1395, 1365, 1230 cm^{-1}. Anal. Calcd for $C_{15}H_{28}O$: C, 80.29; H, 12.16. Found: C, 80.56; H, 12.12.

3,4-Dimethylcycloheptanones (19). Procedure B was employed with 8.17 mmol of enone **6**. The crude adduct, shown by ^{13}C NMR to be a 28:72 mixture of cis and trans stereoisomers of **19**, was chromatographed on silica gel (10:1 hexane/ether) to give 880 mg of **17** (77%), with the same isomer ratio. Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 123 °C, flow rate 0.5 mL/s) showed two peaks in a ratio of 25:75 with retention times of 8.1 and 9.3 min. An analytical sample was prepared by GLC: ^1H NMR (CCl_4) δ 0.85–1.15 (6 H, complex multiplets); IR (neat) 2940, 2930, 1700, 1458 cm^{-1}. Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 76.86; H, 11.32.

A portion of this material was subjected to Wolff–Kishner reduction as follows. A solution of 224 mg (1.60 mmol) of mixed isomers of **19** and 2.06 g (2.0 mL, 41.2 mmol) of hydrazine hydrate in 8 mL of diethylene glycol was heated at 120 °C for 2.5 h. The solution was then cooled to 60 °C, 1.0 g (15 mmol) of 85% KOH was added, and a short-path still was attached to the reaction flask. The mixture was then heated to 210 °C over a 2-h period and maintained at this temperature for an additional 2 h. A total of 2 mL of distillate was obtained. This distillate was combined with the cooled reaction mixture, and the whole was partitioned between 90 mL of pentane and 100 mL of water. The organic phase was washed with 5% HCl, saturated $NaHCO_3$, and brine and then dried ($MgSO_4$). The solvent was removed by careful distillation through a Vigreux column to obtain 201 mg (100%) of a mixture of cis- and trans-1,2-dimethylcycloheptanes, contaminated with a small amount of the starting ketones. Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 121 °C, flow rate 0.5 mL/min) showed the two stereoisomers to be present in a ratio of 70:30 trans/cis, with retention times of 2.4 and 2.6 min, respectively. The ^{13}C NMR spectra of the two stereoisomers were consistent with values reported in the literature.[8a]

4-*tert*-Butyl-3-methylcycloheptanones (20). Procedure B was employed to convert 0.76 mmol of enone **7** to a crude product which was shown by ^{13}C NMR to be the nearly pure trans stereoisomer. Chromatography on silica gel (10:1 hexane/ether) afforded 96 mg (70%) of pure compound. Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 162 °C, flow rate 0.5 mL/s) showed two peaks in a ratio of 96:4 with retention times of 7.2 and 8.6 min. The analytical sample was obtained by GLC: ^1H NMR (CCl_4) δ 0.98 (3 H, d, J = 7 Hz), 0.90 (9 H, s); IR (neat) 2960, 2870, 1698, 1379, 1362 cm^{-1}. Anal. Calcd for $C_{12}H_{22}O$: C, 79.06; H, 12.16. Found: C, 79.32; H, 12.22.

3-*tert*-Butyl-4-methylcycloheptanones (21). Procedure C was employed with 1.95 mmol of enone **6**. The crude product was purified by chromatography on silica gel (10:1 hexane/ether) to furnish 128 mg (36%) of pure *trans*-**21**, as well as 46 mg (19%) of recovered enone **6**. Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 192 °C, flow rate 0.5 mL/s) of the crude product showed two components in a ratio of 98:2 with retention times of 6.9 and 7.7 min. The minor product, presumed to be the cis diastereomer, was lost in chromatography. We were unable to obtain a sufficient quantity of this diastereomer to record its ^{13}C NMR spectrum. An analytical sample was prepared by GLC: ^1H NMR (CCl_4) δ 1.0 (3 H, d, J = 5 Hz), 0.94 (9 H, s); IR (neat) 2965, 2875, 1704, 1465, 1380, 1362 cm^{-1}; mass spectrum m/e (rel intensity) 182 (1.8), 126 (45), 111 (96), 57 (100); high-resolution mass spectrum, m/e required for $C_{12}H_{22}O$ 182.1671, obsd 182.1667. Several attempts to achieve a satisfactory elemental analysis were unsuccessful. However, the compound was pure by all other indications.

***trans*-3-*tert*-Butyl-5-methylcyclohexanone.** Procedure C was followed to convert 5-methylcyclohexenone into the title compound, which was obtained in 78% yield after chromatography on silica gel (10:1 hexane/ether). Analytical GLC (15% SE-30, 10 ft × $^1/_8$ in., 162 °C, flow rate 0.5 mL/s) showed the trans and cis stereoisomers to be present in a ratio of 98:2, with retention times of 7.4 and 8.3 min. An analytical sample was obtained by GLC: ^1H NMR (CCl_4) δ 0.96 (3 H, d, J = 6 Hz), 0.92 (9 H, s); IR (neat) 2960, 2870, 1705, 1382, 1364 cm^{-1}. Anal. Calcd for $C_{11}H_{20}O$: C, 78.51; H, 11.98. Found: C, 78.36; H, 11.78.

Preparation of an Authentic Mixture of *trans*-5-*tert*-Butyl-3-methylcycloheptanone (*trans*-16) and *trans*-3-*tert*-Butyl-5-methylcycloheptanone (*trans*-17). To a solution of 518 mg (3.08 mmol) of *trans*-3-*tert*-butyl-5-methylcyclohexanone in 5 mL of ether at 2 °C was added 656 mg (0.568 mL, 4.62 mmol) of boron trifluoride etherate, followed by 527 mg (0.481 mL, 4.62 mmol) of ethyl diazoacetate, which was added dropwise over a 30-min period. The reaction mixture was allowed to warm to room temperature. After 6 h, the solution was partitioned between 125 mL of saturated $NaHCO_3$ and 150 mL of ether. The organic layer was washed with brine, dried ($MgSO_4$), and concentrated in vacuo to obtain 917 mg of material, shown by TLC to be a mixture of product and unreacted starting material. The product was resubmitted to exactly the foregoing procedure to obtain 1.275 g of yellow oil. This material was chromatographed on silica gel (10:1 hexane/ether) to give 233 mg (30%) of a mixture of β-keto esters **23** and **24**.

A solution of 126 mg (0.496 mmol) of this material in a mixture of 9 mL of glacial HOAc and 3 mL of 10% aqueous HCl was refluxed for 1.5 h and then cooled and extracted with 100 mL of ether. The aqueous layer was made basic with NaOH and extracted once again with 100 mL of ether. The combined ether extracts were washed with 5% NaOH, cold 5% HCl, saturated $NaHCO_3$, and brine. After being dried ($MgSO_4$), the ether was removed in vacuo to obtain 75 mg (83%) of a mixture of *trans*-**16** and *trans*-**17**, shown by ^{13}C NMR to be present in a ratio of 60:40.

4,8,8-Trimethylbicyclo[5.1.0]oct-3-en-2-one (26). Carone[10] (90 g, 0.592 mol) was added to a mixture of 72 g of chlorotrimethylsilane (0.66 mol) and 131 g (1.3 mol) of triethylamine in 220 mL of dry DMF. The mixture was refluxed for 18 h and then cooled to room temperature. The triethylamine hydrochloride was removed by suction filtration and the filter cake was washed with 300 mL of hexane. The combined hexane and DMF solutions were poured into a mixture of 500 mL of saturated $NaHCO_3$ solution and 500 mL of hexane. The aqueous phase was separated and extracted with hexane (2 × 250 mL). The combined organic layers were washed rapidly in succession with 250 mL of cold 1 N HCl and 250 mL of saturated $NaHCO_3$. After being dried ($MgSO_4$), the solvent was removed to give 129.5 g (98%) of a yellow oil which was distilled to furnish 120.3 g of the silyl enol ether [bp 47–48 °C (0.2 torr)]: ^1H NMR (CCl_4) δ 1.57 (3 H, s), 1.13 (3 H, s), 1.02 (3 H, s), 0.25 (9 H, s); IR (neat) 2925, 1682 cm^{-1}. Anal. Calcd for $C_{13}H_{24}OSi$: C, 69.58; H, 10.78. Found: C, 69.55; H, 10.89.

Zinc dust (61.2 g, 0.936 mol) and cuprous chloride (9.3 g, 94 mmol) were suspended in 1200 mL of dry ether and stirred at reflux for 1 h. Methylene iodide (223.0 g, 832 mmol) and 120 g (536 mmol) of the trimethylsilyl enol ether of carone were then added, and reflux was maintained for 40 h. After cooling to room temperature, the mixture was filtered through Celite and the filter cake washed with 500 mL of ether. The ether solution was washed with saturated NH_4Cl (4 × 150 mL), saturated $NaHCO_3$ (150 mL), and brine (150 mL). After being dried ($MgSO_4$), the solvent was removed in vacuo to yield 147.3 g (115%) of a pale yellow oil. This product contained unreacted methylene iodide as the principal contaminant. The crude product could be used directly in the next reaction.

During a similar preparation on a smaller scale, the pure product (4,8,8-trimethyl-2-[(trimethylsilyl)oxy]tricyclo-[5.1.0.0^{2,4}]octane) was obtained in 79% yield by simple distillation [bp 47–48 °C (0.2 torr)]: ^1H NMR (CCl_4) δ 1.13 (3 H, s), 1.07 (6 H, s), 0.42 (2 H, d, J = 0.5 Hz), 0.18 (9 H, s); IR (neat) 2950, 1458,

1380, 1360, 1252 cm^{-1}. A sample was further purified for elemental analysis by preparative GLC on Carbowax 20M (10 ft × $^1/_4$ in., 110 °C). Anal. Calcd for $C_{14}H_{26}OSi$: C, 70.52; H, 10.99. Found: C, 70.53; H, 10.92.

The crude product from the Simmons–Smith reaction (58.8 g, ca. 250 mmol) was dissolved with 19.54 g of pyridine (250 mmol) in 500 mL of DMF (distilled from CaH_2). This solution was added dropwise over a 3-h period to a stirred 0 °C solution of 120 g (740 mmol) of anhydrous ferric chloride in 500 mL of DMF. After the addition was complete, the mixture was stirred for an additional hour while warming to room temperature. The mixture was partitioned between 1000 mL of hexane and 1000 mL of cold 1 N HCl. The aqueous phase was extracted with hexane (2 × 500 mL), and the combined organic layers were washed with 1 N HCl (2 × 300 mL), saturated $NaHCO_3$ (300 mL), and brine (300 mL). The resulting solution was placed in a flask with 800 mL of MeOH and 85 g of NaOAc. The hexane was removed azeotropically, and portions of MeOH were later added to maintain a total volume of MeOH of 600 mL. After the reflux temperature of methanol was reached, heating was continued for 1 h. After cooling, the mixture was poured onto 800 g of ice and extracted with hexane (3 × 400 mL). The organic phase was washed with saturated $NaHCO_3$ and dried ($MgSO_4$) and the solvent removed to furnish 41.2 g (102%) of a light yellow oil. Fractionation of the mixture through a Vigreux column gave 12.2 g (35%) of pure enone **26**. Alternatively, when the reaction was performed on a smaller scale, chromatography on silica gel allowed more efficient purification of the enone, resulting in an isolated yield of 57%: ^1H NMR (CCl_4) δ 5.96 (1 H, br s), 1.90 (3 H, br s), 1.17 (3 H, s), 1.03 (3 H, s); IR (neat) 2945, 1640 cm^{-1}; UV (95% EtOH) λ_{max} 242 nm (log ϵ 4.02). Anal. Calcd for $C_{11}H_{16}O$: C, 80.44; H, 9.82. Found: C, 80.19; H, 9.73.

***endo*-4,8,8-Trimethylbicyclo[5.1.0]octan-2-one (27).** The cyclopropyl enone **26** (7.0 g, 42.6 mmol) was dissolved in 50 mL of 95% EtOH, and 400 mg of 10% Pd/C was added. The solution was stirred under a hydrogen atmosphere for 8 h, at which time the uptake of hydrogen had ceased. After removal of the catalyst by filtration, the solvent was evaporated in vacuo to afford 7.1 g (100%) of a pale yellow oil, homogeneous by GLC (SE-30); ^1H NMR (CCl_4) δ 1.05 (3 H, s), 1.00 (3 H, s), 0.93 (3 H, d, J = 7 Hz); IR (neat) 2950, 1695 cm^{-1}. Anal. Calcd for $C_{11}H_{18}O$: C, 79.46; H, 10.91. Found: C, 79.25; H, 10.85.

***cis*-6-Methyl-3-(2-chloro-2-methylethyl)cycloheptanone (29).** The cyclopropyl ketone **27** (1.49 g, 8.98 mmol) was added dropwise to a cold (0 °C) saturated solution of HCl in ethanol. After addition was complete, the cooling bath was removed and stirring was continued for 30 min. The solution was poured onto 25 g of ice, and the product was isolated by extraction with hexane (3 × 50 mL). The combined organic phase was washed with saturated $NaHCO_3$ (2 × 25 mL) and brine (25 mL) and dried ($MgSO_4$). Removal of solvent left 1.66 g of an oil which crystallized on standing. An analytical sample (mp 32.5–33.0 °C) was prepared by recrystallization from hexane at −60 °C: ^1H NMR (CCl_4) δ 1.53 (6 H, s), 0.95 (3 H, d, J = 6 Hz); IR (CCl_4) 2960, 1701 cm^{-1}. Anal. Calcd for $C_{11}H_{19}ClO$: C, 65.17; H, 9.45; Cl, 17.53. Found: C, 65.05; H, 9.36; Cl, 17.52.

***cis*-3-Isopropenyl-6-methylcycloheptanone (*cis*-13).** The chloro ketone **29** (1.60 g, 7.9 mmol) was added to a solution of 3.3 g of NaOAc in 25 mL of glacial HOAc. The mixture was heated in an oil bath at 100 °C for 1 h. After cooling, the product was partitioned between 25 mL of water and 25 mL of hexane. The aqueous phase was separated and extracted with hexane (3 × 25 mL). The combined organic layers were washed with saturated $NaHCO_3$ solution (2 × 25 mL) and brine (25 mL) and dried ($MgSO_4$), and the solvent was evaporated in vacuo. The crude product (1.30 g, 100%) was purified by bulb-to-bulb distillation [105–110 °C (bath temperature) (2.0 torr)] to obtain 1.15 g (88%) of a colorless oil. ^{13}C NMR revealed the presence of two compounds in a ratio of 4:1. The major product was *cis*-**13**. The minor component was not isolated in a pure form but is believed to be 3-isopropylidene-6-methylcycloheptanone.

6-Isopropyl-3-methylcycloheptanones (14). The mixture of 320 mg of alkenes **13** (obtained by the reaction of Me_2CuLi with enone **3**) in 5 mL of ethanol was stirred under a hydrogen atmosphere in the presence of 48 mg of 10% Pd/C. After 1 equiv of hydrogen was absorbed, the catalyst was removed by filtration and the solvent removed in vacuo to furnish 290 mg (91%) of a colorless oil, which was homogeneous by TLC and GLC. ^{13}C NMR indicated the product to be a 40:60 mixture of *cis*- and *trans*-**14**: ^1H NMR (CCl_4) δ 0.90–1.05 (9 H, overlapping Me doublets); IR (neat) 2960, 1695 cm^{-1}. A similar procedure was applied to pure *cis*-**13** to obtain pure *cis*-**14**. Anal. Calcd for $C_{11}H_{20}O$: C, 78.51; H, 11.98. Found: C, 78.40; H, 11.89.

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Registry No. 1, 71837-39-3; **2**, 71837-40-6; **3**, 71837-41-7; **4**, 71837-42-8; **5**, 71837-43-9; **6**, 71837-44-0; **7**, 71837-45-1; **8**, 55373-58-5; **9**, 71837-46-2; *cis*-**10**, 54396-54-2; *trans*-**10**, 56393-81-8; *cis*-**11**, 71885-43-3; *trans*-**11**, 71837-47-3; *cis*-**12**, 71837-48-4; *trans*-**12**, 71837-49-5; *cis*-**13**, 71837-50-8; *trans*-**13**, 71837-51-9; *cis*-**14**, 71837-52-0; *trans*-**14**, 71837-53-1; *cis*-**15**, 24291-91-6; *trans*-**15**, 71837-54-2; *cis*-**16**, 71837-55-3; *trans*-**16**, 71837-56-4; *cis*-**17**, 71837-57-5; *trans*-**17**, 71837-58-6; *cis*-**18**, 71849-75-7; *trans*-**18**, 71837-59-7; *cis*-**19**, 29584-58-5; *trans*-**19**, 29577-66-0; *cis*-**20**, 71837-60-0; *trans*-**20**, 71837-61-1; *cis*-**21**, 71837-62-2; *trans*-**21**, 71837-62-2; **23**, 71837-63-3; **24**, 71837-64-4; **25**, 497-62-1; **26**, 71837-65-5; **27**, 71837-66-6; **28**, 71883-61-9; **29**, 71837-67-7; methyl iodide, 74-88-4; cyclohepta-2,6-dienone, 1192-93-4; lithium *tert*-butylmethylcuprate, 58096-49-4; isopropenyl bromide, 557-93-7; 4-methylcyclohexanone, 589-92-4; 4-*tert*-butylcyclohexanone, 98-53-3; 4-methyl-3-chlorocycloheptanone, 71837-68-8; cyclohex-2-enone, 930-68-7; Me_2CuLi, 15681-48-8; $(t\text{-}Bu)_2CuLi$, 23402-75-7; *cis*-1,2-dimethylcycloheptane, 13151-51-4; *trans*-1,2-dimethylcycloheptane, 13151-50-3; 5-methylcyclohexanone, 591-24-2; *cis*-3-*tert*-butyl-5-methylcyclohexanone, 71837-69-9; *trans*-3-*tert*-butyl-5-methylcyclohexanone, 71837-70-2; carone trimethylsilyl enol ether, 71837-85-9; 4,8,8-trimethyl-2-[(trimethylsilyl)oxy]tricyclo-[5.1.0.$0^{2,4}$]octane, 71837-71-3.

Supplementary Material Available: A discussion of the method used to estimate ^{13}C NMR chemical shifts for dialkylcycloheptanones (5 pages). Ordering information is given on any current masthead page.