Synthetic Scope of the Triethyloxonium Ion Catalyzed Homologation of Ketones with Diazoacetic Esters[1a]

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Numerous examples of homologation of ketones to β-keto esters with ethyl diazoacetate catalyzed by triethyloxonium fluoroborate are described. Practical considerations concerning this general technique are treated in detail. With unsymmetrical ketones (RCOR′) a preponderance of insertion into the least highly substituted C(O)–C bond is consistently observed. It is feasible to separate the isomeric products by partial, selective hydrolysis and decarboxylation. Analogous expansion reactions were observed with diazoacetonitrile, 2,2,2-trifluorodiazoethane, dimethyl diazomethylphosphonate, and *tert*-butyl diazoacetate. Intramolecular homologation was seen with a diazo ketone. Certain of the same reactions may be catalyzed by antimony pentachloride at −78 °C; the advantages which accrue with this reagent are discussed, and a summary evaluation of the homologation technique is presented.

The homologation of aliphatic and aromatic ketones by one carbon atom is a frequently encountered synthetic objective. The most direct technique is the insertion of a methylene unit from diazomethane (eq 1).[2a–c] This reaction has

$$R_2CO + CH_2N_2 \longrightarrow RCOCH_2R \left(+ R_2C\underset{CH_2}{\overset{O}{\diagup\diagdown}} + RCH_2COCH_2R \text{ etc.}\right) \quad (1)$$

severe experimental limitations, the most serious of which are oxirane formation and multiple homologation (which usually cannot be avoided). Various alternative sequences[2] have been developed to partially overcome these drawbacks; however, all leave something to be desired in terms of requiring multiple steps which impose limits upon the presence of other functionality (not to mention diminution in yield).

A reaction which overcomes many of these restrictions is the triethyloxonium ion catalyzed insertion of a carbalkoxymethylene group from an alkyl diazoacetate into a carbonyl–alkyl or –aryl bond (eq 2).[3] This transformation proceeds se-

$$R_2CO + N_2CHCO_2R' \xrightarrow[CH_2Cl_2,\ 0\ °C]{(C_2H_5)_3O^+} RCOCHR \quad (2)$$
$$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad CO_2R'$$

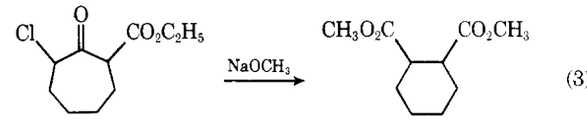
lectively in high yield under mild conditions, results in a useful β-keto ester product, and is compatible with numerous other functional groups. We here summarize the findings of an extensive investigation[1a] into the scope of this novel reaction. In an accompanying article we consider mechanistic information such as is necessary for intelligent application of this homologation technique.[4]

Results

General. Ethyl diazoacetate by itself is insufficiently nucleophilic to attack carbonyl groups. However, under the influence of base[5] or Lewis acid catalysis,[6] products arising from addition to the diazo carbon may be obtained. In the latter case the most efficacious reagents are triethyloxonium fluoroborate and antimony pentachloride (the latter in certain circumstances, as considered subsequently). A generally smooth reaction results when ethyl diazoacetate is dropped into a methylene chloride solution of triethyloxonium fluoroborate and a ketone at 0–25 °C. The progress of the reaction may usually be estimated by the rate of nitrogen evolution, by the disappearance of the color of the ethyl diazoacetate, by TLC analysis (product β-keto esters usually stain intensely blue with alcoholic ferric chloride spray), or by GLC or other conventional technique. Generally the reaction takes 2–5 h (occasionally longer). Standard workup is particularly simple; an excess of aqueous sodium bicarbonate solution is added to the reaction mixture which is then agitated until the catalyst has been consumed. Separation and evaporation of the methylene chloride phase provides a product contaminated only with minor amounts of by-products (see Experimental Section).

Typical Expansions. Table I contains a list of illustrative examples. Only a few of the entries will be commented upon. In the case of unsymmetrical ketones, two β-keto esters are possible, and in general both are produced. In order to determine the product ratio in such instances, it was necessary to hydrolyze and decarboxylate, whence the relative proportions of decarboxylated ketones could be determined by GLC analysis (last column in Table I). As a general pattern it will be noted that the least substituted residue on the carbonyl appears to migrate preferentially in the case of the aliphatic ketones, although an aryl ring does compete relatively effectively in those cases examined. A considerable effort was put into discerning the factors which control the product ratio in such diversely substituted ketones, in order to render the synthetic method more selective. These studies form the body of an accompanying article on the mechanism of this homologation,[4] and will not be further commented upon here.

Of synthetic significance is the apparent insensitivity of this reaction to steric congestion. Yields do not suffer severely with less hindrance than that provided by pinacolone (Table I, entry 5), isobutyrophenone (entry 10), or adamantanone (entry 17). In these cases unreacted ketone was also recovered; the reactions could likely have been forced to higher conversion. The method was attempted on an unsaturated ketone (entry 7) with disappointing results. Since unreacted mesityl oxide was not recovered, a better yield might require substantially modified conditions. Likewise in the case of cyclopentanone, complex by-products consumed the bulk of the reactant (aldol condensations?). No attempt to improve this homologation was made, since carbethoxycyclohexanones are generally available by other means. The method apparently works well for the expansion of cyclobutanones.[7] The case of 2-chlorocyclohexanone (entry 16) deserves comment; the apparently exclusive product was 7-chlorocarbethoxycycloheptanone. With base a clean Favorskii rearrangement of this material was induced (eq 3).[8a] The net transformation (cyclohexanone → dicarbalkoxycyclohexane) is unique. It is noteworthy that reaction of chlorocyclohexanone with diazomethane yielded predominantly an oxirane.[8b]



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Hydrolysis and Decarboxylation. In many synthetic applications a decarbethoxylated homologated ketone will be

Table I. Homologation of Typical Ketones

Registry no.	Reactant (RCOR')[a]	Reaction time, h	Product keto ester(s), total yield, %	Decarbethoxylation, ratio (RCH_2COR':$RCOCH_2R'$)[b]
67-64-1	1. CH_3COCH_3	6[c,e]	78	
96-22-0	2. $CH_3CH_2COCH_2CH_3$	6[c,e]	86	
78-93-3	3. $CH_3COCH_2CH_3$	2[d,e]	89	50:50
565-69-5	4. $CH_3CH_2COCH(CH_3)_2$	13[d,f]	54	66:34
75-97-8	5. $CH_3COC(CH_3)_3$	17[d,f]	10[g]	95:5
103-79-7	6. $CH_3COCH_2C_6H_5$	5[d,f]	96	62:38
141-79-7	7. $CH_3COCH{=}C(CH_3)_2$	5[d,e]	10[g]	2:98[h]
98-86-2	8. $CH_3COC_6H_5$	3[d,f]	78	10:90
495-40-9	9. $CH_3CH_2CH_2COC_6H_5$	20[d,f]	89	43:57
611-70-1	10. $(CH_3)_2CHCOC_6H_5$	17[d,f]	26	69:31
120-92-3	11. $(CH_2)_4CO$ (cyclopentanone)	4[c,e]	38	
108-94-1	12. $(CH_2)_5CO$ (cyclohexanone)	3[c,e]	90	
502-42-1	13. $(CH_2)_6CO$ (cycloheptanone)	4.5[c,e]	81	
502-49-8	14. $(CH_2)_7CO$ (cyclooctanone)	6[d,f]	85	
583-60-8	15. $CH_2COCHCH_3$ $\lfloor(CH_2)_3\rfloor$	4[d,e]	96	85:15
822-87-7	16. $CH_2COCHCl$ $\lfloor(CH_2)_3\rfloor$	4[d,f]	74	98:2[i]
700-58-3	17. $C_9H_{14}CO$ (adamantanone)	4[d,f]	63[j]	

[a] Conditions: $C_2H_5O_2CCHN_2$, 1.7 equiv in each case. [b] Determined by GLC, R, R' as in first column. [c] $(C_2H_5)_3O^+BF_4^-$, 1.7 equiv. [d] $(C_2H_5)_3O^+BF_4^-$, 3.0 equiv. [e] Temperature 0 °C. [f] Temperature 24 °C. [g] Plus several unidentified components. [h] Only $RCOCH_2R'$ detected, $CH_3COCH_2CH{=}C(CH_3)_2$ and $CH_3COCH{=}CHCH(CH_3)_2$, 4:1. [i] Only RCH_2COR' detected by base treatment; see text. [j] Incomplete conversion, product (oil) separated by column chromatography.

desired. This may generally be achieved by hot aqueous acid treatment of the keto esters. However, in our work we have adopted an alternative procedure. The keto ester is simply heated in (neutral) distilled water for several hours in a sealed tube at 230 °C.[9] Our finding is that this technique gives consistently higher yields of cleaner product, apparently since acid-catalyzed side reactions (e.g., aldol) are thereby suppressed. A practical qualification on the latter statement is that the homologated material must be totally free of acid-forming impurities (i.e., methylene chloride); however, simple distillation suffices for this purpose.

We have made further observations which suggest a technique for overcoming the major practical limitation of this homologation technique, namely, its nonexclusive regioselectivity. As may be seen from Table I, unsymmetrical ketones characteristically yield both conceivable products of expansion. Considerable experimental work has failed to yield a reaction modification which will completely avoid this problem[4] (which is common to all homologations). Furthermore, conventional simple purification techniques (distillation, chromatography) are usually inadequate for separation of the isomeric keto ester products, and such statement also applies to the mixture of ketones produced by decarbethoxylation. However, it was discovered in several instances that if the hydrolysis–decarboxylation were carried out at ca. 185 °C instead of 230 °C, selective reaction of one of the keto ester isomers may ensue. For example, the product mixture obtained from *p-tert*-butylacetophenone yielded at 230 °C an 89:11 mixture of arylacetone and butylpropiophenone.[4] However, at 185 °C pure 1-(*p-tert*-butylphenyl)acetone was isolated by distillation of the hydrolysate. An extensive examination of this phenomenon was not undertaken, since it might be expected that the optimum temperature and duration of hydrolysis would have to be determined on an individual basis for each substance. In summary, while neither the keto esters nor the homologated ketones may be readily separated into pure isomers, the difference in physical properties between the keto esters and *one* of the product homologated ketones (produced by an intrinsic rate differential in hydrolysis) renders separation easy. In this regard our two-step methylene insertion method is superior to a single-step diazomethane expansion.

Diazo Variations. In exploring the scope of this new homologation technique, we attempted the expansion of cyclohexanone with several analogues of ethyl diazoacetate. The experiments are summarized in Table II, and discussed individually below. In general, yields have not been optimized.

Diazoacetonitrile[10] substitutes satisfactorily for ethyl diazoacetate, providing 2-cyanocycloheptanone. With trifluorodiazoethane[11] an expanded product was obtained in good yield, which is noteworthy for the ease with which the trifluoromethyl group may be removed. Mild basic hydrolysis (85 °C, 48 h) afforded cycloheptanone directly. A sequence of HF eliminations followed by hydrations is most plausible; however, no deliberate decarboxylation step was experimentally necessary (possibly, cleavage of an intermediate fluoroformyl derivative occurs). The third entry in Table II, dimethyl diazomethylphosphonate,[12] provides a valuable type of homologated intermediate for subsequent synthetic transformations. Treatment of the product keto phosphonate with base (sodium methylsulfinylmethide in dimethyl sulfoxide) followed by *m*-nitrobenzaldehyde yielded the Wadsworth–Emmons product (eq 4). Of utmost significance for the synthesis of complex substances is the successful result with *tert*-butyl diazoacetate[13] (fourth entry in Table II). The keto ester product, which is especially susceptible to mild decarbalkoxylation, may be obtained without appreciable ester interchange involving the triethyloxonium salt. The final entry

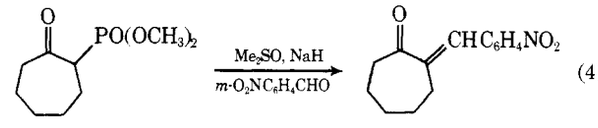

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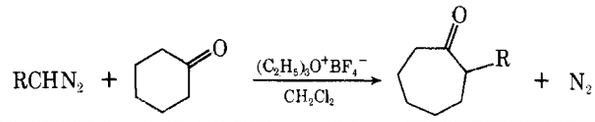
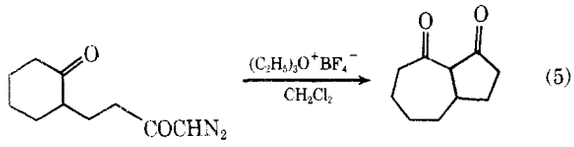
Table II. Homologations with Diverse Diazomethane Derivatives Catalyzed by Triethyloxonium Fluoroborate



Registry no.	Substituent (R)[a]	Catalyst [equiv $(C_2H_5)_3O^+BF_4^-$]	Reaction time, h	Yield, %
13138-21-1	CN	1.7	3[b]	58
371-67-5	CF_3	3.0	2[b]	~85
28447-24-7	$PO(OCH_3)_2$	4.0[c]	5[d]	65
35059-50-8	$CO_2C(CH_3)_3$	3.0	2.5[b]	46[e]
2684-62-0	$COCH_3$	1.7	3[b]	0

[a] With 1.7–2.5 equiv of substituted diazomethane (quantity not optimized). [b] Temperature 0 °C. [c] Trimethyloxonium fluoroborate (triethyloxonium salt gives phosphate ester exchange). [d] Temperature 24 °C. [e] After decarbalkoxylation ($CH_3C_6H_4SO_3H$, C_6H_6, 80 °C).

in Table II indicates failure in an attempted homologation with a diazo ketone. However, such a successful reaction conducted *intramolecularly* uniquely combines ring expansion with annelation to provide another potentially useful type of synthetic intermediate (eq 5).[3] Characterization of this

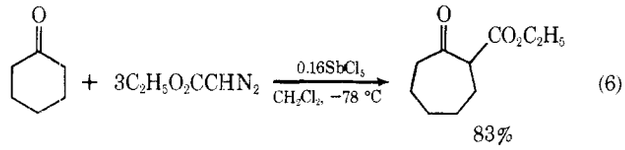


(5)

reaction has been reported;[3] details are in the Experimental Section.

Catalyst Variations. While triethyloxonium fluoroborate is a particularly convenient and efficacious catalyst for the ketone–diazo ester reaction, it is by no means the only Lewis acid which will induce homologation. In conjunction with mechanistic studies we have used trimethyl- and tripropyloxonium fluoroborates.[4] Yields were essentially identical; the trimethyloxonium salt is inferior for solubility reasons and the tripropyloxonium ion is less easily prepared. Boron trifluoride etherate had been shown to catalyze homologation prior to our investigation;[6c] in our experience it gives inferior results.

We have discovered one new catalyst which usefully complements the oxonium salt. Antimony pentachloride induces reaction between ketones and ethyl diazoacetate at −78 °C, a temperature at which the other catalysts are ineffective (eq 6). A coordination complex ($R_2CO{\cdot}SbCl_5$) may actually be



(6)

83%

isolated.[14] As in the other cases, reaction workup is especially easy. Aqueous sodium bicarbonate treatment precipitates the catalyst as a fine, white solid which is removed by filtration. Yields are typically 70–80%. Regioselectivity appears to be slightly greater than in the case of the oxonium ion induced reactions. For example, 2-methylcyclohexanone with $SbCl_5$ yields ultimately a 94:6 mixture of cycloheptanones (2-CH_3:3-CH_3) whereas with $(C_2H_5)_3O^+$ the ratio was 85:15 (Table I). In several other cases examined (see Experimental Section) there was a 7–35% improvement in selectivity with $SbCl_5$. This may be a consequence merely of the lower temperature of reaction, although alternative explanations cannot be excluded.[4]

The antimony catalyst also succeeded in homologation with *tert*-butyl diazoacetate, with a similar improvement in regioselectivity in the case of acetophenone. Furthermore, $SbCl_5$ gave a clean insertion product with acetone and 2,2,2-trichloroethyl diazoacetate (eq 7). In this reaction triethyloxonium fluoroborate was ineffective, yielding a considerably contaminated product. Deesterification of the trichloroethyl carboxylate may be achieved reductively (Zn, HOAc), allowing conversion to an expanded ketone under mild, minimally acidic conditions.[15a] These keto esters have a direct use in regiospecific aldol synthesis.[15b] One further generalization may be made; in the case of hindered ketones somewhat better overall yields were obtained with $(C_2H_5)_3O^+$ BF_4^- than with $SbCl_5$.[1a]

$$CH_3COCH_3 + N_2CHCO_2CH_2CCl_3 \xrightarrow[-N_2]{SbCl_5} CH_3COCH(CH_3)CO_2CH_2CCl_3 \quad (7)$$

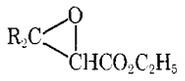
Discussion

The purpose of this article has been to survey the scope of this new homologation technique. Several unique advantages of this reaction may be listed. (1) Foremost is the uniformly high yields (Table I) under simple, standard conditions. An accompanying article provides numerous other examples with arylalkyl and cyclic ketones.[4] (2) Compared to diazomethane expansions and related techniques,[2] our method is far superior with regard to product purity as well as yield. The latter reactions frequently result in complex mixtures containing epoxides and products of multiple expansions. In the diazoacetate homologation these by-products are negligible or totally absent. (3) The keto ester product represents a highly useful type of synthetic intermediate. It may be readily alkylated, etc., prior to hydrolysis and decarboxylation. Although discrimination between possible expansion products in the case of unsymmetrically substituted ketones is less than complete, selective hydrolysis and decarboxylation of the keto esters offers a way to secure homogeneous products. (4) The rate of reaction depends upon the environment of the target carbonyl group in a way which suggests that selectivity would be expected for diketones. (5) The reaction may usefully be run from −14 to 40 °C in methylene chloride. With $SbCl_5$ as catalyst, expansion rapidly goes to completion at −78 °C. Velocity of reaction is directly dependent upon the concentration of triethyloxonium fluoroborate;[4] a 1.5–3 molar excess is recommended routinely. However, a catalytic amount of $SbCl_5$ suffices. (6) Finally, a variety of substituted diazomethanes enter into this reaction (Table II). The diversely functionalized ketones so produced suggest numerous subsequent synthetic uses (see also eq 5). In all cases homologation does not proceed beyond the introduction of one residue. The assortment of substituents which can be accommodated on the diazo species suggests that polyfunctionalized ketones would be acceptable substrates. In unpublished studies we have found this to be so; various esters, lactones, ketals, cyclopropanes, etc., survive homologation unscathed.

Experimental Section

Only a few illustrative examples of homologations will be recorded.[1a] Reagent grade methylene chloride was used without purification. Ethyl diazoacetate[16] was redistilled at reduced pressure (*caution:* explosion hazard). It may be stored under refrigeration. Triethyloxonium fluoroborate[17] may be prepared and stored under dry ether at room temperature; it is quite stable under these conditions. Just prior to use, ether was removed from the salt on a glass filter, and it was evacuated (20 mm) for 15 min at 25 °C. Triethyloxonium fluoroborate was routinely weighed and transferred in the ambient laboratory; however, the hygroscopic nature of the salt requires prompt manipulations and the avoidance of extreme humidity. Glassware was routinely dried at 150 °C, then assembled and allowed to cool in a stream of dry nitrogen. An inert atmosphere was maintained throughout our reactions. This was for the purpose of exclusion of moisture; there is no evidence that oxygen is deleterious. Quantitative analyses of product ratios were determined (in duplicate or triplicate) by cutting and weighing of Xerographic copies of GLC traces; we estimate the error limit as ±2%. Spectroscopic analyses were made on common commercial instrumentation; elemental analyses were by Galbraith Laboratories, Inc. Melting points (capillary) and boiling points are uncorrected.

Reaction Technique. Most of our reaction optimization work was done with cyclohexanone. An experimental procedure has been given[3] (see following typical procedure). Two types of by-products may occur in this homologation, which the experimenter should be prepared to recognize. Although usually undetected in most diazo ester expan-



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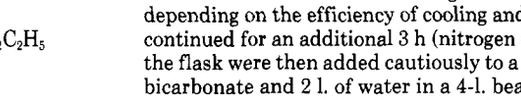

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sions, the glycidic ester from the reactant ketone (e.g., 1) may be found (<5% from cyclohexanone).[18] Such a structure may usually be recognized by an NMR singlet at δ 3.2, corresponding to the newly introduced oxirane proton. The other common contaminant of the product is diethyl diglycolate (2), which is thought to arise from diazoacetic ester, possibly during workup. These easily removable substances ought not to interfere with many subsequent applications of keto ester products, which should be usable with minimal purification.

Additional practical observations, which may prove critical with unreactive ketones, are as follows. It was found that slightly better yields were obtained if the diazoacetate were added gradually to the reaction mixture of ketone plus catalyst, rather than all at once. On the other hand, inordinate delay between exposure of ketone to triethyloxonium fluoroborate and commencement of diazo ester addition is to be avoided; ketone may be consumed in self-condensations of the aldol type.[19] Coloration of the reaction mixture due to diazoacetate and continuous nitrogen evolution should be noted until completion of the homologation (which may conveniently be estimated by cessation of outgassing). It is practical to initiate the reaction at 0 °C, and to allow the temperature of the reaction mixture to come to 25 °C should homologation prove sluggish. The aqueous sodium bicarbonate workup (destruction of triethyloxonium fluoroborate) is critical. Agitation of the two-phase reaction mixture should be vigorously maintained until well after the cessation of carbon dioxide evolution; no catalyst must be carried into a subsequent distillation. It has been our experience (and that of others) that β-keto esters tend to decompose on attempted GLC analysis.

Methylcycloheptanones. A solution of 2.8 g (0.025 mol) of 2-methylcyclohexanone in 100 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube under a nitrogen atmosphere. To the magnetically stirred solution, 15 g (0.079 mol) of triethyloxonium fluoroborate was added, followed by the dropwise addition of 5.2 g (0.046 mol) of ethyl diazoacetate. The reaction mixture was stirred for 4 h at 0 °C, during which time nitrogen was evolved, before the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution, and allowed to warm to room temperature. After stirring vigorously for about 0.5 h, the methylene chloride layer was separated from the aqueous layer (should be ca. pH 8), which was washed twice with 25 ml of methylene chloride. The combined methylene chloride extract was dried over anhydrous magnesium sulfate, solvent was removed, and the residue was distilled at reduced pressure. Distillation gave 4.7 g (96%) of keto ester product, bp 73–78 °C (0.4 mm). The product was not characterized, but 1.0 g (0.0050 mol) was hydrolyzed and decarboxylated by heating it with 5 ml of distilled water in a sealed tube for 2.5 h at 230 °C. The tube was allowed to cool before it was opened and the heterogeneous mixture was extracted three times with 5 ml of methylene chloride. The combined methylene chloride extract was dried over anhydrous magnesium sulfate, solvent was removed, and the residue was distilled at reduced pressure. Distillation gave 0.55 g (87%) of ketonic product, bp 88–90 °C (30 mm). GLC analysis showed two peaks which were collected and identified by NMR as 85% of 2-methylcycloheptanone [NMR (CCl_4) δ 1.0 (d, 3, J = 7 Hz), ca. 1.6 (m, 8), and ca. 2.3 ppm (m, 3)] and 15% of 3-methylcycloheptanone [NMR (CCl_4) 1.0 (d, 3, J = 7 Hz), ca. 1.7 (m, 7), and ca. 2.3 ppm (m, 4)], respectively. The two compounds were distinguished by the fact that 2-methylcycloheptanone showed an NMR methyl group doublet which slowly collapsed to a singlet in trifluoroacetic acid and deuterium oxide, whereas the corresponding doublet from 3-methylcycloheptanone did not coalesce upon deuterium exchange.

The above procedure was also used to expand 2-methylcyclohexanone at room temperature instead of at 0 °C as reported above. The keto ester product (72%) was hydrolyzed and decarboxylated as described. The same products were obtained (ratio 82:18).

2-Carbethoxycyclononanone. The homologation of cyclooctanone, which is a rather unreactive ketone, is here included as an example of a preparative reaction under forcing conditions. A solution of 32 g (0.25 mol) of cyclooctanone in 500 ml of methylene chloride was cooled to 5–10 °C in an ice–water bath under dry nitrogen. With continuous stirring 150 g (0.79 mol) of triethyloxonium fluoroborate was dissolved, and promptly (to minimize aldol condensation)[19] the rapid dropwise addition of 52 g (0.46 mol) of ethyl diazoacetate was commenced. Addition was regulated such that the solution temperature was maintained in the range 15–25 °C, and took 10–60 min, depending on the efficiency of cooling and other factors. Stirring was continued for an additional 3 h (nitrogen evolution). The contents of the flask were then added cautiously to a solution of 200 g of sodium bicarbonate and 2 l. of water in a 4-l. beaker. Magnetic stirring was slowly initiated and finally a state of vigorous agitation was maintained for 2 or 3 h (until well after the cessation of CO_2 evolution). Phases were separated and the aqueous layer (pH ca. 8) was washed with additional CH_2Cl_2. Solvent was removed from the organic extracts (rotary evaporator) and the residue was distilled through a 30-cm Vigreux column to yield 37.4–40.4 g (69–75%) of 2-carbethoxycyclononanone, bp 89–95 °C (0.2 mm). Anal. ($C_{12}H_{20}O_3$) C, H. This material was further characterized spectroscopically and by decarbethoxylation to yield solely cyclononanone (GLC analysis).

2-Carbethoxy-7-chlorocycloheptanone and Subsequent Transformation. 2-Chlorocyclohexanone (3.3 g) was homologated in the usual way (preceding and Table I). The crude product was purified by column chromatography on 80 g of silicic acid ($CHCl_3$ eluent) to give 4 g (74%) of a single, apparently homogeneous product, 2-carbethoxy-7-chlorocycloheptanone: NMR (CCl_4) δ 1.2 (t, 3, J = 7 Hz), ca. 1.8 (m, 8), ca. 3.7 (m, 1), 4.1 (q, 2, J = 7 Hz), and ca. 4.3 ppm (m, 1). Dehydrohalogenation of this material with base yielded no trace of carbethoxycycloheptenone, as should have been expected from 2-carbethoxy-3-chlorocycloheptanone. Instead, Favorskii rearrangement occurred. The chloro keto ester was refluxed in a 1.7 M solution of sodium methoxide in methanol for 8 h. Neutralization and workup yielded 1,2-dicarbomethoxycyclohexane: NMR (CCl_4) δ ca. 1.3 (m, 8), ca. 2.6 (m, 2), and 3.6 ppm (s, 6); MS calcd m/e 200.1050, obsd 200.1049. Saponification yielded *trans*-1,2-cyclohexanedicarboxylic acid, mp 222–224 °C.[20]

Other Ketones. Products of additional homologations included in Table I are listed below. All keto esters were characterized spectroscopically and/or by decarbethoxylation to readily identifiable ketones. Where feasible, comparison was made with authentic materials. The important experimental parameters are in Table I; the procedure follows that in the previous examples. (1) Ethyl 2-methylacetylacetate, bp 90–95 °C (35 mm), glycidic ester specifically absent from product (compare Tai and Warnhoff[6c]). (2) Ethyl 2-ethylpropionylacetate, bp 78–83 °C (3 mm). (3) Products from 2-butanone: keto ester mixture, bp 99–120 °C (31 mm), yielding a 50:50 mixture of 2- and 3-pentanone upon total hydrolysis. (4) Products from 2-methyl-3-pentanone:keto ester mixture, bp 71–100 °C (1 mm), yielding a 66:34 mixture of 2-methyl-3-hexanone and 5-methyl-3-hexanone upon total hydrolysis.[21] (5) Products from 3,3-dimethyl-2-butanone: keto ester mixture (grossly contaminated), bp 55–110 °C (0.1 mm), yielding a 95:5 mixture of 2,2-dimethyl-3-pentanone and 4,4-dimethyl-2-pentanone (by comparison with authentic materials, mixture also containing several unidentified components). (6) Products from phenylacetone:keto ester mixture, bp 114–126 °C (0.5 mm), yielding a 62:38 mixture of 1-phenyl-2-butanone and 4-phenyl-2-butanone. (7) Products from 4-methyl-3-penten-2-one:keto ester mixture (contaminated), bp 66–90 °C (0.4 mm), yielding an 80:20 mixture of 5-methyl-4-hexen-2-one and 5-methyl-3-hexen-2-one (also

contaminated with unhomologated ketone and other materials but free of 5-methyl-4-hexen-3-one). A semicarbazone was obtained from the homologated ketones, mp 149–151 °C. (8) Products from acetophenone:keto ester mixture, bp 88–98 °C (0.2 mm), yielding a 90:10 mixture of phenylacetone and propiophenone upon total hydrolysis. (9) Products from butyrophenone:keto ester mixture, bp 97–120 °C (0.4 mm), yielding a 57:43 mixture of 1-phenyl-2-pentanone and 1-phenyl-1-pentanone upon total hydrolysis. (10) Products from isobutyrophenone:keto ester mixture (incomplete conversion), bp 96–115 °C (0.2 mm), yielding a 69:31 mixture of 1-phenyl-3-methyl-1-butanone and 1-phenyl-3-methyl-2-butanone upon total hydrolysis. (11) 2-Carbethoxycyclohexanone, bp 99–109 °C (4.5 mm); phenylhydrazine derivative (pyrazolone), mp 180–182 °C.[6c] (12) 2-Carbethoxycycloheptanone[3], bp 80–82 °C (0.5 mm, note: incorrect previous[3] pressure recording), phenylhydrazine derivative (pyrazolone) mp 211–212 °C.[6c] (13) 2-Carbethoxycyclooctanone, bp 80–89 °C (0.6 mm); phenylhydrazine derivative (pyrazolone), mp 174–175 °C. (14–16) See preceding. (17) 3-Carbethoxy-2-oxotricyclo[4.3.1.1^{4,8}]undecane, oil (chromatographically purified, silicic acid–chloroform), yielding (upon decarbethoxylation) homoadamantanone, mp 268–270 °C.[22]

2-Cyanocycloheptanone. Diazoacetonitrile[10] was obtained from the diazotization of aminoacetonitrile hydrochloride according to the procedure used for the preparation of ethyl diazoacetate.[16] *Caution:* because of an explosion hazard,[10] diazoacetonitrile was not isolated from the methylene chloride solvent used in the diazotization, but, after partial removal of solvent, the concentration of diazoacetonitrile in methylene chloride was determined from the integral of the NMR spectrum.

A solution of 2.5 g (0.025 mol) of cyclohexanone in 100 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube under a nitrogen atmosphere. To the magnetically stirred solution, 9 g (0.046 mol) of triethyloxonium fluoroborate was added, followed by the dropwise addition of 3.1 g (0.046 mol) of diazoacetonitrile in methylene chloride. The reaction mixture was stirred for 3 h at 0 °C, during which time nitrogen was evolved, before the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution. After stirring for about 0.5 h at room temperature, the reaction mixture was worked up in the usual manner. Distillation gave 2.0 g (58%) of 2-cyanocycloheptanone: bp 103–107 °C (0.1 mm); IR (neat) λ 4.40 and 5.80 μ; NMR (neat) δ ca. 1.7 (m, 8), ca. 2.6 (m, 2), and ca. 3.9 ppm (m, 1); MS calcd *m/e* 137.0841, obsd 137.0851. A semicarbazone derivative was obtained, mp 155–158 °C.[23]

2-(Trifluoromethyl)cycloheptanone. A solution of 1.2 g (0.012 mol) of cyclohexanone in 50 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube, under a nitrogen atmosphere. To the magnetically stirred solution, 7 g (0.037 mol) of triethyloxonium fluoroborate was added, followed by the addition of ca. 3 g (0.03 mol) of 2,2,2-trifluorodiazoethane[11] in 7 ml of methylene chloride. The reaction mixture was stirred for 2 h at 0 °C, during which time nitrogen was evolved, before the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution. After stirring for about 0.5 h at room temperature, the reaction mixture was worked up in the usual manner. Distillation gave 2.2 g of impure 2-(trifluoromethyl)cycloheptanone, bp 85–105 °C (45–50 mm), after preparative GLC (net yield 85%): IR (neat) λ 5.80 μ; NMR (CCl_4) δ ca. 1.8 (m, 8), ca. 2.6 (m, 2), and ca. 3.2 ppm (m, 1). Anal. ($C_8H_{11}F_3O$) C, H.

A mixture of ca. 1 g of 2-(trifluoromethyl)cycloheptanone and 20 ml of aqueous 20% potassium hydroxide was heated at 80–90 °C for 48 h, during which time the reaction mixture appeared to become homogeneous. The basic mixture was cooled and extracted three times with 5 ml of ether. The basic aqueous layer was acidified with hydrochloric acid and again extracted three times with 5 ml of ether. Essentially nothing was obtained from the acidic extract; however, a good yield of cycloheptanone was obtained directly from the basic extract. The 2,4-dinitrophenylhydrazone of the product was obtained (yellow needles), mp 147–148 °C (no mixture melting point depression with authentic DNP derivative of cycloheptanone).

2-Carbo-*tert*-butoxycycloheptanone. A solution of 2.5 g (0.025 mol) of cyclohexanone in 100 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube under a nitrogen atmosphere. To the magnetically stirred solution, 15 g (0.079 mol) of triethyloxonium fluoroborate was added, followed by the dropwise addition of 7.1 g (0.50 mol) of *tert*-butyl diazoacetate.[13] The reaction mixture was stirred for 2.5 h at 0 °C, during which time nitrogen was evolved, before the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution. After stirring for about 0.5 h at room temperature, the reaction mixture was worked up in the usual manner. The crude product after solvent removal was chromatographed on 100 g of silicic acid. Elution with chloroform gave a single major fraction which consisted of 6.2 g of a ferric chloride positive material. While the NMR spectrum showed the required resonances for *tert*-butyl 2-oxocycloheptanecarboxylate, it also showed several unexplained signals, indicating contamination. Therefore, the product was directly refluxed in 50 ml of benzene containing 0.5 g of *p*-toluenesulfonic acid. After 14 h, the reaction mixture still gave a positive ferric chloride test. Regardless, the mixture was cooled and washed with 20 ml of distilled water and then with 20 ml of saturated sodium bicarbonate solution. Benzene was removed and the residue was distilled at reduced pressure. Distillation gave 1.3 g (46%, based on cyclohexanone) of cycloheptanone, bp 80–83 °C (30 mm), as the sole volatile product. It might be noted that superior yields have been obtained with other ketones.[4]

***O,O*-Dimethyl 2-Oxocycloheptylphosphonate.** A solution of 1.2 g (0.012 mol) of cyclohexanone in 50 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube, under a nitrogen atmosphere. To the magnetically stirred solution 7 g (0.047 mol) of trimethyloxonium fluoroborate was added. The ice bath was removed and 4.5 g (0.030 mol) of dimethyl diazomethylphosphonate[12] was dropped into the reaction mixture as it warmed to room temperature. The heterogeneous mixture was stirred for 5 h, during which time nitrogen was evolved, before the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution. After stirring for about 0.5 h, the reaction mixture was worked up in the usual manner. Distillation gave 0.5 g of an unidentified product mixture, bp 53–80 °C (0.3 mm), followed by 1.7 g (65%) of *O,O*-dimethyl 2-oxocycloheptylphosphonate, bp 80–140 °C (0.3 mm). Pure material was obtained by chromatography of the distillation fraction on 40 g of silicic acid with chloroform–methanol (99:1) elution: IR (neat) λ 5.88, 8.0, 9.5, and 9.7 μ; NMR (CCl_4) δ ca. 1.7 (m, 8), ca. 2.8 (m, 3), and 3.7 ppm (d, 6, J = 11 Hz). Anal. ($C_9H_{17}O_4P$) C, H.

Using the above conditions, cyclohexanone was also expanded with dimethyl diazophosphonate using triethyloxonium fluoroborate instead of trimethyloxonium fluoroborate as the catalyst. The reaction product was similarly purified to give the corresponding mixed methyl and ethyl phosphonates, adequate for further synthetic transformation.

To a solution of 200 mg of *O,O*-dimethyl 2-oxocycloheptylphosphonate in 20 ml of dimethyl sulfoxide (Me_2SO) was added 2 ml of 0.65 N sodium methylsulfinylmethide in Me_2SO. After 15 min, 150 mg of *m*-nitrobenzaldehyde was added to the solution. The reaction mixture was heated for 20 h at 55–60 °C before it was cooled and diluted with distilled water. The mixture (pH 7) was then extracted three times with 5 ml of ether. The combined ether extract was dried over anhydrous magnesium sulfate, solvent was removed, and the residue was chromatographed on 5 g of silicic acid. Elution with chloroform gave a single fraction which was identified as 2-(*m*-nitrobenzylidene)cycloheptanone: IR (neat) λ 5.92 and 6.20 μ; NMR ($CDCl_3$) δ 1.9 (m, 6), 2.8 (m, 4), and ca. 7.8 ppm (m, 5); MS calcd *m/e* 245.1052, obsd 245.1058. The product was obtained as an oil in good yield. A 2,4-dinitrophenylhydrazone was obtained as orange needles, mp 192–194 °C.

1-Diazo-4-(2-oxocyclohexyl)-2-butanone. A solution of 5.1 g (0.03 mol) of (2-oxocyclohexyl)propionic acid[24] and 3.1 g (0.03 mol) of triethylamine in 100 ml of ether was cooled to −5 °C in an ice–salt bath. To the magnetically stirred solution, 3.3 g (0.03 mol) of ethyl chloroformate was slowly added dropwise such that the temperature of the reaction mixture remained below 0 °C. After 3 h, triethylammonium chloride was removed by filtration and the filtrate was concentrated to ca. 25 ml under reduced pressure. The ethereal solution of the anhydride was slowly added to a solution of 0.064 mol of diazomethane in 200 ml of dry ether at 0 °C. After 5 h at 0 °C, excess diazomethane and solvent were removed to give the crude diazo ketone as an oil. The product crystallized at −80 °C from ether–petroleum ether to give 2.5 g (50%) of 1-diazo-4-(2-oxocyclohexyl)-2-butanone (yellow needles): mp 33–36 °C; IR (neat) λ 4.75, 5.88, and 6.12 μ; NMR ($CHCl_3$) δ ca. 1.8 (m, 8), ca. 2.2 (m, 5), and 5.2 ppm (s, 1).

Bicyclo[5.3.0]decane-2,10-dione. A solution of 0.5 g (2.6 mmol) of the diazo ketone in 100 ml of methylene chloride was cooled to 0 °C in a dry flask protected with a drying tube under a nitrogen atmosphere. To the magnetically stirred solution, 0.5 g (2.6 mmol) of triethyloxonium fluoroborate was added. The reaction mixture was stirred for 0.5 h, during which time nitrogen was evolved, before the reaction was quenched with 50 ml of saturated aqueous sodium bicarbonate solution. The mixture was allowed to warm to room temperature (0.5 h) before the methylene chloride layer was separated from the aqueous layer. The methylene chloride extract was dried over anhydrous magnesium sulfate and solvent was removed to give bicyclo[5.3.0]decane-2,10-dione. The crude product revealed by GLC

analysis a single substance which was collected for characterization: mp 23–25 °C; IR ($CHCl_3$) λ 6.07 and 6.25 μ; NMR ($CDCl_3$) δ ca. 1.2 (m, 8), ca. 2.4 (m, 5), and ca. 13.6 ppm (broad, 1, enolic OH). Anal. ($C_{10}H_{14}O_2$) C, H. A 2,4-dinitrophenylhydrazine derivative was obtained (yellow-orange plates), mp 191–192 °C.

Structure Proof for Bicyclo[5.3.0]decane-2,10-dione. In order to establish the presence of the β-diketone function in the above product, it was alkylated with methyl iodide. The enolate was prepared in benzene from 0.40 g (2.5 mmol) of the diketone and 0.07 g (3.0 mmol) of sodium hydride. After 1 h, an excess of methyl iodide was added to the mixture and stirring was continued for 24 h. Workup consisted of washing the reaction mixture with 10% hydrochloric acid. Removal of solvent gave 1-methylbicyclo[5.3.0]decane-2,10-dione, which was collected by preparative GLC: IR ($CHCl_3$) λ 5.72 and 5.91 μ; NMR ($CDCl_3$) δ 1.3 (s, 3), ca. 1.8 (m, 9), and ca. 2.4 ppm (m, 5). Anal. ($C_{11}H_{16}O_2$) C, H.

Cleavage of 1.2 g (0.007 mol) of bicyclo[5.3.0]decane-2,10-dione was effected by refluxing the diketone with 10 g of barium hydroxide in 50 ml of water for 20 h. Neutralization of the reaction mixture with carbon dioxide and acidification with 10% sulfuric acid gave, after extraction with chloroform and removal of solvent, 1.0 g (77%) of (3-oxocycloheptyl)propionic acid. Wolff–Kishner reduction of 1 g (0.005 mol) of the keto acid with 1 g of potassium hydroxide and 1 ml of hydrazine hydrate in 30 ml of diethylene glycol, according to the Huang-Minlon procedure,[25] gave 0.68 g (74%) of nearly pure cycloheptylpropionic acid: IR (neat) λ 5.85 μ; NMR ($CHCl_3$) δ ca. 1.5 (m, 15), ca. 2.2 (m, 2), and 9.1 ppm (s, 1). GLC analysis of the product showed a very minor amount of cyclopentylvaleric acid (the other possible acid from cleavage of the diketone), by comparison with authentic samples of the acids. The amide derivative of the major acid was obtained (colorless needles), mp 81.5–82.5 °C (no mixture melting point depression with authentic material).

Authentic cyclopentylvaleric acid was prepared according to the procedure given by Herz.[26a] The authentic isomeric cycloheptylpropionic acid was obtained in the following manner. The reaction between the morpholine enamine of cycloheptanone[26b] and methyl acrylate gave methyl (2-oxocycloheptyl)propionate in 75% yield after workup and distillation. Hydrolysis of the ester with sodium hydroxide gave (2-oxocycloheptyl)propionic acid. Reduction of 4 g (0.022 mol) of the acid by the Huang-Minlon procedure gave 3.2 g (87%) of cycloheptylpropionic acid, from which the amide was obtained, mp 84–85 °C.

Homologations Catalyzed with Antimony Pentachloride. A. Cyclohexanone. A solution of 2.5 g (0.025 mol) of cyclohexanone in 80 ml of methylene chloride was cooled to −78 °C in a dry flask, protected with a drying tube, under a nitrogen atmosphere. To the magnetically stirred solution, 3.7 g (0.012 mol) of antimony pentachloride was added, followed by the dropwise addition of 5.2 g (0.046 mol) of ethyl diazoacetate. The reaction mixture was stirred for 1 h at −78 °C, during which time nitrogen was evolved, before the cold bath was removed and the reaction mixture was allowed to warm to room temperature. After ca. 15 min of warming, the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution and stirred for about 0.5 h. During the workup, the antimony pentachloride precipitated as an inorganic complex that was removed from the aqueous layer, which phase was washed twice with 25 ml of additional methylene chloride. The combined methylene chloride extract was dried over anhydrous magnesium sulfate, solvent was removed, and the residue was distilled at reduced pressure. Distillation gave 3.6 g (77%) of 2-carbethoxycycloheptanone, bp 81–92 °C (0.6 mm). The spectral properties of the product were identical with those previously described; however, GLC analysis indicated that the product was somewhat less contaminated with trace components than in the case of triethyloxonium fluoroborate catalysis.

B. Other Ketones. (1) 2-Methylcyclohexanone was homologated by the above procedure to give a keto ester mixture (72%), bp 74–85 °C (0.5 mm), yielding a 94:6 mixture of 2- and 3-methylcycloheptanones on total hydrolysis. (2) *trans*-2-Isopropyl-5-methylcyclohexanone gave a keto ester mixture (63%), bp 92–97 °C (0.3 mm), yielding a 94:6 mixture of 2-isopropyl-5-methyl- and 3-isopropyl-6-methylcycloheptanone on total hydrolysis. (3) *cis*-2-Isopropyl-5-methylcyclohexanone gave a keto ester mixture (27%), bp 110–125 °C (0.4 mm), contaminated with lower boiling unreacted ketone and ethyl glycolate, yielding a 74:26 mixture of 2-isopropyl-5-methyl- and 3-isopropyl-6-methylcycloheptanone on total hydrolysis. (4) Bicyclo[2.2.1]heptan-2-one (norbornanone) gave a keto ester mixture (79%), bp 79–86 °C (0.3 mm), yielding a 86:14 mixture of bicyclo[3.2.1]octan-2-one and bicyclo[3.2.1]octan-3-one on total hydrolysis. (5) Phenylacetone gave a keto ester mixture (89%), bp 92–106 °C (0.3 mm), yielding a 77:23 mixture of 1-phenyl- and 4-phenyl-2-butanone on total hydrolysis. Product ratios (and identities) for the preceding substituted cyclohexanones may be compared with the results of triethyloxonium ion catalyzed homologations reported in the accompanying article.[4]

C. Acetophenone Complex. Acetophenone was homologated after first isolating the antimony pentachloride–acetophenone complex, which was then treated with ethyl diazoacetate. A solution of 6 g (0.05 mol) of acetophenone in 150 ml of carbon tetrachloride was cooled to 0 °C. To the magnetically stirred solution, 15 g (0.05 mol) of $SbCl_5$ was cautiously added. The complex immediately crystallized from solution. The ice bath was removed and the reaction mixture was allowed to warm to room temperature. The mixture was filtered under dry nitrogen and washed with carbon tetrachloride to give the complex in nearly quantitative yield. A few grams were recrystallized from methylene chloride–carbon tetrachloride to give colorless needles of $C_6H_5COCH_3 \cdot SbCl_5$: mp 134 °C dec (lit. 138 °C dec[14]); NMR ($CDCl_3$) δ 3.2 (s, 3) and ca. 7.8 ppm (m, 5). The complex was slightly soluble in chloroform, moderately soluble in methylene chloride, and quite soluble in liquid sulfur dioxide.

The hygroscopic complex as prepared above was added to 150 ml of methylene chloride in a dry flask, protected with a drying tube, under a nitrogen atmosphere. The partially soluble mixture was cooled to −78 °C and 9.9 g (0.087 mol) of ethyl diazoacetate was added dropwise. The reaction mixture was magnetically stirred for 1.5 h at −78 °C, during which time nitrogen was evolved and the reaction solution became homogeneous, whereupon the cold bath was removed and the mixture was allowed to warm to room temperature. After 0.5 h, the reaction was quenched with 200 ml of saturated sodium bicarbonate solution. The mixture was stirred for about 0.5 h before the precipitated antimony pentachloride complex was removed by suction filtration. The methylene chloride layer was separated from the aqueous layer, which was washed twice with 25 ml of methylene chloride. Solvent was removed from the combined methylene chloride extract. The crude product was hydrolyzed and decarboxylated by heating it with 75 ml of 10% sulfuric acid on a steam bath. After 40 h the reaction mixture was extracted with ether, which was worked up in the usual manner. Distillation gave 3.5 g (52%, from acetophenone) of ketonic product, bp 52–62 °C (0.8 mm), shown to be a mixture of some unreacted acetophenone and phenylacetone by GLC analysis. Significantly, propiophenone was specifically absent (<2%).

D. Homologation of Acetophenone with *tert*-Butyl Diazoacetate. A solution of 3.0 g (0.025 mol) of acetophenone in 100 ml of methylene chloride was cooled to −78 °C in a dry flask, protected with a drying tube, under a nitrogen atmosphere. To the magnetically stirred solution, 4.0 g (0.020 mol) of antimony pentachloride was added, followed by the dropwise addition of 7.1 g (0.050 mol) of *tert*-butyl diazoacetate.[13] The reaction mixture was stirred for 1.5 h at −78 °C, during which time nitrogen was evolved, before the cold bath was removed and the reaction mixture was allowed to warm to room temperature. After briefly warming, the reaction was quenched with 150 ml of saturated aqueous sodium bicarbonate solution, which treatment was followed by the usual workup. The crude product was chromatographed on 100 g of neutral silicic acid and eluted with chloroform. Obtained was 3.5 g of a ca. 1:1 mixture of phenylacetone and *tert*-butyl 2-phenylacetylacetate, plus a small amount of acetophenone, followed by ca. 1.0 g of mixture of unidentified components. The major product mixture was further decarbalkoxylated by heating it in 50 ml of benzene containing 0.2 g of *p*-toluenesulfonic acid for 16 h. After the usual workup and distillation, GLC analysis revealed only phenylacetone and acetophenone (85:15); propiophenone was again absent. Significantly, attempts to catalyze the reaction between acetophenone and *tert*-butyl diazoacetate with triethyloxonium fluoroborate gave a complex mixture of unidentified products.

E. 2,2,2-Trichloroethyl 2-Methylacetylacetate. A solution of 10.6 g (0.043 mol) of 2,2,2-trichloroethyl glycinate hydrochloride[27] in 50 ml of methylene chloride and 50 ml of distilled water was cooled to 0 °C, at which point some of the glycinate hydrochloride precipitated. To the mixture was added 4 g of sodium nitrite in 10 ml of distilled water, followed by 10 ml of 10% sulfuric acid. The temperature of the reaction mixture rose briefly to 10 °C. After 0.5 h, the methylene chloride layer was separated from the aqueous layer. The golden methylene chloride extract was washed with a saturated sodium bicarbonate solution and was dried over anhydrous sodium sulfate. Solvent was removed, and the residue was distilled at reduced pressure, yielding 5.3 g (56%) of 2,2,2-trichloroethyl diazoacetate: bp 53–55 °C (0.2 mm); IR (neat) λ 4.70 and 5.84 μ; NMR (CCl_4) δ 4.7 (s, 2) and 4.9 ppm (s, 1).

A solution of 0.3 g (5.2 mmol) of acetone in 25 ml of methylene chloride was cooled to −78 °C in a dry flask, protected with a drying tube, under a nitrogen atmosphere. To the magnetically stirred solution 1.0 g (3.3 mmol) of antimony pentachloride was added, followed

by the dropwise addition of 2.5 g (0.011 mol) of 2,2,2-trichloroethyl diazoacetate. The reaction mixture was stirred for 1 h at −78 °C, during which time nitrogen was evolved, before the cold bath was removed and the reaction mixture was allowed to warm to room temperature. After warming for 0.5 h, the reaction was quenched with 75 ml of saturated aqueous sodium bicarbonate solution. The mixture was stirred for about 0.5 h before the antimony complex was removed by suction filtration. The methylene chloride layer was separated and the aqueous layer was washed twice with 10 ml of methylene chloride. The combined methylene chloride extract was dried over anhydrous magnesium sulfate, solvent was removed, and the crude product was analyzed by GLC. Two peaks were collected and identified. The first was 2,2,2-trichloroethyl hydroxyacetate. The second product was identified as 2,2,2-trichloroethyl 2-methylacetylacetate: IR (CCl_4) λ 5.68 and 5.80 μ; NMR (CCl_4) δ 1.4 (d, 3, J = 7 Hz), 2.3 (s, 3), 3.6 (q, 1, J = 7 Hz), and 4.8 ppm (s, 2). Anal. ($C_7H_9Cl_3O_3$) C, H.

Attempts to catalyze the reaction between acetone and 2,2,2-trichloroethyl diazoacetate with triethyloxonium fluoroborate failed to give any of the desired product. The products obtained were difficult to separate and were not identified.

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Registry No.—Triethyloxonium fluoroborate, 368-39-8; 2-methylcycloheptanone, 932-56-9; 3-methylcycloheptanone, 933-17-5; 2-carbethoxycyclononanone, 4017-57-6; 2-carbethoxy-7-chlorocycloheptanone, 60719-11-1; 1,2-dicarbomethoxycyclohexane, 4336-20-3; 2-carbethoxycyclooctanone phenylhydrazone, 60719-12-2; 2-cyanocycloheptanone, 7391-45-9; 2-(trifluoromethyl)cycloheptanone, 60719-13-3; cycloheptanone 2,4-DNP, 3349-73-3; dimethyl diazomethylphosphonate, 27491-70-9; *O,O*-dimethyl 2-oxocycloheptylphosphonate, 60719-14-4; *m*-nitrobenzaldehyde, 99-61-6; 2-(*m*-nitrobenzylidene)cycloheptanone, 60719-15-5; 2-(*m*-nitrobenzylidene)cycloheptanone 2,4-DNP, 60719-16-6; (2-oxocyclohexyl) propionic acid, 2275-26-5; 1-diazo-4-(2-oxocyclohexyl)-2-butanone, 60719-17-7; bicyclo[5.3.0]decane-2,10-dione, 60719-18-8; bicyclo[5.3.0]decane-2,10-dione di(2,4-DNP), 60719-19-9; 1-methylbicyclo[5.3.0]decane-2,10-dione, 60719-20-2; (3-oxocycloheptyl)propionic acid, 60719-21-3; cycloheptylpropionic acid, 4448-78-6; cycloheptylpropionamide, 60719-22-4; cycloheptanone morpholine enamine, 60719-23-5; methyl (2-oxocycloheptyl)propionate, 10407-26-8; acetophenone $SbCl_5$, 25538-03-8; 2,2,2-trichloroethyl glycinate HCl, 21646-95-7; 2,2,2-trichloroethyl diazoacetate, 60719-24-6; 2,2,2-trichloroethyl 2-methylacetylacetate, 60719-25-7.

References and Notes

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