A semicarbazone was formed in the usual way. Two recrystallizations from ethanol gave an analytical sample, m.p. 221–222°.

Anal. Calcd. for $C_{12}H_{21}ON_3$: C, 64.54; H, 9.48; N, 18.82. Found: C, 64.46; H, 9.45; N, 18.96.

A 2,4-dinitrophenylhydrazone was formed in the normal way. Three recrystallizations from ethanol gave an analytical sample, m.p. 131–132°.

Anal. Calcd. for $C_{17}H_{22}O_4N_4$: C, 58.94; H, 6.40; N, 16.18. Found: C, 58.89; H, 6.25; N, 15.89.

(+)-1,5,5-Trimethylbicyclo[2.1.1]hexan-*endo*-6-ol(III).—A solution of trifluoroperacetic acid[21] was prepared by mixing 3.40 ml. of trifluoroacetic anhydride with 0.52 ml. of 90% hydrogen peroxide in 6.60 ml. of methylene chloride.

The resulting peracid solution was added dropwise to a stirred solution of 1.60 g. of XXVI, 3.90 g. of anhydrous dibasic sodium phosphate and 20 ml. of methylene chloride. The reaction mixture was stirred and refluxed for 8 hr., filtered, and the inorganic salts washed thoroughly with methylene chloride. The filtrate was dried over anhydrous magnesium sulfate, filtered, and the solvent removed under reduced pressure. The infrared spectrum of the residue indicated some unchanged ketone was still present.

The total reaction product was, therefore, recycled by dissolving it in 20 ml. of methylene chloride to which 3.90 g. of anhydrous dibasic sodium phosphate had been added. The trifluoroperacetic acid obtained from 3.40 ml. of trifluoroacetic anhydride, 0.52 ml. of 90% hydrogen peroxide and 6.60 ml. of methylene chloride was added dropwise. Refluxing was maintained for 12 hr. The solution was cooled, filtered and the inorganic salts washed thoroughly with methylene chloride. The filtrate was dried over anhydrous magnesium sulfate, filtered, and the solvent removed under reduced pressure to give 1.83 g. of acetate (containing some trifluoroacetate, as indicated by infrared absorption at 5.60 as well as 5.78 μ).

The crude acetate was dissolved in 10 ml. of anhydrous ether and added dropwise to a stirred suspension of 1.00 g. of lithium aluminum hydride in 20 ml. of anhydrous ether. After stirring at room temperature for 8 hr., the reaction mixture was cooled to 0° and quenched by the dropwise addition of 4.0 ml. of water. The hydrolyzed mixture was stirred for 1 hr. and the precipitated salts were removed by filtration. The salts were washed thoroughly with ether, and the combined filtrates were dried over anhydrous magnesium sulfate. The drying agent was removed by filtration and the solvent was removed under reduced pressure. Sublimation of the crude product gave 1.01 g. (73% yield based on XXVI) of III, m.p. 95–97° with preliminary softening at 85°, $[\alpha]_D$ + 15.1° (EtOH). Preparative vapor phase chromatography gave an analytically pure sample, m.p. 121–122°. This material showed a 2.45 min. retention time on a column of the type used for the methyl esters, operated at 100°. No impurity was detectable.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.00; H, 11.39.

A *p*-nitrobenzoate was formed in the normal way. Two recrystallizations from aqueous ethanol gave an analytical sample, m.p. 98.5–99°.

Anal. Calcd. for $C_{16}H_{19}O_4N$: C, 66.42; H, 6.62; N, 4.84. Found: C, 66.65; H, 6.63; N, 5.06.

1,5,5-Trimethylbicyclo[2.1.1]hexan-6-one (XXVII).—To the complex formed from 2.70 g. of chromium trioxide in 40 ml. of dry pyridine[22] was added dropwise with stirring a solution of 1.50 g. of III in 20 ml. of dry pyridine. The resulting mixture was stirred at room temperature for 3 days, and then 160 ml. of water was added. The mixture was extracted with ether, and the ether washed repeatedly with water and then dried over anhydrous magnesium sulfate. The drying agent was removed by filtration and the solvent was evaporated under reduced pressure to give 0.76 g. (51%) of XXVII; infrared spectrum (neat): 5.61 μ, with no absorption in the hydroxyl region of the spectrum. This ketone showed a surprising tendency to decompose upon distillation.

(−)-1,5,5-Trimethylbicyclo[2.1.1]hexan-*exo*-6-ol (IV).—A solution of 0.75 g. of crude XXVII in 15 ml. of anhydrous ether was added dropwise to a stirred suspension of 0.50 g. of lithium aluminum hydride in 25 ml. of anhydrous ether at −5°. After stirring for 2 hr. at −5°, the mixture was hydrolyzed by the dropwise addition of 2.0 g. of water. The reaction mixture was filtered and the inorganic salts washed thoroughly with ether. The combined filtrates were dried over anhydrous magnesium sulfate, filtered and the solvent removed under reduced pressure. The residue was sublimed under reduced pressure to give 0.56 g. (73%) of a waxy white solid. Preparative vapor phase chromatography gave an analytical sample, m.p. 124–125.5°, $[\alpha]_D$ −17.4°. This material showed a v.p.c. retention time of 2.55 min., with no detectable impurity, under the conditions used to examine its epimer III.

Anal. Calcd. for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.15; H, 11.62.

An attempt to form a *p*-nitrobenzoate in the normal way was unsuccessful.

[CONTRIBUTION FROM AVERY LABORATORY, UNIVERSITY OF NEBRASKA, LINCOLN, NEBR.]

Elimination Reactions of α-Halogenated Ketones. VII.[1] Kinetics of Several Dehydrobromination Reactions of 4-Biphenylyl 1-Bromocyclohexyl Ketone

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The α-bromoketone 4-biphenylyl 1-bromocyclohexyl ketone (I) has been found to undergo elimination reaction in solvent acetonitrile and in solvent benzene to yield the α,β-unsaturated ketone 4-biphenylyl 1-cyclohexenyl ketone (II). The kinetics of the elimination reaction as promoted by piperidine, by morpholine, by tetraethylammonium bromide and by piperidine hydrobromide are reported. The kinetic results are discussed in terms of possible reaction mechanism. 4-Biphenylyl 2-piperidinocyclohexyl ketone (III) and 4-biphenylyl 2-bromocyclohexyl ketone (IV) have been prepared and characterized.

Introduction.—This communication reports upon the kinetics of several elimination reactions of 4-biphenylyl 1-bromocyclohexyl ketone (I) in solvent acetonitrile and in solvent benzene. Elimination from 4-biphenylyl 1-bromocyclohexyl ketone (I) produces the α,β-unsaturated ketone 4-biphenylyl 1-cyclohexenyl ketone (II).[2]

Previous communications in this series have reported upon the kinetics of elimination reactions of 2-bromo-2-benzyl-4,4-dimethyl-1-tetralone (V) in solvent acetonitrile.[3,1] A merged substitution and elimination mechanism was proposed for these elimination reactions.

Discussion of Results

The decompositions of α-bromoketone I, of piperidine and of morpholine in both acetonitrile and in benzene were found, even at 90.6°, to be

(1) For paper VI in this series see D. N. Kevill and N. H. Cromwell, *J. Am. Chem. Soc.*, **83**, 3815 (1961).

(2) N. H. Cromwell and P. H. Hess, *ibid.*, **82**, 136 (1960).

(3) D. N. Kevill and N. H. Cromwell, *ibid.*, **83**, 3812 (1961).

much too slow to affect either the kinetics or the products of the reactions reported here. All the reactions were found to be kinetically of first order in α-bromo-ketone I but, as can be seen in Table I, not all were of first order in the other reactant. For all reactants the rate coefficients were found to be identical in value whether considered in terms of acid production (or amine neutralization) or in terms of bromide ion production.

TABLE I

A SUMMARY OF THE KINETIC RESULTS OBTAINED FOR ATTACK OF ADDITIVES UPON 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I)

Rate coefficient (k_x) such that the over-all order of elimination reaction is x; Arrhenius parameters $\log_{10} A$ and E as represented by $k_x = Ae^{-E/RT}$.

Additive	Solvent	k_x	$10^4 k_x$[a] at 90.6°	$\log_{10} A$	E, kcal./mole
None	C_6H_6	..	Stable	..	..
$C_5H_{11}N$	C_6H_6	k_2	0.66	4.5	14.6
C_4H_9ON	C_6H_6	k_2	0.036	5.0	17.4
None	CH_3CN	k_1	~0.003	..	..
$C_5H_{11}N$	CH_3CN	k_2	163	6.2	13.3
C_4H_9ON[b]	CH_3CN	k_2	20	6.5	15.3
		$(+k_1)$	~0.02	..	..
NEt_4Br	CH_3CN	k_2	127	11.9	22.9
$C_5H_{11}NHBr$	CH_3CN	$k_3/_2$	2.9	..	..

[a] In appropriate units of liters, moles and seconds. [b] Mainly second-order kinetics with small first-order contribution.

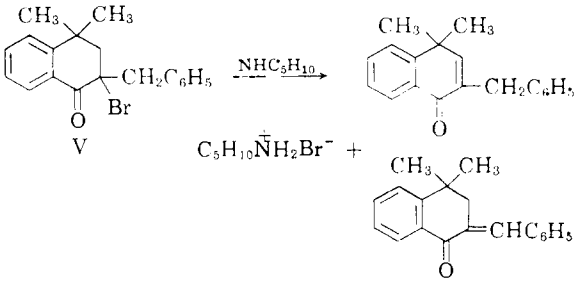
Preliminary kinetic studies,[2] which indicated that the piperidine-promoted elimination reaction in solvent benzene was essentially second order, have been confirmed and the morpholine-promoted elimination reaction in solvent benzene has also been found to have essentially second-order kinetics.

For the morpholine reaction in solvent benzene a slight upward drift in the values for the second-order rate coefficient with increasing morpholine concentration was observed at each temperature. This can be attributed to a medium effect, a common occurrence in media of low dielectric constant.

In solvent benzene the dipolar development in the carbon–bromine bond of the α-bromoketone I will not be expected to be large since benzene is a poor solvent for stabilization of such charge development. It has been proposed previously that there exists a whole spectrum of reaction mechanisms with a gradation away from mechanisms with pure E2 characteristics as increasing amounts of SN2 character enter into the mechanism which, however, eventually leads to an elimination product. In benzene solution there is no evidence to indicate other than that attack of the amines takes place at the β-hydrogen atoms leading to an E2 mechanism. On the basis of simple kinetic data alone the possibility of a certain amount of admixed SN2 character cannot, however, be excluded.

In benzene solution reaction with amines proceeds with precipitation of the amine hydrochloride. No evidence for any heterogeneous autocatalysis was obtained.

In solvent acetonitrile elimination promoted by piperidine led to second-order kinetics at each temperature studied. At these same temperatures, and within identical reactant concentrations, 2-bromo-2-benzyl-4,4-dimethyl-1-tetralone (V) has previously been found to give mixed order kinetics in its elimination reaction[3]



The carbon–bromine bond is stronger in the α-bromoketone I than in the bromotetralone V, so that sufficient elongation of the carbon–bromine bond prior to attack of the piperidine, such as to lead to a first-order component to the reaction scheme, does not occur for the bromoketone I. Evidence supporting the view that the carbon–bromine bond is stronger in α-bromoketone I than in bromotetralone V has previously been obtained.[2] It was found that under identical conditions the relative extent of silver bromide precipitation in reaction with alcoholic silver nitrate was 6.3% for α-bromoketone I and 45.3% for bromotetralone V. Further, the activation energies for second-order piperidine attack in solvent acetonitrile of 13.3 kcal./mole for α-bromoketone I and 12.1 kcal./mole for bromotetralone V[1] are consistent with a stronger carbon–bromine bond in the α-bromoketone I.

In solvent acetonitrile reaction with morpholine was found to be largely of first order in α-bromoketone I and first order in morpholine, accompanied at each temperature, within the concentration range studied, by a small component of zero order in morpholine. Only approximate values for the first-order rate coefficient with respect to α-bromoketone I could be obtained. The values were at each temperature greater by a factor of about five than the corresponding initial values obtained for the decomposition of the α-bromoketone I in solvent acetonitrile. It appears probable that the small component to the reaction scheme of zero order in morpholine is similar in character to the somewhat larger component of zero order in piperidine previously observed in the piperidine promoted elimination from bromotetralone V.[1]

In both of the solvents it was found that the second-order rate coefficients at a given temperature were greater for reaction with piperidine than with morpholine. The Arrhenius parameters show that in both solvents frequency factor considerations favor a slightly higher rate for the reaction of morpholine relative to piperidine, but these considerations are outweighed by the greater activation energy of morpholine relative to piperidine. The frequency factor values were not very different, consistent with the known almost identical steric demands of piperidine and of morpholine.

Measurements of the base strength of both piperidine and morpholine have been carried out in several organic solvents including acetonitrile.[4] Mor-

(4) H. K. Hall, *J. Phys. Chem.*, **60**, 63 (1956).

pholine was found to be somewhat anomalous in that it acted as a stronger base in organic solvents than one would predict from its pK_a in water. Its apparent pK_a in water of 9.50, as calculated from data in acetonitrile, is, however, still considerably lower than the measured value for piperidine of 11.13.[5]

The second-order rate coefficients for piperidine and for morpholine promoted elimination from the α-bromoketone I in solvent acetonitrile at, for example, 90.6° differ only by a factor of eight; even allowing for the apparent increase in base strength of morpholine relative to piperidine in acetonitrile, as compared to their values in water, the ratio of the rate coefficients does not reflect the relative base strengths of the two amines. It is of interest to note that although morpholine is a considerably weaker base than piperidine it has been found in many instances to have considerable nucleophilicity toward carbon.[6] The seemingly anomalous reactivity of morpholine relative to piperidine in solvent acetonitrile when the reactions are considered to proceed through an E2 mechanism can be explained if one assumes a contribution to the elimination mechanism of a certain amount of SN2 character such that nucleophilicity toward carbon is a rate-controlling factor.

Tetraethylammonium bromide and piperidine hydrobromide are insoluble in benzene and elimination from the α-bromoketone I as promoted by these salts has been investigated only in acetonitrile.

Elimination from the α-bromoketone I as promoted by bromide ions closely resembles the previously observed kinetic behavior of the bromotetralone V.[2] The reaction with tetraethylammonium bromide is found to be second order at each temperature considered, first order in α-bromoketone I and first order in salt. The reaction has a high activation energy but proceeds at a convenient rate because it also possesses a high frequency factor.

The product isolated from the reaction at 90.6° of a solution 0.0200 M in both α-bromoketone I and tetraethylammonium bromide was the α,β-unsaturated ketone II admixed with an amount of saturated ketone. Titration of the acid developed showed that an equilibrium was set up corresponding to 77% α,β-unsaturated ketone in the products. The α,β-unsaturated ketone II was isolated from the reaction product by recrystallization from methanol.

It is unlikely that the equilibrium would be between the α-bromoketone I and the α,β-unsaturated ketone II since the back addition of hydrogen bromide to the α,β-unsaturated ketone II would be expected to be a 1,4-addition to yield the β-bromoketone, 4-biphenylyl 2-bromocyclohexyl ketone (IV). The β-bromoketone IV was prepared by the direct addition of hydrogen bromide to the α,β-unsaturated ketone II in ether solution at room temperature. The infrared spectrum of the reaction product was found to be superimposable upon that of a synthetic mixture of 77% α,β-unsaturated ketone II and 23% β-bromoketone IV.

(5) H. K. Hall, *J. Am. Chem. Soc.*, **78**, 2570 (1956).

(6) N. H. Cromwell and P. H. Hess, *ibid.*, **83**, 1237 (1961).

The integrated values for the first-order rate coefficient with respect to α-bromoketone I fell throughout each individual run as would be expected for a reaction moving toward an equilibrium; such a fall off would, however, be predicted even in the absence of any equilibrium due to the removal of bromide ions from solution as HBr_2^- triple ions by the hydrogen bromide formed in the reaction.[3,7]

The reaction with piperidine hydrobromide at 90.6° was found to be of 3/2 order, first order in α-bromoketone I and half order in piperidine hydrobromide. The kinetic pattern parallels that for attack upon bromotetralone V.[3]

The rate of tetraethylammonium bromide attack relative to the rate of piperidine hydrobromide attack is at a given temperature a constant irrespective of whether attack is upon the α-bromoketone I or upon the bromotetralone V. This is consistent with the view that the differing rates of attack result from the differing equilibrium concentrations of kinetically reactive bromide ions in the two salts and the same species, the bromide ion, is attacking the bromoketones irrespective of which salt is employed.

For attack upon the α-bromoketone I at 90.6°

$$\frac{k_2(NEt_4Br)}{k_{3/2}(C_5H_{11}NHBr)} = 45 \text{ liters}^{1/2} \text{ moles}^{-1/2}$$

For attack upon the bromotetralone V at 90.6°

$$\frac{k_2(NEt_4Br)}{k_{3/2}(C_5H_{11}NHBr)} = 51 \text{ liters}^{1/2} \text{ moles}^{-1/2}$$

The data for the bromotetralone V were taken from a previous publication[3]; the value for the second-order rate coefficient for tetraethylammonium bromide promoted elimination from the bromotetralone V at 90.6° was calculated from the Arrhenius data.

It has been reported that, although the bromide ion has scarcely any affinity for an hydrogen nucleus, it does possess a moderate affinity for a carbon nucleus.[8] This is consistent with the merged substitution and elimination mechanism as proposed in a previous publication in which attack takes place primarily at the carbon nucleus and then, after considerable weakening of the carbon–halogen bond in the α-halogenated ketone has occurred, attack of the nucleophile is diverted so that removal of a β-proton takes place rather than collapse to a substitution product.[1]

Experimental Results

The concentrations quoted in this communication were not corrected for expansion of the solvent from room temperature to reaction temperature. Other entities quoted which are concentration dependent are similarly uncorrected.

Stability of Reactants in Solvent Benzene.—It was found that a 0.16 M solution of α-bromoketone I in benzene solution at 90.6° produced no free bromide ions during a period of 14 days. A 0.0800 M solution of piperidine in benzene at 90.6° was found to undergo less than 3% reduction in base concentration during a period of 11 days. A 0.0800 M solution of morpholine in benzene at 90.6° was similarly found to undergo less than 2% reduction in base concentration during a period of 11 days.

Stability of Piperidine and Morpholine in Solvent Acetonitrile.—It was found that a 0.0200 M solution of piperi-

(7) I. M. Kolthoff, S. Bruckenstein and M. K. Chantooni, Jr., *ibid.*, **83**, 3927 (1961).

(8) C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, p. 452.

dine in acetonitrile at 90.6° underwent 14.8% reduction in base concentration during a period of 7 days. A 0.00554 *M* solution of morpholine in acetonitrile at 90.6° underwent 2.4% reduction in base concentration during a period of 5 days.

A solution 0.0186 *M* in piperidine was flushed with nitrogen and prior to sealing the air space above the solution was similarly flushed. After 7 days at 90.6°, only a 4.0% reduction in base strength had occurred. It appears that a reduction in the oxygen concentration increases the stability of the piperidine.

Stability of 4-Biphenylyl 1-Bromocyclohexyl Ketone (I) in Solvent Acetonitrile.—A 0.0400 *M* solution of the α-bromoketone I in acetonitrile was maintained at 90.6° for 12 days; the solution developed a yellowish brown coloration, and titration showed that after this time the bromide ion development was consistent with an 85% reaction and the acid development was consistent with a 48% reaction. The acetonitrile was removed by evaporation, the residue ether extracted and the ether solution washed with a little water, dried over anhydr. magnesium sulfate and evaporated to dryness; the solid residue had m.p. 58–68° and gave a negative Beilstein test. The crude product isolated had in the infrared spectrum $\gamma_{C=O}$ 1679/87 and $\gamma_{C=O}$ 1666/79. No disturbance was observed in the frequency region of 1647 cm.$^{-1}$ where the α,β-unsaturated ketone would show carbonyl absorption.[2] The indefinite melting point and a change observed in the relative intensities of the two carbonyl peaks after recrystallization from methanol suggests a mixture of two or more compounds.[9]

The kinetics of the reaction of the α-bromoketone I were followed both by determination of the extent of bromide ion formation and by determination of the extent of acid formation; both methods yielded identical results. The reaction was found to be subject to an extremely strong autocatalysis which rendered accurate determination of the initial values for the rate coefficients impossible.

TABLE II

INTEGRATED FIRST-ORDER RATE COEFFICIENTS k_1 FOR BROMIDE ION PRODUCTION IN THE DECOMPOSITION OF 0.0200 *M* 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) IN SOLVENT ACETONITRILE AT 90.6° AND VALUES FOR THE RATIO OF EXTENT OF BROMIDE ION PRODUCTION TO EXTENT OF ACID PRODUCTION, *Z*

5.05-ml. aliquots of a solution made up at 24°

Time, minutes	0	132	247	443	1398	1690
Vol. of 0.0100 *M* $AgNO_3$ soln., ml.	0.04	0.07	0.15	0.30	2.35	3.32
Vol. of 0.0114 *M* morpholine soln., ml.	0.02	0.05	0.11	0.26	2.06	2.85
Z	..	1.14	0.93	1.05	1.01	0.98
k_1, sec.$^{-1}$ × 10^7	..	3.5	6.5	8.9	27.9	34.7

For each run the values for the integrated first-order coefficient throughout the reaction were extrapolated to zero extent of reaction to yield approximate values for the true first-order coefficient for bromide ion production.

TABLE III

INITIAL VALUES FOR THE FIRST-ORDER RATE COEFFICIENT FOR BROMIDE ION PRODUCTION k_1 IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) IN ACETONITRILE AT VARIOUS TEMPERATURES

t, °C.	60.0	75.0	90.6	90.6
[Bromoketone]	0.0200	0.0100	0.0100	0.0200
k_1, sec.$^{-1}$ × 10^7	~0.4	~1.3	~3	~3

Kinetics of the Piperidine Promoted Elimination from α-Bromoketone I in Solvent Benzene.—The kinetics of the piperidine promoted elimination were followed both by determination of the rate of piperidine neutralization and by determination of the rate of bromide ion formation. At a given temperature the two methods gave identical initial values for the second-order rate coefficient. In the majority of runs no drift could be detected in the values for the integrated second-order rate coefficients throughout an individual run; in several instances constancy was observed over as much as 50% of possible reaction. In one or two instances, principally at 90.6°, the integrated second-order rate coefficients for piperidine neutralization showed a slight increase as reaction proceeded and initial values were obtained by extrapolation to zero extent of reaction.

TABLE IV

INITIAL VALUES FOR THE SECOND-ORDER RATE COEFFICIENT FOR PIPERIDINE NEUTRALIZATION, $k_2^{(H^+)}$, AND FOR THE SECOND-ORDER RATE COEFFICIENT FOR BROMIDE ION PRODUCTION, $k_2^{(Br^-)}$, IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH PIPERIDINE IN SOLVENT BENZENE AT VARIOUS TEMPERATURES

t, °C.	[Bromoketone]	[Piperidine]	$10^5\ k_2^{(Br^-)}$, l. moles^{-1} sec.$^{-1}$	$10^5\ k_2^{(H^+)}$, l. moles^{-1} sec.$^{-1}$
60.0	0.0800	0.0400	..	1.05
60.0	.0800	.0800	..	1.02
75.0	.0800	.0800	..	2.7
75.0	.0800	.160	2.6	..
90.6	.0800	.0400	..	6.6
90.6	.0400	.0800	6.0	..
90.6	.0800	.0800	6.7	6.7
90.6	.0800	.160	6.8	..

$k_2 = Ae^{-E/RT}$; $A = 10^{4.5}$ l. moles^{-1} sec.$^{-1}$; $E = 14.6$ kcal./mole.

Kinetics of the Morpholine Promoted Elimination from Bromoketone I in Solvent Benzene.—The extremely slow reaction of bromoketone I with morpholine, under the experimental conditions, was followed only by a determination of the rate of formation of bromide ions; no drift was observed in the values for the integrated second-order rate coefficient throughout any individual run, but in no instance was more than 30% of the possible reaction followed.

TABLE V

INITIAL VALUES FOR THE SECOND-ORDER RATE COEFFICIENTS FOR BROMIDE ION PRODUCTION, $k_2^{(Br^-)}$, IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH MORPHOLINE IN SOLVENT BENZENE AT VARIOUS TEMPERATURES

t, °C.	[Bromoketone]	[Morpholine]	$10^6\ k_2^{(Br^-)}$, l. moles^{-1} sec.$^{-1}$
60.0	0.0800	0.0800	0.43
60.0	.0800	.160	0.50
75.0	.0800	.0400	1.11
75.0	.0800	.0800	1.16
90.6	.0800	.0400	3.3
90.6	.0800	.0800	3.6
90.6	.0800	.160	4.2

The initial values for the second-order rate coefficient show a slight increase in value as the morpholine concentration is increased. The values obtained are insufficient in number to allow extrapolation to zero morpholine concentration and consequently the Arrhenius plot of the temperature variation has been carried out using the initial second-order rate coefficients obtained for a concentration of morpholine of 0.0800 *M*. In this way values for the frequency factor of $10^{5.0}$ liters moles^{-1} sec.$^{-1}$ and for the activation energy of 17.4 kcal./mole are obtained.

Kinetics of the Piperidine Promoted Elimination from α-Bromoketone I in Solvent Acetonitrile.—The kinetics of the elimination reaction have been followed both by titration of the rate of disappearance of piperidine and by titration of the rate of appearance of bromide ions. For any given set of reaction conditions both titration techniques lead to identical results.

(9) The decomposition appears to be complex and further study is contemplated. Carbonium ions, *e.g.*, as formed from olefins in the presence of acids, are known to be reactive toward acetonitrile; see for example H. Plaut and J. J. Ritter, *J. Am. Chem. Soc.*, **73**, 4076 (1951).

The kinetic results have been analyzed in terms of integrated second-order rate coefficients, first order with respect to both α-bromoketone I and to piperidine. These rate coefficients were found to be constant in value throughout the major part of each run and mean values were taken within this range. The mean values obtained from each run for the integrated second-order rate coefficients were found to be a constant at each temperature independent of the reactant concentrations.

TABLE VI

MEAN VALUES FOR THE SECOND-ORDER RATE COEFFICIENTS FOR PIPERIDINE NEUTRALIZATION, $k_2^{(H+)}$, AND FOR THE SECOND-ORDER RATE COEFFICIENTS FOR BROMIDE ION PRODUCTION, $k_2^{(Br-)}$, IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH PIPERIDINE IN SOLVENT ACETONITRILE AT VARIOUS TEMPERATURES

t, °C.	[Bromoketone]	[Piperidine]	$10^3\ k_2^{(Br-)}$, l. moles^{-1} sec.$^{-1}$	$10^3\ k_2^{(H+)}$, l. moles^{-1} sec.$^{-1}$
60.0	0.0100	0.00500	..	3.1
60.0	.0100	.0200	..	3.0
75.0	.0100	.00250	7.9	8.3
75.0	.0100	.00500	..	7.2
75.0	.00500	.0100	..	6.7
75.0	.0100	.0100	6.7	7.2
75.0	.0200	.0100	7.4	7.1
75.0	.0100	.0200	..	7.1
75.0	.0200	.0400	..	6.9
90.6	.00500	.0100	..	15.8
90.6	.0200	.0400	..	16.8

$k_2 = Ae^{-E/RT}$; $A = 10^{6.2}$ l. moles^{-1} sec^{-1}; $E = 13.3$ kcal./mole.

Kinetics of the Morpholine Promoted Elimination from α-Bromoketone I in Solvent Acetonitrile.—The morpholine promoted elimination was followed by a determination of the rate of neutralization of morpholine, but two of the runs were duplicated and it was shown that after a given time the extent of reaction as determined by bromide ion production was in each case identical with that as determined by morpholine neutralization.

Analysis of the data was carried out in terms of integrated second-order rate coefficients, first order in α-bromoketone I and first order in morpholine. Throughout each individual run a marked upward drift in the values for the second-order rate coefficient with increasing extent of reaction occurred. The initial values for the second-order rate coefficient obtained by extrapolation to zero extent of reaction fell slightly in value as the concentration of morpholine was increased.

TABLE VII

INITIAL VALUES FOR THE SECOND-ORDER RATE COEFFICIENTS FOR MORPHOLINE NEUTRALIZATION, $k_2^{(H+)}$, AND FOR THE SECOND-ORDER RATE COEFFICIENTS FOR BROMIDE ION PRODUCTION, $k_2^{(Br-)}$, IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH MORPHOLINE IN SOLVENT ACETONITRILE AT VARIOUS TEMPERATURES

t, °C.	[Bromoketone]	[Morpholine]	$10^3\ k_2^{(Br-)}$, l. moles^{-1} sec.$^{-1}$	$10^3\ k_2^{(H+)}$, l. moles^{-1} sec.$^{-1}$
60.0	0.0100	0.00500	..	0.32
60.0	.0100	.0200	..	.29
75.0	.0100	.00250	..	.98
75.0	.0100	.0100	0.83	.86
90.6	.0100	.00250	..	2.9
90.6	.0100	.00500	..	2.2
90.6	.0200	.0100	2.4	2.4
90.6	.0100	.0200	..	1.8

It appears that there is a first-order component to the reaction path. If at each temperature the first-order rate coefficient is $k_1°$ (sec.$^{-1}$) and the second-order rate coefficient is $k_2°$ (liters moles^{-1} sec.$^{-1}$) then

k_2[bromoketone][morpholine] = $k_1°$[bromoketone] + $k_2°$[bromoketone][morpholine]

A plot of the second-order rate coefficient, k_2 (liters moles^{-1} sec.$^{-1}$), against the reciprocal of the morpholine concentration will have as the intercept $k_2°$ and as the slope $k_1°$. Accurate values for $k_2°$ were obtained in this way. The first-order component to the reaction scheme within the concentration ranges studied at each temperature was too small in magnitude to allow for other than a very approximate determination of the corresponding $k_1°$ values.

TABLE VIII

VALUES FOR THE SECOND-ORDER RATE COEFFICIENT, $k_2°$, AND APPROXIMATE VALUES FOR THE FIRST-ORDER RATE COEFFICIENT, $k_1°$, FOR MORPHOLINE NEUTRALIZATION IN THE MIXED ORDER REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH MORPHOLINE IN SOLVENT ACETONITRILE AT VARIOUS TEMPERATURES

t, °C.	60.0	75.0	90.6
$10^6\ k_1°$, sec.$^{-1}$	~0.2	~0.4	~2.0
$10^3\ k_2°$, l. moles^{-1} sec.$^{-1}$	0.28	0.82	2.0

$k_2° = Ae^{-E/RT}$; $A = 10^{6.5}$ l. moles^{-1} sec.$^{-1}$; $E = 15.3$ kcal./mole.

Kinetics of the Tetraethylammonium Bromide Promoted Elimination from α-Bromoketone I in Solvent Acetonitrile.—In each case the extent of elimination reaction was determined by titration of the acid developed, but for one run at 90.6° the extent of reaction was also determined by potentiometric titration of the bromide ion developed. The extent of reaction at any given time was found to be independent of whether it was determined in terms of hydrogen ion production or in terms of bromide ion production.

The behavior throughout each individual run was such that a steady fall off in the integrated values for the first order coefficient with respect to α-bromoketone I was observed. During the initial stages of reaction the second order coefficients, first order in α-bromoketone I and first order in tetraethylammonium bromide, were at each temperature constant from run to run within the concentration range studied.

TABLE IX

INITIAL SECOND-ORDER RATE COEFFICIENTS, k_2, FOR ACID PRODUCTION IN THE REACTION OF 4-BIPHENYLYL 1-BROMOCYCLOHEXYL KETONE (I) WITH TETRAETHYLAMMONIUM BROMIDE IN ACETONITRILE AT VARIOUS TEMPERATURES

t, °C.	[Bromoketone]	[NEt_4Br]	$10^3\ k_2$, l. moles^{-1} sec.$^{-1}$
60.0	0.0100	0.00500	0.66
60.0	.0100	.0200	0.78
75.0	.0100	.00250	3.0
75.0	.0200	.00500	3.1
90.6	.0100	.00250	13.6
90.6	.0100	.00500	12.6
90.6	.0200	.00500	13.2
90.6	.0100	.0100	12.0[a]
90.6	.0100	.0200	13.1

[a] Initial second-order rate coefficient for bromide ion production: 12.0×10^{-3} l. moles^{-1} sec.$^{-1}$; $k_2 = Ae^{-E/RT}$; $A = 10^{11.9}$ liters moles^{-1} sec.$^{-1}$; $E = 22.9$ kcal./mole.

Kinetics of the Piperidine Hydrobromide Promoted Elimination from Bromoketone I in Solvent Acetonitrile.—The kinetics of the piperidine hydrobromide promoted elimination from bromoketone I were briefly investigated at 90.6° by a titration of the acid concurrently developed.

An analysis of the kinetic data was carried out in terms of initial values for the second-order rate coefficient, first order in both α-bromoketone I and in piperidine hydrobromide. The initial values for the second-order rate coefficient were found to fall as the concentration of piperidine hydrobromide increased. An analysis in terms of initial 3/2 order rate coefficients was found to lead to constant values for the rate coefficient as defined by

initial velocity = $k_{3/2}$ [bromoketone] [piperidine hydrobromide $^{1/2}$

TABLE X

INITIAL SECOND-ORDER RATE COEFFICIENTS, k_2, AND INITIAL 3/2 ORDER RATE COEFFICIENTS, $k_{3/2}$, FOR ACID PRODUCTION IN THE REACTION OF 4-BIPHENYL 1-BROMOCYCLOHEXYL KETONE (I) WITH PIPERIDINE HYDROBROMIDE IN ACETONITRILE AT 90.6°

[Bromoketone]	[$C_5H_{11}NHBr$]	$10^3 k_2$, l. moles^{-1} sec.$^{-1}$	$10^4 k_{3/2}$, l.$^{1/2}$ moles$^{-1/2}$ sec.$^{-1}$
0.0200	0.00267	5.5	2.8
.0200	.00667	3.6	3.0
.0200	.0133	2.6	3.0

Experimental Methods

Materials.—Preparation of the 4-biphenylyl 1-bromocyclohexyl ketone,[2] the preparation of 4-biphenylyl 1-cyclohexenyl ketone[2] and the purification of the piperidine[1] have previously been described. Technical grade morpholine was dried over potassium hydroxide and fractionated. Preparation of the bromide salts has previously been described.[3] Analytical reagent benzene (Mallinckrodt) was dried over calcium hydride and fractionated. The acetonitrile was Eastman Kodak Co. "Spectro Grade."

Kinetic Methods.—The kinetic techniques have been fully described previously[1,3]; several illustrative runs are given below. The integrated second-order rate coefficients are calculated with respect to the α-bromoketone I and to piperidine or morpholine. The integrated first-order rate coefficients, k_1 (sec.$^{-1}$), are calculated with respect to α-bromoketone I.

(A) Temperature, 90.6°; 5.05-ml. aliquots at 24°; solvent, benzene; [bromoketone] = 0.0800 *M*; [piperidine] = 0.0400 *M*; titers in ml. of 0.0525 *M* HCl

Time, min.	0	300	400	1140	1460	1830	2630
Titers	3.78	3.45	3.33	2.65	2.35	2.16	1.66
$10^5 k_2$	..	6.6	6.9	7.1	7.6	7.3	7.9

Initial k_2: 6.6×10^{-5} l. moles^{-1} sec.$^{-1}$.

(B) Temperature, 75.0°; 5.05-ml. aliquots at 24°; solvent, benzene; [bromoketone] = 0.0800 *M*; [piperidine] = 0.160 *M*; titers in ml. of 0.0500 *M* $AgNO_3$

Time, min.	0	215	390	1440	1640	1840	2040
Titers	0.01	0.40	0.77	2.24	2.53	2.81	2.96
$10^5 k_2$	..	2.4	2.7	2.5	2.6	2.7	2.6

Mean value for k_2 is 2.6×10^{-5} l. moles^{-1} sec.$^{-1}$.

(C) Temperature, 90.6°; 5.05-ml. aliquots at 24°; solvent, benzene; [bromoketone] = 0.0800 *M*; [Morpholine] = 0.160 *M*; titers in ml. of 0.0500 *M* $AgNO_3$

Time, min.	0	896	2380	7260	10,080	11,280
Titers	0.01	0.28	0.70	1.85	2.32	2.48
$10^6 k_2$	..	4.0	3.8	3.9	3.8	3.7

Mean value for k_2 is 3.8×10^{-6} l. moles^{-1} sec.$^{-1}$.

(D) Temperature, 90.6°; 5.05-ml. aliquots at 24°; solvent, acetonitrile; [bromoketone] = 0.0200 *M*; [NEt_4-Br] = 0.00500 *M*; titers in ml. of 0.0112 *M* morpholine solution

Time, min.	0	5	10	20	40	60	172
Titer	0.19	0.36	0.51	0.80	1.26	1.66	2.81
$10^5 k_1$	..	6.5	6.2	6.0	5.4	5.1	3.4

Initial k_1 is 6.6×10^{-5} sec.$^{-1}$, corresponding to an initial second-order rate coefficient of 13.2×10^{-3} l. moles^{-1} sec.$^{-1}$.

(E) Temperature, 75.0°; 5.05-ml. aliquots at 24°; solvent, acetonitrile; [bromoketone] = 0.0200 *M*; [piperidine] = 0.0100 *M*; titers in ml. of 0.0100 *M* $AgNO_3$ solution

Time, min.	0	10	20	38	62	112	172
Titer	0.22	0.61	0.91	1.41	1.91	2.80	3.45
$10^3 k_2$	..	7.7	7.2	7.2	7.0	7.7	7.7

Mean value for k_2 is 7.4×10^{-3} l. moles^{-1} sec.$^{-1}$.

(F) Temperature, 90.6°; 5.05-ml. aliquots at 24°; solvent, acetonitrile; [bromoketone] = 0.0200 *M*; [morpholine] = 0.0100 *M*; titers in ml. of 0.0106 *M* HCl solution

Time, min.	0	20	40	65	90	124	350
Titer	4.35	4.12	3.90	3.64	3.36	2.96	0.80
$10^3 k_2$	..	2.42	2.45	2.41	2.66	2.96	5.73

Initial k_2 is 2.4×10^{-3} l. moles^{-1} sec.$^{-1}$.

Product Studies[10]

Product Studies under Conditions of Kinetic Measurement in Solvent Benzene.—Product studies were carried out only for the piperidine reaction. The morpholine reaction was considered to be too slow for convenient product study under the kinetic conditions, but morpholine is known to produce the α,β-unsaturated ketone II.[2]

A 30-ml. portion of a solution 0.0800 *M* in α-bromoketone I and 0.160 *M* in piperidine was allowed to react for 276 hours at 90.6°. The solution was filtered, washed with a little water and evaporated to dryness. The residue was dissolved in ether, washed several times with water, dried over magnesium sulfate and evaporated to dryness. A yield of 0.36 g. of a yellowish solid was obtained. This represented a 56% yield calculated as α,β-unsaturated ketone II. The melting point was 64–67°, which after recrystallization from methanol was raised to 67–68°. The infrared spectrum of the crude material had $\gamma_{C=O}$ 1646/91 and the recrystallized material had $\gamma_{C=O}$1647/92. Both the infrared spectrum and the melting point indicate that the product is the α,β-unsaturated ketone II.[2]

To test whether any piperidino-addition (or substitution) product is formed in benzene solution but subsequently decomposed during isolation of the products, a 5-ml. portion of the same solution was identically treated and the piperidine hydrobromide (98% yield) filtered off. The infrared spectrum of the benzene solution has a broad carbonyl peak $\gamma_{C=O}$ 1637/93, presumably due to the α,β-unsaturated ketone II, and a very slight shoulder, $\gamma_{C=O}$ 1674/60, probably due to a little unreacted α-bromoketone I. The initial reaction mixture had one carbonyl peak $\gamma_{C=O}$ 1674/88.

A further 5-ml. portion of the reaction mixture, identically treated, had, on titration in the usual manner against 0.0525 *M* HCl, 44.5% of the initial piperidine concentration remaining.

Elimination Promoted by Piperidine in Solvent Acetonitrile.—A 30-ml. portion of a solution 0.0200 *M* in α-bromoketone I and 0.0400 *M* in piperidine was maintained at 90.6° for 172 hours. The acetonitrile was removed by evaporation and the residue extracted with ether. The ether solution was washed several times with water, dried over anhydr. magnesium sulfate and evaporated to dryness. The residue, m.p. 56–63°, weighed 0.10 g., a 64% yield calculated as unsaturated ketone. The infrared spectrum had $\gamma_{C=O}$ 1649/92 and the spectrum was superimposable upon that for an authentic sample of α,β-unsaturated ketone II. After recrystallization from methanol the melting point was raised to 67–69°.

Elimination Promoted by Morpholine in Solvent Acetonitrile.—The investigation was carried out exactly as for the piperidine promoted elimination except in that the solution was maintained at 90.6° for 252 hours. The yield calculated as unsaturated ketone was 57%. The melting point of the crude product was 61–68°. The infrared spectrum was superimposable upon that for an authentic sample of the α,β-unsaturated ketone II, $\gamma_{C=O}$ 1647/90 cm.$^{-1}$ After recrystallization from methanol the melting point was raised to 67–69°.

Elimination Promoted by Tetraethylammonium Bromide in Solvent Acetonitrile.—Titration of the acid developed in 5.00-ml. samples of a solution 0.0200 *M* in α-bromoketone I and 0.0200 *M* in tetraethylammonium bromide, maintained at 90.6°, showed that after 22 hours 6.85 ml. of 0.0112 *M* morpholine solution was required for neutralization. It appears that the reaction comes to an equilibrium corresponding to 77% of the stoichiometrically possible acid formation.

A 30-ml. sample of the above reaction mixture was maintained at 90.6° for 22 hours. The acetonitrile was evaporated off and the residue ether extracted. The ether solution was evaporated to dryness to yield 0.13 g. of a white solid, m.p. 56–63°. The infrared spectrum showed two carbonyl absorption peaks, $\gamma_{C=O}$ 1650/85 and $\gamma_{C=O}$ 1681/57. The infrared spectrum was superimposable upon that obtained for a synthetic mixture 77% α,β-unsaturated ketone

(10) Melting points were read with a calibrated thermometer. Infrared spectra were measured with a Perkin–Elmer model 21 double beam recording instrument employing sodium chloride optics and matched sodium chloride cells with carbon tetrachloride solutions or a potassium bromide pellet for the insoluble amine hydrochloride. The ultraviolet spectrum was determined with a Cary model 11-MS recording spectrophotometer using a reagent grade methanol solution.

II and 23% β-bromo ketone IV. After recrystallization from methanol the infrared spectrum was superimposable upon that of an authentic sample of the α,β-unsaturated ketone II, $\gamma_{C=O}$ 1649/91. The melting point was raised to 66–68°.

Product Studies on the Addition of Piperidine to the α,β-Unsaturated Ketone II.—A 1.12-g. sample of the α,β-unsaturated ketone II was dissolved in 10 ml. of piperidine and allowed to stand at room temperature for 25 days. The reaction mixture was poured into water and ether extracted. The ether solution was washed several times with distilled water, dried over anhydr. magnesium sulfate and dry hydrogen chloride was bubbled into the solution. The precipitate formed, 1.18 g., was found to be the hydrochloride of the β-aminoketone III contaminated with about 5% of piperidine hydrochloride, m.p. 192–195° dec. The infrared spectrum showed only one carbonyl peak, $\gamma_{C=O}$ 1669 cm.$^{-1}$.

Anal. Calcd. for $C_{24}H_{30}ONCl$: C, 75.11; H, 7.82; N, 3.65. Calcd. for 95.2% $C_{24}H_{30}ONCl$ and 4.8% $C_5H_{12}NCl$: C, 73.87; H, 7.92; N, 4.04. Found: C, 73.88; H, 7.88; N, 4.04.

A portion of the hydrochloride was dissolved in water and potassium carbonate solution added; a white precipitate was ether extracted. The ether solution was washed several times with distilled water and dried over anhydr. magnesium sulfate. Evaporation of the ether left a white solid, m.p. 105–118°. The infrared spectrum had $\gamma_{C=O}$ 1677/85 due to the β-aminoketone III and $\gamma_{C=O}$ 1649/39 due to a little admixed α,β-unsaturated ketone II, presumably formed by decomposition of the β-aminoketone III during its isolation. A portion of the product was recrystallized from methanol, m.p. 120–123.5°, but was not analyzed.

4-Biphenylyl 2-Bromocyclohexyl Ketone (IV).—A 0.37-g. sample of the α,β-unsaturated ketone II was dissolved in 50 ml. of ether, saturated with dry hydrogen bromide, and then allowed to stand for 48 hours prior to evaporation to dryness. The residue was recrystallized from acetone–water and washed well with water. The crude β-bromoketone IV, 0.32 g. (65% yield), was recrystallized from carbon tetrachloride–petroleum ether solution; m.p. 124°, λ_{max} 287 mμ (ϵ 23,400), $\gamma_{C=O}$ 1681/82 cm.$^{-1}$.

Anal. Calcd. for $C_{19}H_{19}BrO$: C, 66.48; H, 5.58; Br, 23.28. Found: C, 66.35; H, 5.90; Br, 23.19.

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[CONTRIBUTION FROM THE DEPARTMENTS OF CHEMISTRY OF THE UNIVERSITY OF WISCONSIN, MADISON, WIS., AND OF STANFORD UNIVERSITY, STANFORD, CALIF.]

The Acid-catalyzed Reaction of Diazomethane with Some α,β-Unsaturated Ketones

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α,β-Unsaturated ketones have been shown to react with diazomethane, in the presence of either fluoboric acid or boron trifluoride catalyst, to give linear homologation. The main product is that formed by insertion of a methylene group between the carbonyl group and the α-carbon atom holding the double bond to yield a β,γ-unsaturated ketone. Hitherto the uncatalyzed reaction was known either to give pyrazolines or to fail altogether. Thus the following transformations were effected: Δ^4-cholestene-3-one to A-homocholestenone (I); testosterone propionate to A-homotestosterone propionate (VII). Preliminary studies on the homologation of benzalacetone and benzalacetophenone are also described.

The acid-catalyzed reaction of diazomethane with an α,β-unsaturated ketone to effect linear homologation is new.[1,2] Previously it was known that treatment of α,β-unsaturated ketones with diazomethane gave either pyrazoline derivatives[3] or no reaction at all.[4]

The discovery that fluoboric acid or boron trifluoride catalyzes a reaction of diazomethane with α,β-unsaturated ketones was made in our laboratories inadvertently when testosterone was submitted to the treatment with the view to preparing the 17-methyl ether.[5] The reaction mixture contained, in addition to the expected product,[5] an appreciable amount of material exhibiting unconjugated carbonyl absorption in the infrared spectrum.

In order to elucidate the nature of this new ketonic product, we first turned our attention to a simpler system, namely Δ^4-cholestene-3-one. This ketone failed to react with diazomethane under normal conditions, but in the presence of a small amount (about 6 mole % in methylene chloride solution) of fluoboric acid or boron trifluoride, a rapid reaction occurred accompanied by evolution of nitrogen. The extinction coefficient of the ultraviolet absorption maximum due to the α,β-unsaturated ketone at 241 mμ was 6500 for the crude product as compared with 16,600 for the starting ketone. From this mixture there was readily separated a ketone, m.p. 94–95°, $\lambda_{max}^{CH_2Cl_2}$ 5.84 (C=O) and 6.1 μ (weak, C=C). The ultraviolet spectrum of the pure ketone exhibited only end absorption in the short wave length region. This product could be readily isolated in yields as high as 40% when pure cholestenone was used.[6]

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(4) See, for example: A. Wettstein, *Helv. Chim. Acta*, **27**, 1803 (1944); C. Djerassi and C. R. Scholz, *J. Org. Chem.*, **14**, 660 (1949); and A. L. Nussbaum and F. E. Carlon, *J. Am. Chem. Soc.*, **79**, 3831 (1957).

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(6) Cholestenone was prepared from cholesterol which had been purified as described by L. F. Fieser, *Org. Syntheses*, **35**, 43 (1955). Commercial cholesterol contains significant amounts of cholestanol (L. F. Fieser, *J. Am. Chem. Soc.*, **73**, 5007 (1951); **75**, 4395 (1953)). We have found that cholestenone prepared directly (as recommended by J. F. Eastham and R. Teranishi, *Org. Syntheses*, **35**, 39 (1955)) from commercial cholesterol affords a product which, although not showing a depressed m.p., is contaminated with cholestanone. This fact was first suggested when K. L. Williamson of our laboratories carried out a Wolff–Kishner reduction on ordinary Δ^4-cholestene-3-one and obtained a mixture from which cholestane was isolated in 2% yield. Moreover, catalytic hydrogenation of (impure) cholestenone had always yielded a mixture of coprostanone and cholestanone, rendering particularly difficult the isolation of the former substance in a pure form. For many years we, as well as others, had regarded the cholestanone thus isolated as being formed by non-stereoselective reduction of the unsaturated ketone; whereas in fact it has now been