

uptake (240 cc., 1.0 equiv.) ceased, the reaction mixture was filtered and concentrated to leave 1.551 g. of crude acidic product. Crystallization from petroleum ether afforded 860.4 mg. (53%) of the pure acid **28** as white needles, m.p. 58–59° (lit.³⁵ m.p. 57–58°), with infrared absorption¹⁸ at 3000 (broad, O–H) and at 1710 cm.⁻¹ (carboxyl C=O), a molecular ion peak at m/e 162 in the mass spectrum, and n.m.r. absorption¹⁸ at δ 12.20 (1H, –CO₂H) as well as complex absorption in the regions δ 7.0–7.5 (4H, aryl C–H) and 2.0–4.3 (5H, aliphatic C–H).

B. Complete Hydrogenation to Acid 29.—A solution of 9.6 g. (0.060 mole) of the unsaturated acid **27** in 120 ml. of acetic acid was hydrogenated at 60° and 2–3-atm. pressure over the catalyst from 1.0 g. of platinum oxide. The hydrogen uptake (0.256 mole, 1.07 equiv.) ceased after 12 hr. and the reaction mixture was filtered and concentrated to leave 9.083 g. of the crude acid **29**³⁶ as a brown oil. An ethereal solution of this product was esterified with excess diazomethane to give, after washing, drying, and concentration, 6.928 g. (64% based on the starting unsaturated acid **27**) of a mixture of esters as a pale yellow liquid. This material contained²⁹ the ester **20** (2%, 15.4 min.), the ester **21** (18.6 min.) partially resolved from a small amount of an unknown component A (ca. 20 min., total 25%), the ester **22** (67%, 23.4 min.), and two additional compounds B (1%, 29.4 min.) and C (5%, 38.6 min.). Collected²⁹ samples of esters **20–22** were identified with previously described samples by comparison of retention times and infrared and mass spectra. The collected sample of ester **22** has infrared absorption¹⁸ at 1740 cm.⁻¹ (ester C=O) with a molecular ion peak at m/e 182 in its mass spectrum as well as abundant fragment peaks at m/e 150, 108, 87, 81, 67, 55, and 41. The n.m.r. spectrum¹⁸ of ester **22** has a singlet at δ 3.74 (3H, –CO₂CH₃) with a broad multiplet centered at δ 2.85 (1H, CH–CO₂R) and complex absorption in the region δ 1.0–2.5 (14H, aliphatic C–H).

Anal. Calcd. for C₁₁H₁₈O₂: C, 72.49; H, 9.96. Found: C, 72.62; H, 10.05.

A collected²⁹ sample of component B, with infrared absorption

(35) R. A. Heacock, R. L. Wain, and F. Wightman, *Ann. Appl. Biol.*, **46**, 352 (1958).

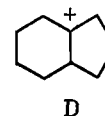
(36) Preparations of the acid **29** have been reported by (a) D. W. Mathieson [*J. Chem. Soc.*, 3251 (1953)], who reported m.p. 94–95° for one isomer believed to have a *cis*-fused ring juncture, and (b) M. J. LeGoffic and F. LeGoffic [*Compt. rend.*, **255**, 539 (1962)], who prepared a *p*-bromophenacyl ester derivative, m.p. 88–89°, of uncertain stereochemistry.

at 1710 and 1645 cm.⁻¹ and a molecular ion peak at m/e 180 in the mass spectrum, appears to be one or more of the tetrahydroindancarboxylic esters. No further characterization of components A, B, and C was attempted.

The above ester mixture (602.2 mg., 3.4 mmoles) from hydrogenation and subsequent esterification was dissolved in 5 ml. of methanol containing 16 mmoles of sodium methoxide. After the resulting mixture had been refluxed for 24 hr., it was diluted with water and petroleum ether. The organic layer was separated, dried, and concentrated at which time the residual yellow liquid contained²⁹ primarily the ester **21** accompanied by smaller amounts of esters **20** and **22** as well as components B and C. A collected sample of ester **21** from this reaction was identified with the previously described material by comparison of retention times and infrared spectra. A comparable equilibration employing 28.2 mg. (0.16 mmole) of the pure²⁹ ester **22** in 1 ml. of methanol containing 0.9 mmole of sodium methoxide afforded a mixture composed of²⁹ 88% of the ester **21** and 12% of the ester **22**.¹⁸ Application of the same equilibration procedure to the ester **20** failed to reveal the formation of a second component. However, it is possible that the two epimers of the *trans*-fused ester (**20** and its C-1 epimer) were not resolved by the gas chromatography column²⁹ used.

Preparation of the Acid Chloride 23.—A solution of 3.74 g. (22 mmoles) of the *trans* acid **24** in 4.5 ml. of thionyl chloride was refluxed for 2 hr. and then concentrated under reduced pressure. Distillation of the residue afforded 3.783 g. (92%) of the acid chloride **23** as a colorless liquid, b.p. 90–92° (7 mm.), n_D^{20} 1.4956. The product has infrared bands¹⁸ of equal intensity at

1790 and 1815 cm.⁻¹ (O=C–Cl, doublet presumably caused either by Fermi resonance or by the presence of comparable concentrations of two rotation isomers) with abundant fragment peaks in its mass spectrum at m/e 123 (D), 122, 93, 81, 80, 79, 67, 55, and 41.



Anal. Calcd. for C₁₀H₁₆ClO: C, 64.33; H, 8.10; Cl, 18.99. Found: C, 64.61; H, 8.01; Cl, 18.62.

The Synthesis and Attempted Rearrangement of a Blocked Dienone

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In order to determine whether the dienone–phenol rearrangement would proceed in a manner which would disrupt the aromaticity of a benzene ring, 3,4,4-trimethyl-1-oxo-1(4H)-dihydronaphthalene has been synthesized. The Friedel–Crafts reaction of 3,4,4-trimethylbutyrolactone and benzene gave 3,4,4-trimethyl-1-tetralone, 3,3,4-trimethyl-1-tetralone, and a third isomeric ketone of unknown structure. The structures of the first two ketones were confirmed by alternate syntheses. In an effort to identify the third compound, 3,4-dimethyl benzosuberone, 2,2,3-trimethyl-1-tetralone, 3-methyl-3-isopropyl-1-indanone, 3,3-dimethyl-1-indanone, and 3-isopropyl-1-indanone were synthesized. The desired dienone was prepared by bromination followed by dehydrobromination of 3,4,4-trimethyl-1-tetralone. Attempted rearrangement of this compound gave no phenol, but did afford a disulfonation product.

Although many studies of the dienone–phenol rearrangement have been carried out in recent years in order to more clearly define the course of this rearrangement, all attempts to design a system where the rearrangement would proceed through an aromatic ring have failed. The two reported attempts³ both proceeded

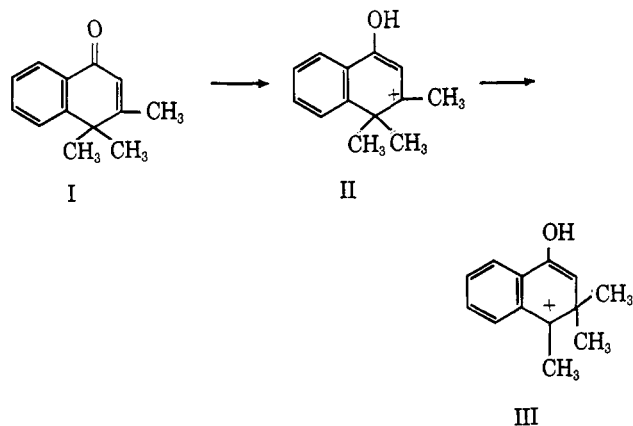
in an anomalous, though logical, manner without disrupting the aromaticity of the systems involved.

In order to have available a system where rearrangement without disrupting the aromatic character of the system is precluded, we have prepared and treated with acid 3,4,4-trimethyl-1-oxo-1(4H)-dihydronaphthalene (I). It will be noted that protonation of I could give rise to a carbonium ion (II), which although it may rearrange to ion III can undergo no further normal rearrangement, and in fact might be expected to revert to I. It was anticipated that, if rearrangement did occur, it would of necessity proceed from I

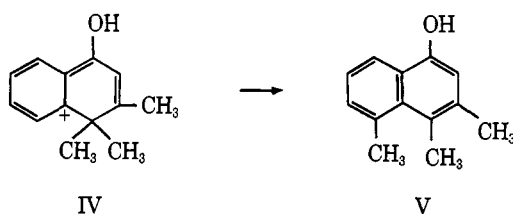
(1) General Electric Fellow, Harvard University, 1956–1957; Department of Chemistry and Geology, Clemson University.

(2) Abstracted from the Ph.D. Thesis of T. W. Bethea, Clemson University.

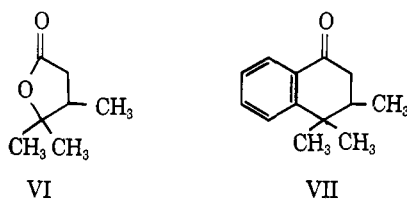
(3) (a) E. N. Marvell and A. C. Geiszler, *J. Am. Chem. Soc.*, **74**, 1259 (1952); (b) E. N. Marvell and J. L. Stephenson, *ibid.*, **77**, 5177 (1955).



to a carbonium ion (IV) resulting from the disruption of the aromatic ring. A series of methyl shifts, followed by rearomatization would then give V.



The synthetic approach chosen for I was a modification of that used by Arnold in his synthesis of the 4,4-dimethyl analog.⁴ It was envisioned that reaction of 3,4,4-trimethylbutyrolactone (VI) with benzene under Friedel-Crafts conditions should afford 3,4,4-trimethyl-1-tetralone (VII), since 4,4-dimethylbutyrolactone⁴ and butyrolactone⁵ itself give the corresponding tetralone in good yield.

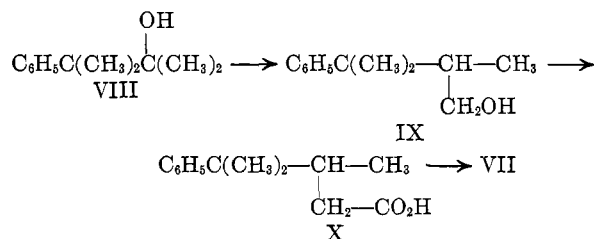


The trimethyl lactone, which had previously been prepared from terpenylic acid⁶ and in several steps from methyl isopropyl ketone⁷ was obtained by a modification of the latter method. The Reformatsky product from ethyl bromoacetate and methyl isopropyl ketone followed by reaction with acid gave VI in 46% yield. The product was homogeneous by gas chromatography, and the n.m.r. spectrum was in agreement with the proposed structure. When the Friedel-Crafts reaction with benzene was carried out, gas chromatography of the major fraction of the distilled product showed three components in a ratio of 6:41:53, in order of increasing retention time. Quantities of these compounds, sufficient for characterization, were obtained by preparative gas chromatography.

The compound having the longest retention time had an infrared maximum at 5.95 μ , indicative of a 1-

tetralone, gave a 2,4-dinitrophenylhydrazone of formula $C_{19}H_{20}N_4O_4$, and a benzylidene derivative. The ultraviolet spectrum of the dinitrophenylhydrazone also showed the absorption expected for a 1-tetralone (see Experimental). The n.m.r. spectrum showed two singlets (about three protons each) at τ 8.63 and 8.78, which may be assigned to the protons of the methyl groups attached at C-4 in VII. A doublet centered at τ 9.01 (three protons, $J = 6.5$ c.p.s.) and an ABC pattern centered at 7.54 may be assigned to the methyl at C-3 and the protons α and β to the carbonyl. The aromatic protons appeared as two complex multiplets at τ 2.08 and 2.64 (one and three protons, respectively). On the basis of the above data, it was felt that this compound was the desired, 3,4,4-trimethyl-1-tetralone (VII).

The assigned structure was proven by the synthesis of VII. 3-Methyl-3-phenyl-2-butanone, prepared either



by the rearrangement of 2-phenyl-3-methylbutane-2,3-diol or oxidation of the alcohol obtained from dimethylphenylacetaldehyde and methyl Grignard, upon reaction with methylmagnesium iodide gave the tertiary alcohol VIII. VIII on heating in dimethyl sulfoxide⁸ gave the corresponding olefin which upon hydroboration and oxidation gave IX. Conversion of IX to the tosylate followed by displacement with cyanide and hydrolysis to 3,4-dimethyl-4-phenylpentanoic acid (X), although apparently straightforward, proceeded in only 17% yield.⁹ Cyclization of the tetralone proceeded normally to give VII, identical in all respects with that obtained from the initial Friedel-Crafts reaction.

The compound with intermediate retention time also showed infrared absorption at 5.95 μ , and gave a dinitrophenylhydrazone isomeric with that from VII. The ultraviolet spectrum of this derivative indicated that the compound was also a substituted 1-tetralone.

The n.m.r. spectrum of this ketone showed a sharp singlet at τ 8.99 (six protons) which is about the same place as the signal from the protons on the β -methyl in VII. There was also a three-proton doublet ($J = 7$ c.p.s.) at τ 8.72, indicative of a single methyl group attached to a benzyl carbon. The benzyl proton appeared downfield as a quartet centered about τ 7.26. The balance of the high field portion of the spectrum consisted of an AB pattern ($J = 17.5$ c.p.s.) centered at τ 7.26, indicating two protons α to the carbonyl

(8) V. J. Traynelis, W. L. Hergenrother, and J. R. Livingston, *J. Org. Chem.*, **27**, 2377 (1962).

(4) R. T. Arnold, J. S. Buckley, and J. Richter, *J. Am. Chem. Soc.*, **69**, 2322 (1947).

(5) (a) W. E. Truce and C. E. Olson, *ibid.*, **74**, 4721 (1952); (b) C. E. Olson and A. R. Brader, "Organic Syntheses," Coll. Vol. IV, John Wiley and Sons, Inc., New York, N. Y., 1963, p. 898.

(6) R. Fittig and O. Krafft, *Ann.*, **208**, 71 (1881).

(7) S. B. Schryver, *J. Chem. Soc.*, **63**, 1327 (1893).

(9) This low yield may be attributed to several factors. First, the tosylate derived from XI would not be expected to undergo S_N2 attack readily (see, J. Hine, "Physical Organic Chemistry," 2nd Ed., McGraw-Hill Book Co., New York, N. Y., 1962, pp. 174, 175). In addition the hydrolysis of the nitrile required prolonged heating with base, and this would appear to be a case in which Newman's "rule of six" is applicable [M. S. Newman, *J. Am. Chem. Soc.*, **72**, 4783 (1950)]. For this reaction hydroxide ion would be designated one and there would be two methyls and a phenyl six atoms removed.

variation of the reaction will not take place under normal acidic conditions.

Experimental¹⁴

3,4,4-Trimethylbutyrolactone.—To 91 g. of granular, 20-mesh zinc, activated by washing with 5% hydrochloric acid, water, acetone, then anhydrous ether, and dried over an open flame *in vacuo*, was added 37.4 g. (46 ml., 0.43 mole) of 3-methyl-2-butanone in 150 ml. of benzene. A crystal of iodine and then a few milliliters of ethyl bromoacetate were added to the vigorously stirred mixture. The reaction vessel was heated with an open flame to induce reaction. Once the reaction had begun, it was kept under control by means of an ice bath. In all, 100 g. (66 ml., 0.60 mole) of bromo ester were added during 30 min. at a rate such that the solution was kept at gentle reflux. After heating at reflux on the steam bath during 1.5 hr., the reaction mixture was cooled to room temperature and carefully poured into 10% aqueous acetic acid. The aqueous layer was drawn off and extracted well with ether. The organic fractions were combined and then washed well with 10% ammonium hydroxide, 10% aqueous hydrochloric acid, and then with water. The yellow organic phase was dried, and the solvent was removed leaving 68.8 g. of orange oil. This hydroxy ester was used without further purification. The oil was heated on the steam bath for 12 hr. with 350 ml. of 70% sulfuric acid, cooled, poured into water, cooled, and extracted with ether. The ethereal solution was washed with saturated sodium bicarbonate solution, water, and dried. The ether was removed and the lactone was distilled giving 25.85 g. (46%), b.p. 62° (1 mm.) and 216–217° (744 mm.) (lit. b.p. 220° and 217–221°, both at atmospheric pressure), m.p. 8–9° (lit. m.p. 11° and 10°). The lactone was homogeneous by vapor phase chromatography; it showed an infrared maximum at 5.66 μ .

Anal. Calcd. for C₇H₁₂O₂: C, 65.60; H, 9.44. Found: C, 65.68; H, 9.53.

Attempted Preparation of 3,4,4-Trimethyl-1-tetralone.—A solution of 15.35 g. (0.12 mole) of 3,4,4-trimethylbutyrolactone in 96 ml. of dry benzene was slowly added to a chilled, stirred slurry of 55 g. (0.24 mole) of anhydrous aluminum chloride in 385 ml. of dry benzene. The brown slurry was stirred in a cold water bath during 1 hr. and then heated under reflux on the steam bath for 2 hr. The solution was cooled to room temperature and poured into a stirred slurry of ice and concentrated hydrochloric acid. The aqueous layer was drawn off and extracted well with ether. The organic solutions were combined, washed well with 5% sodium hydroxide and water, and dried, and the solvent was removed at reduced pressure. Distillation afforded 17.81 g. (78%) of a viscous, water-white liquid, b.p. 111–119° (1.9–2.3 mm.) This material was shown by vapor phase chromatography (180°) to consist of three components in a ratio of 6:41:53 in order of increasing retention time. Small, pure samples of these three compounds were obtained by preparative vapor phase chromatography.¹⁵ The first compound (1) eluted showed an infrared maximum at 5.96, the second (2) at 5.95, and the third (3) at 5.96 μ .

The 2,4-dinitrophenylhydrazone derivatives of each compound were prepared and were recrystallized from ethanol-ethyl acetate. The physical properties of these derivatives are summarized in Table I.

Compound 3 formed a benzylidene derivative, m.p. 93–94° from pentane, using the procedure of Rapson and Shuttleworth.¹⁶

(14) All melting points were taken on a Hershberg melting point apparatus and are uncorrected. Boiling points are uncorrected. Infrared spectra were taken either as liquid films on sodium chloride plates or as potassium bromide disks employing either a Perkin-Elmer Model 137 infrared spectrophotometer or a Perkin-Elmer Model 221 infrared spectrophotometer. Ultraviolet spectra were taken on a Perkin-Elmer Model 4000A ultraviolet-visible spectrophotometer in 95% ethanol or chloroform. The n.m.r. spectra determined at Clemson were taken on a Varian A-60 n.m.r. spectrometer, using carbon tetrachloride as the solvent and tetramethylsilane as an internal standard. Vapor phase chromatograms were carried out on a Perkin-Elmer Model 154D vapor fractometer with a 0.25 in. \times 1 or 2 m. column of silicone grease on diatomaceous earth (Perkin-Elmer column O₂) using helium as the carrier gas. Microanalyses were determined by Galbraith Laboratories, Knoxville, Tenn., unless otherwise noted.

(15) We would like to thank the Deering-Milliken Research Corp., Spartanburg, S. C., for carrying out this separation.

(16) W. S. Rapson and R. G. Shuttleworth, *J. Chem. Soc.*, 636 (1940).

TABLE I

| Compd. | M.p., °C. | Anal., ^a % | | | $\lambda_{\max.}^b$, μ (log e) |
|--------|-----------|-----------------------|------|-------|--|
| | | C | H | N | |
| 1 | 144–145 | 61.67 | 5.53 | 14.96 | 380 (4.46) |
| 2 | 175–176 | 61.73 | 5.28 | 15.48 | 385 (4.36) |
| 3 | 159–160 | 62.09 | 5.06 | 15.06 | 384 (4.50) |

^a Calcd. for C₁₉H₂₀N₄O₄: C, 61.94; H, 5.47; N, 15.21. ^b In chloroform solution.

Anal. Calcd. for C₂₀H₂₀O: C, 86.91; H, 7.30. Found: C, 87.10, H, 7.07.

Under the same conditions neither of the other compounds gave a derivative.

3-Phenyl-3-methyl-2-butanol.—A solution of 22.5 g. of 2-methyl-2-phenylpropanal¹⁷ in 100 ml. of dry ether was slowly added to a solution of methylmagnesium iodide, formed from 11.1 g. of magnesium and 73 g. of methyl iodide in 250 ml. of ether. Following the addition of the aldehyde the solution was heated at reflux for 2 hr. then poured cautiously onto ice. The resulting slurry was acidified with dilute sulfuric acid and the aqueous layer was drawn off and extracted thoroughly with ether. The combined ethereal extracts were washed with 5% sodium bicarbonate and water and dried, and the solvent was removed at reduced pressure. The pale yellow oil was distilled affording 15.3 g. (62%) of water-white liquid, b.p. 66–69° (1.5 mm.). The α -naphthylurethane was formed in the usual manner, and after recrystallization from hexane had a melting point of 108–109°.

*Anal.*¹⁸ Calcd. for C₂₂H₂₃NO₂: C, 79.25; H, 6.95; N, 4.20. Found: C, 79.02; H, 6.79; N, 4.26.

3-Phenyl-3-methyl-2-butanone. A.—A solution of 10.0 g. of 3-phenyl-3-methyl-2-butanol in 75 ml. of benzene was added slowly to a chilled, vigorously stirred solution of 17.8 g. of sodium dichromate in 16 ml. of glacial acetic acid, 65 ml. of sulfuric acid, and 75 ml. of water. The solution was stirred at 0° for 1 hr., then allowed to warm to room temperature and stirred for 8 hr. more. The aqueous phase was separated and the organic layer was washed with 5% sodium bicarbonate and water. The solution was dried and the solvent was removed at the water pump. The pale yellow oil which was obtained was distilled through a 24-in. Podbielniak column, giving two fractions. The lower-boiling fraction, 0.85 g., b.p. 38–40° (0.5 mm.), gave a red-orange 2,4-dinitrophenylhydrazone, m.p. 248–250°. The mixture melting point of this material with the 2,4-dinitrophenylhydrazone of acetophenone was 247–249°. The higher boiling fraction, 6.34 g., b.p. 69–75° (0.5 mm.), was considered to be the desired phenylbutanone. The yellow 2,4-dinitrophenylhydrazone, after recrystallization from ethanol-ethyl acetate, melted at 149–151°.

*Anal.*¹⁸ Calcd. for C₁₇H₁₉N₄O₄: C, 59.64; H, 5.30; N, 16.37. Found: C, 59.92; H, 5.49; N, 16.22.

B.—To 300 ml. of concentrated sulfuric acid, cooled to –5° with an ice-salt bath and magnetically stirred, was added 10.0 g. of 2-methyl-3-phenylbutane-2,3-diol.¹⁹ After 15 min. the reaction mixture was carefully poured over ice and extracted with ether. The ether solution was washed well with saturated sodium bicarbonate, then with water, and dried. The ether was removed leaving 8.74 g. of yellow oil. Distillation afforded 8.69 g. (97%) of colorless liquid, b.p., 66–67° (0.75 mm.) (lit.²⁰ b.p. 76–77° at 2 mm.), infrared maximum 5.87 μ . This compound was homogeneous by vapor phase chromatography. The semicarbazone melted at 185–187° (lit. m.p. 185.5–188.5²⁰ and 184.5–186.5²¹). The 2,4-dinitrophenylhydrazone was identical with that obtained in part A.

2,3-Dimethyl-3-phenyl-1-butanone.—To the stirred, ethereal, Grignard reagent prepared from 4.0 g. of magnesium turnings and 23.0 g. (162 mmoles) of iodomethane was added 8.05 g. (49.6 mmoles) of 3-methyl-3-phenyl-2-butanone in ether. The resulting slurry was stirred for 1 hr. at reflux after the addition of the ketone was completed. After cooling to room tempera-

(17) (a) J. W. Huffman and L. E. Browder, *J. Org. Chem.*, **27**, 3208 (1962); (b) N. H. Cromwell and H. H. Eby, *J. Am. Chem. Soc.*, **74**, 4201 (1952).

(18) This analysis was by S. N. Nagy Associates, Massachusetts Institute of Technology.

(19) (a) K. Alder, K. Heimbach, and K. Neufang, *Ann.*, **586**, 138 (1954); (b) R. Roger, *J. Chem. Soc.*, **127**, 518 (1925).

(20) C. G. Overberger and H. Gainer, *J. Am. Chem. Soc.*, **80**, 4556 (1958).

(21) C. M. Suter and A. W. Weston, *ibid.*, **64**, 533 (1942).

ture, the mixture was poured into a dilute hydrochloric acid-slush. The layers were separated and the aqueous portion was extracted with ether. The combined ether solutions were washed with a dilute solution of sodium bisulfite, saturated sodium bicarbonate, and water, and then dried. Removal of the ether left 10.35 g. of crude 2,3-dimethyl-3-phenyl-2-butanol as a yellow oil. This oil was mixed with 85 ml. of dried dimethyl sulfoxide and heated at 145–150° for 17 hr. The homogeneous, yellow solution was cooled to room temperature and diluted with ca. 1 l. of water; this mixture was extracted with hexane. The hexane solution was washed with water and dried. Removal of the solvent left a pale yellow oil, which was distilled, b.p. 40.45° (0.55–1.1 mm.), giving 6.88 g. (86%) of 2,3-dimethyl-3-phenyl-1-butene. By vapor phase chromatography, this liquid contained a consistent impurity (6%), and was used directly in the next step.

To a solution of 6.67 g. (41.6 moles) of the alkene in ether under a nitrogen atmosphere, was added 21.0 g. of freshly distilled boron trifluoride etherate. Then 4.17 g. of lithium aluminum hydride in ether was added slowly with constant stirring. After stirring for 16 hr., the excess lithium aluminum hydride was decomposed by the careful addition of water. The layers were separated, the aqueous portion was washed with ether, the organic solutions were combined, and the ether was removed. To the resulting oil, cooled to 5°, was added 98 ml. of dioxane, 320 ml. of 3 N sodium hydroxide, and 175 ml. of 30% hydrogen peroxide slowly over 1.5 hr. The solution was warmed to room temperature, diluted with water, and extracted with ether. The ethereal solutions were combined, concentrated, and dried. Removal of the ether left 6.96 g. of oil. Distillation gave 4.49 g. (60%) of alcohol, b.p. 105–106.5° (0.6 mm.), homogeneous by vapor phase chromatography.

Anal. Calcd. for $C_{12}H_{18}O$: C, 80.85; H, 10.18. Found: C, 80.70; H, 10.24.

3,4-Dimethyl-4-phenylpentanoic Acid. A.—To a stirred solution of 4.43 g. (24.7 mmoles) of 2,3-dimethyl-3-phenyl-1-butanol in 100 ml. of dry pyridine, chilled in an ice-salt bath, was added 5.23 g. of *p*-toluenesulfonyl chloride in one portion. The solution was kept at 0° for 2 hr. and 10 ml. of water was added in 1-ml., 1-ml., 1-ml., 2-ml., and 5-ml. portions at 5-min. intervals. Then 100 ml. of water was added and the aqueous pyridine solution was extracted well with chloroform. The chloroform extracts were combined and washed with 5% aqueous hydrochloric acid, water, saturated sodium bicarbonate solution, and finally water. The solution was dried and the chloroform was removed leaving 8.04 g. of crude tosylate as a viscous oil. To this tosylate was added 1.3 g. (26.5 mmoles) of sodium cyanide in 50 ml. of water, and ethanol was added until homogeneity was obtained. The solution was heated on the steam bath for 40 hr., cooled, poured into water, and extracted with ether. The ethereal extracts were washed with water, saturated sodium bicarbonate solution, 10% hydrochloric acid, and water, and dried. The ether was removed leaving 4.13 g. of orange oil. The infrared spectrum of this material showed bands attributable to both nitrile and hydroxyl. To this mixture was added 50 ml. of 20% aqueous sodium hydroxide and 25 ml. of ethanol. The solution was heated under reflux for 72 hr., cooled, poured into water, and extracted well with ether. The extracts were washed with water and dried. Removal of the solvent left 2.38 g. (49%) of recovered alcohol. The basic, aqueous portion was acidified with hydrochloric acid and extracted with ether. The ethereal solution was washed with water and dried. Removal of the ether left 0.86 g. (17%) of 3,4-dimethyl-4-phenylpentanoic acid as an oil which solidified on chilling in a Dry Ice-acetone bath. Two recrystallizations from pentane gave material of m.p. 72–75°. The analytical sample, after recrystallization from pentane, melted at 74.5–75.5°.

Anal. Calcd. for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80. Found: C, 75.86; H, 8.95.

B.—To a slurry of 20.0 g. (0.15 mole) of anhydrous aluminum chloride in 100 ml. of dry benzene, 15.38 g. (0.12 mole) of 3,4,4-trimethylbutyrolactone in 150 ml. of dry benzene was added slowly. The reaction mixture was heated at reflux for 4 hr., then poured into an ice-concentrated hydrochloric acid mixture. The layers were separated and the aqueous layer was extracted with benzene. The benzene portions were combined and extracted four times with 10% sodium hydroxide. The basic solutions were combined, acidified with concentrated hydrochloric acid, and extracted with chloroform. The chloroform solution was washed with water and dried. Removal of the sol-

vent left 19.18 g. of very viscous yellow oil which solidified on being chilled in a Dry Ice-acetone bath. Recrystallization from pentane at –70° gave 14.85 g. (60%) of material, m.p. 65–71°; the infrared spectrum of this acid was identical with that of the acid from A, above, and the mixture melting point showed no depression.

The benzene solution, from above, was washed with water and dried. After removing the benzene, 5.59 g. of crude 3,4,4-trimethyl-1-tetralone was obtained.

3,4,4-Trimethyl-1-tetralone.—Cyclization of 10.00 g. (48.5 mmoles) of the pentanoic acid was effected with 200 g. of polyphosphoric acid. The mixture was heated on the steam bath during 1 hr., or until a homogeneous solution was obtained, and then let stand at room temperature for 12 hr. with occasional stirring. The solution was poured slowly into water and the mixture was extracted with ether. The ether was washed first with saturated sodium bicarbonate and then with water and dried, and the ether was removed giving 9.11 g. of crude tetralone. Distillation afforded 8.01 g. (88%) of tetralone, homogeneous by vapor phase chromatography, b.p. 103° (0.9 mm.), n_D^{25} 1.5470. The infrared spectrum was identical with that of the third compound obtained from the preparative gas chromatogram and the retention times on gas chromatography were identical; infrared maximum 5.96 μ ; ultraviolet λ_{max} 249 m μ ($\log \epsilon$ 4.08) and 292 m μ ($\log \epsilon$ 3.23).

2,2-Dimethyl-1-tetralone.—This compound was prepared in 78% yield from 1-tetralone by the method of Mousseron.¹⁰ The product of b.p., 91–95° (6 mm.) was homogeneous by gas chromatography, n_D^{25} 1.5446. The 2,4-dinitrophenylhydrazone, m.p. 157–158° (lit.¹⁰ m.p. 161–162°), had λ_{max} 380 m μ ($\log \epsilon$ 4.43).

1-Methylene-2,2-dimethyltetralin.—To a solution of methylmagnesium iodide prepared from 14.20 g. of iodomethane and 2.43 g. of magnesium turnings was added during 0.5 hr. 10.00 g. (57.4 mmoles) of 2,2-dimethyl-1-tetralone in ether. The mixture was stirred at room temperature for 1 hr. and heated on the steam bath under reflux for 1 hr., then cooled to room temperature, and poured over ammonium chloride and ice. The isolation of the product from the Grignard reaction was carried out as previously described. Removal of the solvents left 11.35 g. of oil. The infrared spectrum showed that some dehydration to the olefin had occurred. The crude oil was mixed with 75 ml. of dried dimethyl sulfoxide and heated at 130° for 14.5 hr. The product was isolated as previously described. Distillation of the resulting oil afforded 8.30 g. (84%) of colorless olefin, b.p. 81–82° (1 mm.), n_D^{25} 1.5528.

1,2,2-Trimethyltetralin.—To a solution of 5.20 g. (30.2 mmoles) of the above olefin in 350 ml. of 95% ethanol was added 0.50 g. of platinum oxide, and the mixture was shaken under hydrogen at 40 p.s.i. for 4 hr. at room temperature. The catalyst was filtered off, the filtrate was diluted with water and extracted with hexane. The hexane solution was dried and the solvent was removed leaving 5.19 g. of colorless oil. Distillation gave 3.91 g. (74%) of trimethyl tetralin, b.p. 63° (0.75 mm.), n_D^{25} 1.5233.

Anal. Calcd. for $C_{13}H_{18}$: C, 89.59; H, 10.41. Found: C, 89.39; H, 10.57.

Oxidation of 1,2,2-Trimethyltetralin.—To a stirred solution of 1.00 g. (5.74 mmoles) of the trimethyltetralin in 6 ml. of glacial acetic acid was added 1.09 g. (11 mmoles) of chromic acid in 0.5 ml. water and 4 ml. of glacial acetic acid. The solution was stirred for 12 hr. at room temperature; then 4 ml. of methanol was added. The solution was poured into 200 ml. of water and extracted four times with 50-ml. portions of ether. The ethereal solution was washed with saturated sodium bicarbonate and dried. Removal of the ether left 1.00 g. of a three-component mixture: unreacted tetralin, 3,3,4-trimethyl-1-tetralone, and an unknown compound. The desired ketone was separated from the other components by chromatography on Merck alumina. The 2,4-dinitrophenylhydrazone of this ketone melted at 175–176° and the mixture melting point of this derivative and that of the second compound obtained from the reaction of 3,4,4-trimethylbutyrolactone and benzene was 175–176°. The infrared spectra and retention times of the respective ketones were identical.

Attempted Isomerization of 3,4,4-Trimethyl-1-tetralone with Aluminum Chloride.—A solution of 191 mg. (1.01 mmoles) of 3,4,4-trimethyl-1-tetralone, in 3 ml. of dry benzene was added to a chilled slurry of 270 mg. (2.02 mmoles) of anhydrous aluminum chloride. The reaction was stirred for 1 hr. at about 10° and then for an additional 2 hr. on the steam bath. After isola-

tion of the product in the usual manner there was obtained 171 mg. (90%) of unchanged 3,4,4-trimethyl-1-tetralone.

3,4,4-Trimethyl-1-oxo-1(4H)-dihydronaphthalene.—A solution of 0.25 g. of bromine (1.54 g.-atoms) in 5 ml. of carbon tetrachloride was added dropwise to a stirred solution of 0.29 g. (1.54 mmoles) of 3,4,4-trimethyl-1-tetralone in 20 ml. of carbon tetrachloride. The solution was stirred for 45 min. after the addition was complete. After pouring into water the organic layer was separated, washed with water, and dried. The carbon tetrachloride was removed under reduced pressure on a rotary evaporator with a minimum of applied heat. The resulting bromo ketone, 0.41 g., was dissolved in 10 ml. of redistilled γ -collidine and heated under reflux in 1 atm. of nitrogen for 15 min. The flask was cooled to room temperature and ether was added to precipitate the collidine hydrobromide. The hydrobromide (0.26 g., 84%) was removed by filtration and was washed with ether. The ether solution was washed well with 10% hydrochloric acid, then water, and dried. Removal of the ether under reduced pressure on a rotary evaporator with no applied heat gave 0.29 g. (100%) of dienone, infrared maximum 6.02 μ (carbonyl), λ_{\max} 252 $m\mu$ ($\log \epsilon$ 4.09) and 271 $m\mu$ ($\log \epsilon$ 3.99). Occasionally, all of the tetralone was not brominated. In these cases, separation of the dienone from the tetralone was effected by chromatography on Merck alumina. The tetralone was eluted with 2:1 hexane-benzene, whereas the dienone was eluted with benzene. The 2,4-dinitrophenylhydrazones formed deep violet crystals, m.p. 243–245°, from ethanol-ethyl acetate.

Anal. Calcd. for $C_{19}H_{19}N_4O_4$: C, 62.28; H, 4.95; N, 15.29. Found: C, 62.43; H, 4.96; N, 15.49.

Attempted Rearrangement of 3,4,4-Trimethyl-1-oxo-1(4H)-dihydronaphthalene. A.—To a stirred solution of 1.22 g. (6 mmoles) of dienone in 20 ml. of acetic anhydride was added 0.40 g. (4 mmoles) of 96% sulfuric acid in 20 ml. of acetic anhydride. The yellow solution was stirred for 1 hr., then poured into 150 ml. of water and let stand overnight. The aqueous solution was extracted well with ether; the ether washings were combined and extracted with five 100-ml. portions of water, saturated sodium bicarbonate, and water, and then dried. Removal of the ether at reduced pressure with no applied heat gave 0.56 g. of recovered dienone.

B.—To a stirred solution of 1.82 g. (9.8 mmoles) of dienone in 20 ml. of acetic anhydride was added 1.01 g. of 96% sulfuric acid. The solution was stirred for 15 min. and then 4 drops (0.08 g.) of sulfuric acid was added every minute for 5 min., making 1.41 g. (12.8 mmoles) of acid in all. As the last of the acid was being added, a solid started to precipitate. The mixture was immediately poured into water. Attempted isolation of the products in the usual manner afforded no material.

C.—To a stirred solution of 0.29 g. (1.5 mmoles) of dienone in 5 ml. of acetic anhydride was added 0.22 g. (2.2 mmoles) of 96% sulfuric acid. After about 10 min., solid precipitated from the solution. The mixture was stirred, in total, for 1 hr. and then filtered through a sintered glass funnel. The hygroscopic solid, 0.25 g., was washed well with ether and recrystallized from ethanol-ethyl acetate to give pale yellow platelets, m.p. 180–181 dec., λ_{\max} 262 $m\mu$ ($\log \epsilon$ 3.81) and 280 $m\mu$ ($\log \epsilon$ 3.79).

Anal. Calcd. for $C_{13}H_{14}O_7S_2 \cdot 2.5H_2O$: C, 39.89; H, 4.89; S, 16.39; neut. equiv., 173. Found: C, 39.71; H, 5.23; S, 16.16; neut. equiv., 190.

D.—To 0.20 g. (1.1 mmoles) of dienone was added 20 g. of polyphosphoric acid. The mixture was stirred until homogeneity was attained. The solution was stirred occasionally at room temperature for 9.5 hr. and then poured into water. After isolation of the product in the usual manner only unreacted dienone was obtained.

3,4-Dimethylbenzosuberone. Ethyl 3,4-Dimethyl-5-phenyl-2- and -3-pentenoates.—The Reformatsky reaction was carried out as previously described. From 32.69 g. of activated zinc, 20.90 g. (1.29 mmoles) of 3-methyl-4-phenyl-2-butanone, and 28.39 g. (1.70 mmoles) of ethyl bromoacetate, 32.38 g. of crude hydroxy ester, which showed one peak on vapor phase chromatography, was obtained. The hydroxy ester was mixed with 125 ml. of dry pyridine and 40 ml. of phosphorus oxychloride, heated on the steam bath for 1 hr., cooled, and poured carefully into water. The mixture was extracted with ether, and the ether extracts were combined, washed with 10% hydrochloric acid, saturated sodium bicarbonate solution, water, and dried. Removal of the ether left 26.60 g. of red oil which upon distillation gave 22.73 g. (76%) of material boiling at 144° (15 mm.). The vapor phase chromatogram showed three peaks, presumably

some combination of the *cis* and *trans* isomers of the Δ^2 - and Δ^3 -unsaturated esters. The analytical sample was molecularly distilled at 0.2 mm.

Anal. Calcd. for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.31; H, 8.40.

3,4-Dimethyl-5-phenylpentanoic Acid.—Hydrogenation of 18.52 g. (79.7 mmoles) of the mixed unsaturated esters was carried out at atmospheric pressure in 125 ml. of 95% ethanol employing 0.1 g. of platinum oxide as catalyst. After the isolation of the product, 18.31 g. (98%) of saturated ester was obtained. This ester was heated under reflux in 40 ml. of 20% aqueous potassium hydroxide, 15 ml. of water, and 25 ml. of ethanol for 6.5 hr. Isolation of the product in the usual manner, followed by distillation afforded 14.11 g. (86%) of acid, b.p. 149.5–150° (1.2 mm.). The analytical sample was molecularly distilled at 0.5 mm.

Anal. Calcd. for $C_{13}H_{18}O_2$: C, 75.69; H, 8.80. Found: C, 75.63; H, 8.89.

3,4-Dimethyl-1-benzosuberone.—Cyclization of 5.00 g. (24.2 mmoles) of 3,4-dimethyl-5-phenylpentanoic acid was accomplished with 100 g. of polyphosphoric acid by heating on the steam bath for 3.5 hr. After product isolation in the usual manner and distillation, 4.08 g. (89%) of colorless oil, b.p. 113° (0.8 mm.), was obtained. The vapor phase chromatogram showed two components, apparently the *cis* and *trans* isomers, infrared maximum 5.99 μ . The 2,4-dinitrophenylhydrazones melted at 208–210° after recrystallization from ethanol-ethyl acetate, λ_{\max} 374 $m\mu$ ($\log \epsilon$ 4.47).

Anal. Calcd. for $C_{19}H_{20}N_4O_4$: C, 61.95; H, 5.47; N, 15.21. Found: C, 62.20; H, 5.70; N, 14.98.

2,2,3-Trimethyl-1-tetralone. Ethyl 2,2,3-Trimethyl-4-phenyl-2-butenolate.—The Reformatsky reaction was carried out as previously described. From 13.42 g. (0.10 mole) of phenylacetone, 27.31 g. (0.14 mole) of ethyl α -bromoisobutyrate, and 16.35 g. of zinc, there was obtained 18.93 g. of crude hydroxy ester. A duplicate run produced 20.42 g. of product. The material from the two runs was combined and distilled giving 25.50 g. (50%) of hydroxy ester, b.p. 145–150° (6 mm.). There was a large pot residue (about 12 g.) which did not show a peak on the vapor phase chromatogram within 25 min. Under the conditions used, the hydroxy ester was eluted in 2.4 min. Dehydration of the hydroxy ester was carried out using 40 ml. of phosphorus oxychloride and 125 ml. of pyridine. After distillation there was obtained 20.11 g. (43% based on phenylacetone) of clear, colorless oil, b.p. 134–138° (5 mm.). The vapor phase chromatogram showed two peaks, apparently the *cis* and *trans* isomers. The analytical sample was molecularly distilled at 0.4 mm., n_D^{25} 1.5098.

Anal. Calcd. for $C_{15}H_{20}O_2$: C, 77.55; H, 8.68. Found: C, 77.50; H, 8.65.

2,2,3-Trimethyl-4-phenylbutyric Acid.—Hydrogenation of 11.13 g. (47.3 mmoles) of the unsaturated ester was carried out using 0.20 g. of platinum oxide catalyst in 100 ml. of 95% ethanol at 15 p.s.i. for 4 hr. at room temperature. The catalyst was removed by filtration through Celite and most of the ethanol removed at reduced pressure on a rotary evaporator. To the resulting solution was added 75 ml. of 15% sodium hydroxide solution and the solution was heated under reflux for 36 hr. After isolation of the product in the usual manner there was obtained 9.01 g. of recovered crude ester and, after one recrystallization from hexane, 1.38 g. (14%) of saturated acid, m.p. 117–120° (lit.²² m.p. 115–120°).

2,2,3-Trimethyl-1-tetralone.—Cyclization of 4.00 g. (19.3 mmoles) of the trimethylbutyric acid was carried out using 50 g. of polyphosphoric acid. The mixture was stirred vigorously by hand and carefully heated with a microburner until the acid had just melted. The solution was stirred occasionally at room temperature during 60 hr. After isolation of the neutral product, 3.62 g. of yellow oil was obtained. Distillation afforded 2.48 g. (68%) of tetralone, b.p. 93–95° (1.1 mm.), n_D^{25} 1.5356, infrared maximum 5.95 μ . This tetralone has been prepared previously,²³ but no analytical data were given.

Anal. Calcd. for $C_{13}H_{16}O$: C, 82.93; H, 8.75. Found: C, 82.94; H, 8.70.

3-Methyl-3-isopropyl-1-indanone. Ethyl 2-Cyano-3,4-dimethyl-3-phenylpentanoate.—The Grignard reagent prepared from 47.11 g. (0.30 mole) of bromobenzene and 7.30 g. of mag-

(22) Analysis was by Alfred Bernhardt Mikroanalytisches Laboratorium, Mülheim (Ruhr), Germany.

(23) H. Adkins and D. C. England, *J. Am. Chem. Soc.*, **71**, 2958 (1949).

nesium in 150 ml. of ether was added to 45.31 g. (0.25 mole) of ethyl 2-cyano-3,4-dimethyl-2-pentenoate²⁴ and 0.5 g. of cuprous chloride in 100 ml. of ether. After the addition was completed, the solution was heated under reflux for 2 hr. After product isolation in the usual manner, distillation afforded 45.22 g. (75%) of a pale yellow, viscous oil, homogeneous by vapor phase chromatography, b.p. 140–143° (1.25 mm.). A forerun, 8.04 g., of biphenyl and recovered cyano ester was obtained. Upon standing at room temperature for 2 days, most of the material from the Grignard reaction solidified. The solid was removed from the liquid and was recrystallized from ether–hexane to give the analytical sample, m.p. 65–66°.

Anal. Calcd. for C₁₆H₂₁NO₂: C, 74.10; H, 8.16; N, 5.40. Found: C, 74.28; H, 8.16; N, 5.38.

3,4-Dimethyl-3-phenylpentanoic Acid.—A vigorously stirred mixture of 25.93 g. (0.10 mole) of the saturated cyano ester, 50 g. of potassium hydroxide, and 200 ml. of diethylene glycol was heated at 180–195° under 1 atm. of nitrogen for 23 hr. The solution was cooled, poured over ice, and extracted with ether. The solution was acidified with hydrochloric acid and extracted with five 100-ml. portions of ether. The ethereal solution was washed well with water, dried, filtered, treated with decolorizing carbon, and filtered again. Removal of the ether left an oil which crystallized on standing. After one recrystallization from ether–hexane, 17.15 g. (83%) of acid, m.p. 73–76°, was ob-

tained. The analytical sample, after recrystallization from the same solvent pair, melted at 75.5–77°.

Anal. Calcd. for C₁₃H₁₈O₂: C, 75.69; H, 8.80. Found: C, 75.92; H, 8.85.

3-Methyl-3-isopropyl-1-indanone.—A mixture of 10.00 g. (48.5 mmoles) of the pentanoic acid and 100 g. of polyphosphoric acid was heated on the steam bath until homogeneous. The viscous solution was allowed to cool and then stirred occasionally for 9 hr. at room temperature. After isolating the neutral product in the usual manner, 9.73 g. of clear oil was obtained. Distillation afforded 8.42 g. (92%) of clear, colorless oil, b.p. 89–91° (0.8 mm.), infrared maximum 5.86 μ (carbonyl), *n*_D²⁰ 1.5374. The 2,4-dinitrophenylhydrazone, m.p. 173–174°, was obtained from ethanol–ethyl acetate, λ_{max} 384 mμ (log ε 4.50).

Anal. Calcd. for C₁₉H₂₀N₄O₄: C, 61.94; H, 5.47; N, 15.21. Found: C, 62.11; H, 5.65; N, 15.46.

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(24) A. Brandstrom, *Acta. Chem. Scand.*, **13**, 963 (1959).

Amino Ketone Rearrangements. III.

The Rearrangement of α-Hydroxy N-Phenylimines^{1,2}

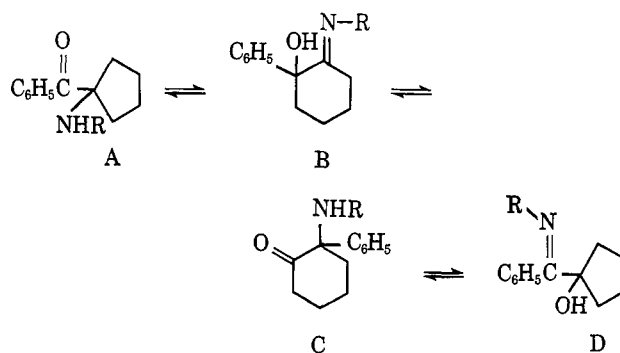
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Seven C-phenyl- and N-phenyl-substituted 1-(α-phenyliminobenzyl)cyclopentanols were prepared and subjected to thermal rearrangement to their respective 2-phenyl-2-phenylaminocyclohexanones. Isomeric C-phenyl- and N-phenyl-substituted hydroxy imines were seen to have identical first-order rearrangement rate constants, and a reaction constant, ρ, of –0.32 was obtained for the series. The reaction mechanism is discussed.

The thermal rearrangement of α-amino ketones is a general phenomenon.⁵ The rearrangement of α-amino ketones with accompanying alkyl *disubstitution* on the α-carbon atom bearing the amino group is unique with double carbon skeletal rearrangement being encountered. The thermal rearrangement of a specific α-amino ketone is envisioned as involving an equilibrium between four isomeric partners. For example, A–D would be the compounds involved in thermal equilibration of a 1-aminocyclopentyl phenyl ketone. Thus, proceeding from A through C one encounters alkyl migration, phenyl migration, and alkyl migration in that order, and, indeed, with other specific but analogous compounds, thermal rearrangement from all four isomer types has been observed. In conjunction with our study of this phenomenon, we desired to isolate one equilibrium reaction of the three for an initial kinetic analysis. The conversion C to D was chosen for two reasons: first, the C ⇌ D equilibrium



constant is very small in most systems so that the rearrangement of D to C could, for practical purposes, be treated as an irreversible reaction; second, α-hydroxy imines of type D (R = C₆H₅) were readily available from the reaction of epoxy ethers with substituted anilines.⁶ The cyclopentyl phenyl ketone carbon skeleton was chosen because its rearrangement reactions were the cleanest and of the highest yield of those systems studied. Further, all compounds involved were crystalline and easily characterized. It was hoped that ring-size stability effects, while cer-

(1) Presented in part at the 144th National Meeting of the American Chemical Society, Los Angeles, Calif., April 1963; Abstracts, p. 14M.

(2) Paper II of this series: C. L. Stevens, R. D. Elliott, and B. L. Winch, *J. Am. Chem. Soc.*, **85**, 1464 (1963).

(3) NATO Fellow, 1961–1962.

(4) National Science Foundation Predoctoral Fellow, 1963–1964. This paper was abstracted in part from the Ph.D. Dissertation of F. A. Daniher, Wayne State University, 1964.

(5) K. L. Nelson, J. C. Robertson, and J. J. Duvall, *J. Am. Chem. Soc.*, **86**, 684 (1964), and included references.

(6) For synthesis of α-hydroxy imines of general type D with R = alkyl, cf. C. L. Stevens, P. Blumbergs, and M. Munk, *J. Org. Chem.*, **28**, 331 (1963).