black color with ferric chloride and forms a sodium salt with aqueous sodium hydroxide or sodium bicarbonate.

Anal. Calcd. for $C_{15}H_{14}O_4$: C, 69.7; H, 5.5. Found: C, 69.5; H, 5.5.

The **enol acetate** of VIIa crystallized from methanol in needles; m. p. 132.5–133.5°.

Anal. Calcd. for $C_{17}H_{16}O_5$: C, 68.0; H, 5.4. Found: C, 68.0; H, 5.3.

The **benzylamide of the glyoxalic acid** obtained from VIIa and benzylamine crystallized from dilute methanol in fine needles; m. p. 151.5–152° dec. when inserted into the bath at room temperature and 155–156° dec. when introduced at 150°.

Anal. Calcd. for $C_{22}H_{23}O_4N$: C, 72.3; H, 6.4; N, 3.8. Found: C, 71.9; H, 6.5; N, 3.5.

(c) **From 2-(*m*-Anisyl)-cyclohexanone.**—The **γ-lactone of 2-hydroxy-3-(*m*-anisyl)-2-cyclohexeneglyoxalic acid** (VIIb), obtained in nearly quantitative yield, crystallized from methanol in rectangular prisms; m. p. 166–166.5°.

Anal. Calcd. for $C_{15}H_{14}O_4$: C, 69.7; H, 5.5. Found: C, 69.7; H, 5.5.

(d) **From 2-(*p*-Isopropylphenyl)-cyclohexanone.**—The **γ-lactone of 2-hydroxy-3-(*p*-isopropylphenyl)-2-cyclohexeneglyoxalic acid** (VIIc), prepared in 57% yield, crystallized from methanol in pale-yellow rectangular plates; m. p. 158–159°.

Anal. Calcd. for $C_{17}H_{18}O_3$: C, 75.5; H, 6.7. Found: C, 75.4; H, 6.8.

(e) **From 2-Carbomethoxycyclohexanone.**—From 490 g. of cyclohexanone and 590 g. of dimethyl oxalate, 330 g. (43%) of 2-carbomethoxycyclohexanone was prepared by the method employed for the ethyl ester[12]; b. p. 105–106° at 18–20 mm. To a solution of sodium methoxide prepared from 3 g. of sodium and 30 ml. of methanol under nitrogen was added 15 g. of dimethyl oxalate, followed by a solution of 10 g. of 2-carbomethoxycyclohexanone in 75 ml. of methanol. After four hours at room temperature most of the methanol was removed under reduced pressure, and the residue was added to water and benzene. The benzene contained 5 g. of unchanged keto ester; the aqueous solution contained the sodium enolate from which 3.7 g. of the **γ-lactone of 3-carbomethoxy-2-hydroxy-2-cyclohexeneglyoxalic acid** (VIII) was isolated; m. p. 195–199°. It crystallized from methanol in colorless needles; m. p. 196–197°. It gives an immediate dark green color with ferric chloride and is soluble in aqueous alkali.

Anal. Calcd. for $C_{10}H_{10}O_5$: C, 57.2; H, 4.8. Found: C, 57.3; H, 4.8.

The **enol acetate** of VIII crystallized from methanol in colorless needles; m. p. 88–89°.

Anal. Calcd. for $C_{12}H_{12}O_6$: C, 57.2; H, 4.8. Found: C, 57.2; H, 4.9.

A solution of 0.5 g. of the lactone and 1.2 ml. of benzylamine in 10 ml. of ethanol which had been warmed on a steam-bath for a few minutes deposited 0.15 g. of the di-N-benzylamide of oxalic acid; m. p. 215–216°. It crystallized from pyridine in plates; m. p. 219–220°, alone and when mixed with an authentic specimen.

Summary

The reaction of dimethyl oxalate with 2-arylcyclohexanones gave unsaturated lactones instead of the glyoxalates. A lactone was also obtained from 2-carbomethoxycyclohexanone. The enol ethers and acetate of some of the lactones were prepared.

The preparation of phenyl-, 2-(*p*-anisyl)-, 2-(*m*-anisyl)- and 2-(*p*-isopropylphenyl)-cyclohexanone and the synthesis of 7-methoxy-9-oxo-octahydrophenanthrene from 2-(*p*-anisyl)-cyclohexanone are described.

2-Phenylcyclohexanone undergoes air oxidation to δ-benzoylvaleric acid.

ANN ARBOR, MICHIGAN RECEIVED NOVEMBER 7, 1949

---

[12] Snyder, Brooks and Shapiro, *Org. Syntheses*, Coll. Vol. II, 531 (1943).

[CONTRIBUTION FROM THE CHEMISTRY DEPARTMENT OF THE UNIVERSITY OF MICHIGAN]

Reactions of 2-Arylcyclohexanones. II. The Preparation of Intermediates in the Synthesis of Resin Acids

BY W. E. BACHMANN AND L. B. WICK[1]

Although the structures of dehydroabietic acid (I, R = $CH(CH_3)_2$, R′ = H) and of the resin acid podocarpic acid (I, R = H, R′ = OH) have been constructed,[2] apparently the natural stereoisomers have not yet been obtained. The 2-arylcyclohexanones appeared to offer another route to these compounds. Methylation of properly substituted 2-arylcyclohexanones would give II, from which the acid IV could probably be prepared by methods employed extensively in the synthesis of steroids and related compounds.[3] This would include glyoxalation of II, decarbonylation of the glyoxalate followed by methylation of the β-keto ester to III, and conversion of III to IV by way of the Reformatsky reaction; by obvious steps the acid IV could be converted into the resin acid structures. As a model we used the readily available 2-phenylcyclohexanone, which would yield desoxypodocarpic acid (I, R = R′ = H) if the synthesis proved successful.

After the work had been initiated, Newman and Farbman[4] reported the preparation of 2-methyl-2-phenylcyclohexanone (II, R = R′ = H) and its glyoxalate for another purpose. We found that the glyoxalate lost carbon monoxide readily when heated with powdered glass or with Cargille boiling stones and gave 2-methyl-2-phenyl-6-carbomethoxycyclohexanone, which with sodium methoxide and methyl iodide yielded the desired 2,6-dimethyl-2-phenyl-6-carbomethoxycyclohexanone (III, R = R′ = H) as a separable

---

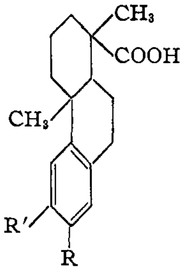
[1] From the Ph.D. dissertation of L. B. Wick.

[2] Haworth and Barker, *J. Chem. Soc.*, 1299 (1939); Haworth and Moore, *ibid.*, 633 (1946); Bhattacharaya, *J. Indian Chem. Soc.*, **22**, 165 (1945).

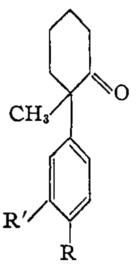
[3] Compare Bachmann, Cole and Wilds, THIS JOURNAL, **62**, 824 (1940).

[4] Newman and Farbman, *ibid.*, **66**, 1550 (1944).

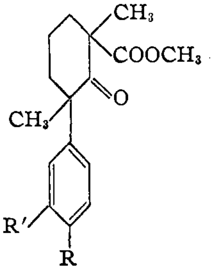
mixture of crystalline solid and liquid. These probably represent the two possible diastereo isomers in the form of racemic mixtures. The synthesis of 2,6-dimethyl-2-(*p*-isopropylphenyl)-6-carbomethoxycyclohexanone (III, R = CH(CH_3)$_2$, R′ = H) from 2-(*p*-isopropylphenyl)-cyclohexanone was carried out in a similar manner.



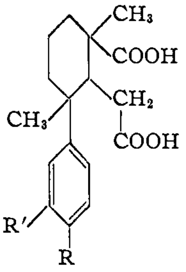
I



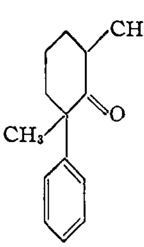
II



III



IV



V

When 2,6-dimethyl-2-phenyl-6-carbomethoxycyclohexanone was heated with a mixture of acetic acid and hydrochloric acid, hydrolysis and decarboxylation took place with the formation of 2,6-dimethyl-2-phenylcyclohexanone (V). This dimethyl ketone formed a 2,4-dinitrophenylhydrazone much more slowly than the less hindered 2-methyl-2-phenylcyclohexanone; only a few minutes were needed for the formation of the derivative from the monomethyl ketone, while about two hours were required for a satisfactory yield of the derivative from the dimethyl ketone under similar conditions. This result foreshadowed the behavior of the methyl keto esters (III) in the Reformatsky reaction, for the steric effect was manifested to a marked degree in the attempted reaction of the two compounds of this type with zinc and methyl bromoacetate under the usual conditions. Only low yields of acidic products were obtained from the reaction mixture after dehydration and alkaline hydrolysis. Other means of introducing the acetic acid side chain are being sought.

We are grateful to the Abbott Laboratories, and the Horace K. Rackham School of Graduate Studies for fellowships.

Experimental

Synthesis of 2,6-Dimethyl-2-phenyl-6-carbomethoxycyclohexanone (III, R = R′ = H).—2-Phenylcyclohexanone was methylated with sodamide and methyl iodide to 2-methyl-2-phenylcyclohexanone by the excellent procedure of Newman and Farbman[4] in exactly the yields reported by them.

The oxime was prepared by heating a mixture of 2 g. of the ketone, 2 g. of hydroxylamine hydrochloride, 10 ml. of pyridine and 10 ml. of absolute alcohol for two hours; m. p. 158–162°; weight, 1.8 g. after one recrystallization from methanol. Further recrystallization gave stout colorless needles; m. p. 158–159°.

Anal. Calcd. for $C_{13}H_{17}NO$: C, 76.8; H, 8.4; N, 6.9. Found: C, 76.8; H, 8.3; N, 6.9.

The 2,4-dinitrophenylhydrazone formed in a few minutes when a mixture of 0.1 g. of the ketone and 3 ml. of a solution prepared from 0.5 g. of 2,4-dinitrophenylhydrazine, 1 ml. of concentrated sulfuric acid, 8 ml. of methanol and 3 ml. of water was heated on a steam-bath; yield, quantitative; m. p. 163–166°. The derivative crystallized from ethyl acetate in yellow prisms; m. p. 170–171.5°.

Anal. Calcd. for $C_{19}H_{20}N_4O_4$: C, 61.9; H, 5.5; N, 15.2. Found: C, 61.8; H, 5.3; N, 15.0.

The reaction of 20 g. of 2-methyl-2-phenylcyclohexane with 30 g. of dimethyl oxalate in the presence of sodium methoxide gave an 85% yield of glyoxalate in agreement with that reported.[4] The product gave a dark red color with alcoholic ferric chloride solution. By fractional crystallization from methanol the product (m. p. 70–85°) yielded colorless prisms, m. p. 116–117° (reported,[4] 117.4–117.9°), and long colorless needles, m. p. 93–96°. For the next step the mixture of stereoisomers was used without separation.

In a typical decarbonylation experiment, two mixtures, each containing 11.5 g. of the glyoxalate and 8 g. of Cargille boiling stones[5] under nitrogen, were introduced into a bath at 160–165°. Vigorous bubbling set in after two minutes and proceeded for seven minutes; after another three minutes the bath was removed. A solution of the products in benzene was washed with 2% sodium hydroxide and saturated salt solution and dried over magnesium sulfate. A similar result was obtained with powdered soft glass as the catalyst. By evaporative distillation at 115–120° and 0.1 mm. the 2-methyl-2-phenyl-6-carbomethoxycyclohexanone was obtained as a colorless, viscous liquid; it gave an immediate deep bluish-purple color with alcoholic ferric chloride. In the next step the crude β-keto ester was employed.

The crude β-keto ester from the 23 g. of glyoxalate was methylated with a total of 40 ml. of methyl iodide in the presence of sodium methoxide from 7.5 g. of sodium by the procedure employed in a similar case.[3] The methylated keto ester distilled at 120–125° and 0.3 mm. as a colorless liquid; yield, 19.54 g. (89% based on the glyoxalate). The liquid gradually deposited crystals; from a solution in methanol 8.55 g. (44% of the mixture) crystallized; m. p. 70–73°. This crystalline isomer gave a negative ferric chloride test; the residual liquid slowly gave a purple color, showing that it was probably contaminated with a small amount of the unmethylated keto ester. The **2,6-dimethyl-2-phenyl-6-carbomethoxycyclohexanone** (III, R = R′ = H) crystallized from methanol in rhombic prisms; m. p. 71.5–72.5°.

Anal. Calcd. for $C_{16}H_{20}O_3$: C, 73.8; H, 7.7. Found: C, 73.7; H, 7.7.

2,6-Dimethyl-2-phenylcyclohexanone (V).—A mixture of 2 g. of the crystalline III (R = R′ = H), 40 ml. of acetic acid, 20 ml. of concentrated hydrochloric acid and 10 ml. of water was refluxed for four hours under nitrogen. The ketone (1.5 g.) which was isolated was obtained as a colorless liquid by evaporative distillation under reduced pressure.

The **2,4-dinitrophenylhydrazone** was prepared by the procedure used for 2-methyl-2-phenylcyclohexanone; no solid derivative appeared during the first fifteen minutes of heating. After two to three hours a 75–85% yield of the crude derivative (m. p. 160–169°) was collected. It crystallized from ethyl acetate in orange prisms; m. p. 178–179°.

---

[5] From Cargille Scientific, Inc., New York, N. Y.

Anal. Calcd. for $C_{20}H_{22}N_4O_4$: C, 62.8; H, 5.8; N, 14.6. Found: C, 62.5; H, 5.5; N, 14.2.

2-Methyl-2-(*p*-isopropylphenyl)-cyclohexanone.[6]—This ketone was prepared in 87% yield by methylation of 2-(*p*-isopropylphenyl)-cyclohexanone[7] by the procedure described for a similar case[4]; b. p. 133–136° at 0.2 mm.

Anal. Calcd. for $C_{16}H_{22}O$: C, 83.4; H, 9.6. Found: C, 83.4; H, 9.5.

The **oxime**, prepared in absolute alcohol and pyridine, crystallized from absolute alcohol in colorless prisms; m. p. 136–137°. By warming a solution of 1 g. of the oxime in 10 ml. of concentrated hydrochloric acid on a steam-bath for eight hours a 95% yield of distilled regenerated ketone was obtained.

Anal. Calcd. for $C_{16}H_{23}NO$: C, 78.3; H, 9.4; N, 5.7. Found: C, 78.4; H, 9.3; N, 5.5.

The **semicarbazone** crystallized from alcohol in colorless prisms; m. p. 171–173°.

Anal. Calcd. for $C_{17}H_{25}N_3O$: C, 71.0; H, 8.8; N, 14.6. Found: C, 70.9; H, 8.6; N, 14.5.

2,6-Dimethyl-2-(*p*-isopropylphenyl)-6-carbomethoxycyclohexanone (III, R = $CH(CH_3)_2$, R′ = H).—The reaction between 3 g. of 2-methyl-2-(*p*-isopropylphenyl)-cyclohexanone and 3 g. of dimethyl oxalate in the presence of sodium methoxide from 0.6 g. of sodium, conducted as described for a similar case,[8] gave 4 g. (97%) of the glyoxalate as a liquid (presumably a mixture of stereoisomers), which gave an immediate deep maroon color with an alcoholic solution of ferric chloride. Without further purification the glyoxalate was heated with 1 g. of powdered glass at 160–165° for seven minutes. Distillation of the product at 180–185° and 0.2 mm. gave 2.54 g. of the keto ester as a viscous colorless liquid, which slowly gave a deep purple color with alcoholic ferric chloride. Methylation of 4.7 g. of the keto ester with 13 ml. of methyl iodide in the presence of sodium methoxide from 1.8 g. of sodium in the manner described[8] yielded 4 g. of III (R = $CH(CH_3)_2$, R′ = H) after distillation at 162–164° and 0.2 mm. Complete methylation was indicated by the absence of color with alcoholic ferric chloride. For analysis a sample was treated with hydroxylamine hydrochloride in pyridine and absolute alcohol; this treatment converted some contaminating ketone present in traces into the oxime, which was readily extracted from the methyl keto ester (which remained unaffected) by cold concentrated hydrochloric acid.

Anal. Calcd. for $C_{19}H_{26}O_3$: C, 75.5; H, 8.6. Found: C, 75.8; H, 8.7.

Summary

2,6-Dimethyl-2-phenyl-6-carbomethoxycyclohexanone and 2,6-dimethyl-2-(*p*-isopropylphenyl)-6-carbomethoxycyclohexanone were prepared as intermediates in proposed syntheses of resin acids.

ANN ARBOR, MICHIGAN RECEIVED NOVEMBER 7, 1949

---

[6] Prepared by G. I. Fujimoto in this laboratory.

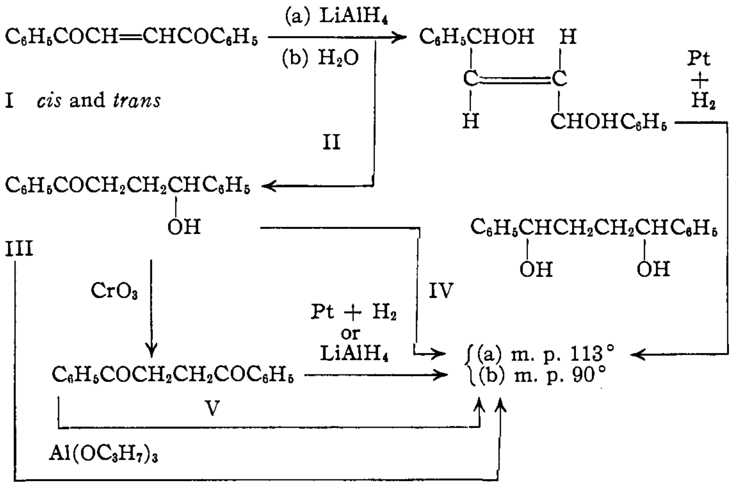
[7] Bachmann, Fujimoto and Wick, THIS JOURNAL, **72**, 1995 (1950).

[CONTRIBUTION FROM THE COBB CHEMICAL LABORATORY, UNIVERSITY OF VIRGINIA]

1,4-Reduction of Unsaturated 1,4-Diketones by Lithium Aluminum Hydride[1a]

BY ROBERT E. LUTZ AND J. S. GILLESPIE, JR.[1b]

The use of lithium aluminum hydride seemed of particular interest in this field because, in contrast with aluminum isopropoxide,[2] this reagent should not only be more powerful, but it also should theoretically be able to bring about 1,4-reductions analogous to 1,4-additions of the Grignard reagent with which it is to be compared.[3a] Up to this time no such 1,4-reduction by this reagent has been demonstrated although a few systems capable of undergoing it have been studied.[3]



When *cis*- and *trans*-dibenzoylethylenes (I) were reduced with an amount of lithium aluminum hydride in excess of that calculated for complete reduction, in ether at 35°, the same two products were obtained in identical yield ratios in each case. One of these, the minor product, was the *trans* unsaturated glycol (II) which underwent subsequent platinum–hydrogen reduction exclusively to the higher-melting saturated glycol (IVa).[2] Doubtless *cis*-to-*trans* isomerization occurred before reduction, as has been shown to occur in the case of aluminum isopropoxide reduction.[2]

Identification of the second and main product of the reduction as the partially reduced compound, 1,4-diphenyl-4-hydroxy-1-butanone (III), was accomplished by analysis, chromic acid oxida-

---

[1] (a) Taken from a Doctorate Dissertation, University of Virginia, May, 1949. This work was reported at the Atlantic City Meeting of the American Chemical Society, September 12, 1949. (b) Present location, University of Richmond, Richmond, Va.

[2] Lutz and Gillespie, THIS JOURNAL, **72**, 344 (1950).

[3] (a) Nystrom and Brown, *ibid.*, **70**, 1197, 2548, 3738 (1948). (b) Hochstein and Brown, *ibid.*, **70**, 3484 (1948); Hochstein, *ibid.*, **71**, 305 (1949).