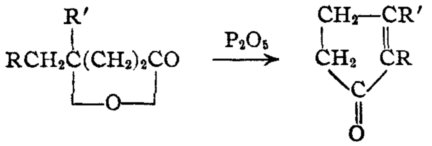
[CONTRIBUTION FROM THE NOYES CHEMICAL LABORATORY, UNIVERSITY OF ILLINOIS]

The Preparation of Cyclopentenones from Lactones

BY ROBERT L. FRANK, ROSE ARMSTRONG, JACK KWIATEK AND HAROLD A. PRICE

The reaction of lactones with phosphorus pentoxide to form cyclopentenones, by which syntheses of dihydrojasmone (VII)[1] and dihydrocinerone (VI)[2] have been recently accomplished, has now been further investigated to determine its scope and usefulness as an alternative method to those developed by Hunsdiecker[3] and by Johnson and Petersen.[4]

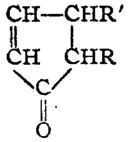


I, R = R′ = H
II, R = H, R′ = CH_3
III, R = n-C_6H_{13}, R′ = H
IV, R = R′ = CH_3
V, R = n-C_3H_7, R′ = CH_3
VI, R = n-C_4H_9, R′ = CH_3
VII, R = n-C_5H_{11}, R′ = CH_3
VIII, R = n-C_6H_{13}, R′ = H

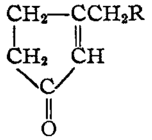
The lactones were prepared in yields of 15–64% by the addition of the appropriate Grignard reagents to esters of levulinic acid, using the low-temperature technique of Cason, Adams, Bennett and Register.[5] Both ethyl and cyclohexyl levulinates were used, the choice depending on the ease of separation by fractional distillation of the lactones from the starting materials.

The reaction of the simplest lactones (I and II) with phosphorus pentoxide was found to yield only black tarry products rather than the desired cyclopentenones, probably because of insufficient steric hindrance around the α,β-unsaturation of the products to prevent polymerization in the strongly acidic reaction mixture.

Better results are obtained with increased substitution, the respective yields being 30, 32, 30[2] and 50%[1] of the cyclopentenones represented by Structures IV, V, VI and VII. In these instances, in which R′ = methyl, the transformation gives only 2-cyclopentenones. 2,3-Disubstituted 4-cyclopentenones (IX) were not found; nor were β-substituted products (X), which might have been expected by ring closure involving the γ-methyl group. If formed these latter compounds would have been readily detected through their ultraviolet absorption spectra, as described below. Thus, a methylene group adjacent to the γ-position of the lactone appears to react in preference to a similarly-attached methyl group in the formation of the five-membered ring.

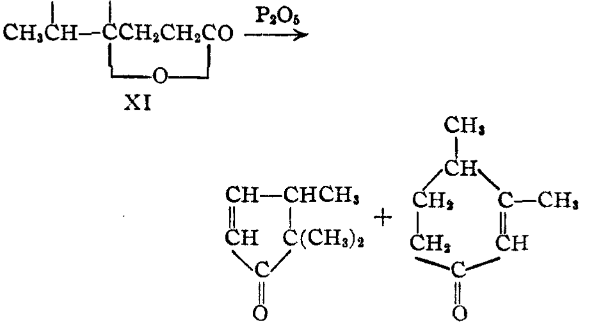


IX



X

γ,δ-Dimethyl-γ-caprolactone (XI), however, a *gamma* lactone having a methyl and a methinyl group attached to the *gamma* carbon atom, gives on treatment with phosphorus pentoxide a complex mixture containing at least two α,β-unsaturated ketones. A 6% yield of 2,2,3-trimethyl-4-cyclopentenone (XII), characterized by ozonolysis to trimethylsuccinic acid and reduction to 2,2,3-trimethylcyclopentanone, was isolated by fractional distillation.



XI

XII XIII

The other ketone (6%) has not been positively identified, but its C-methyl determination (1.5)[6,7] and ultraviolet absorption maximum of 231 mμ[8] indicate its structure to be 3,4-dimethyl-2-cyclohexenone (XIII), the reaction product which would result by ring closure involving the δ-methyl group of the lactone (XI).

One additional lactone, γ-undecanolactone (III), gave results similar to those of Plattner and St. Pfau[9] in their study of the action of sulfuric acid on ω-undecylenic acid. The main product was 2-n-hexyl-2-cyclopentenone (VIII), but the yield was low (17%) and high purity of product difficult to attain due to the occurrence of smaller amounts of an isomer, 2-n-hexyl-4-cyclopentenone.

It is significant that when the lactone contains both a methyl and a methylene group, a single product is formed, while a complex mixture results if the methyl group is absent.

The ultraviolet absorption spectra of substituted cyclopentenones have been studied by Gil-

---

[1] Frank, Arvan, Richter and Vanneman, THIS JOURNAL, **66**, 4 (1944).

[2] LaForge and Barthel, *J. Org. Chem.*, **10**, 222 (1945).

[3] Hunsdiecker, *Ber.*, **75B**, 447 (1942).

[4] Johnson and Petersen, THIS JOURNAL, **67**, 1366 (1945).

[5] Cason, Adams, Bennett and Register, *ibid.*, **66**, 1764 (1944).

[6] Kuhn and L'Orsa, *Z. angew. Chem.*, **44**, 847 (1931).

[7] Barthel and LaForge, *Ind. Eng. Chem.*, *Anal. Ed.*, **16**, 434 (1944); Pregl-Grant, "Quantitative Organic Microanalysis," 4th ed., The Blakiston Co., Philadelphia, Pa., 1945, pp. 167–169.

[8] Woodward, THIS JOURNAL, **63**, 1123 (1941); **64**, 76 (1942).

[9] Plattner and St. Pfau, *Helv. Chim. Acta*, **20**, 1474 (1937).

lam and West,[10] who have shown for several 2,3-disubstituted 2-cyclopentenones an approximate deviation of −11 mμ from Woodward's average value of 247 ± 5 mμ for open-chain α,β-unsaturated carbonyl compounds triply substituted around the double bond with non-absorbing groups. Gillam and West have suggested that this can be extended as a general amendment to Woodward's rule.[8] The absorption maxima for 2-cyclopentenones unsubstituted, singly substituted, and doubly substituted at the double bond should, therefore, appear at 214 ± 5 mμ, 224 ± 5 mμ and 236 ± 5 mμ, respectively.

Absorption spectra of our cyclopentenones, with one exception (XII), fall within the range of these predictions, with maxima as follows: 2,3-dimethyl-2-cyclopentenone (IV), 235 mμ; 2-*n*-propyl-3-methyl-2-cyclopentenone (V), 235 mμ; 2-*n*-hexyl-2-cyclopentenone (VIII), 229 mμ; 2,2,3-trimethyl-4-cyclopentenone (XII), 221 mμ; 2-*n*-hexyl-4-cyclopentenone, 212 mμ.

Experimental

Cyclohexyl Levulinate.—This was prepared by a procedure analogous to that for ethyl levulinate[1] from 581 g. (5.00 moles) of levulinic acid, 990 g. (9.88 moles) of cyclohexanol and 1 ml. of concentrated sulfuric acid in 500 ml. of benzene. The yield was 803 g. (81.5%) of cyclohexyl levulinate, b. p. 116–118° (2 mm.); $n^{20}_{\rm D}$ 1.4559; sp. gr. $^{20}_{20}$ 1.023; *MR* calcd., 52.35; *MR* found, 52.66.

Anal.[11] Calcd. for $C_{11}H_{18}O_3$: C, 66.54; H, 9.15. Found: C, 66.60; H, 9.35.

Preparation of Lactones.—Procedures similar to that of Cason, Adams, Bennett and Register[5] for γ-methyl-γ-*n*-propylbutyrolactone were used. γ-Methyl-γ-valerolactone was prepared from 200 g. (1.41 moles) of methyl iodide and 34.0 g. (1.40 gram atoms) of magnesium turnings in 500 ml. of dry ether and 318 g. (1.60 moles) of cyclohexyl levulinate in 1 liter of dry ether. The crude product, after shaking with zinc dust, was fractionally distilled through a twelve-inch helix-packed column to give a fore-run of cyclohexanol and 78.8 g. of the lactone, b. p. 85–90° (18 mm.). Redistillation gave 67.4 g. (42%) of colorless product, b. p. 89–91° (17 mm.); $n^{20}_{\rm D}$ 1.4352; sp. gr. $^{20}_{20}$ 1.020; *MR* calcd.: 29.24; *MR* found, 29.22.

γ-Methyl-γ-caprolactone was prepared similarly from 230 g. (2.11 moles) of ethyl bromide and 48.6 g. (2.00 gram atoms) of magnesium turnings in 500 ml. of dry ether and 396.5 g. (2.00 moles) of cyclohexyl levulinate in 2 liters of dry benzene and 500 ml. of dry ether. Fractional distillation of the crude product gave 146.5 g. (65% based on unrecovered cyclohexyl levulinate) of lactone, b. p. 102–103.5° (15 mm.); $n^{20}_{\rm D}$ 1.4412; sp. gr. $^{20}_{20}$ 1.004; *MR* calcd., 33.86; *MR* found, 33.71. There were also obtained 86.5 g. of cyclohexanol and 46.6 g. of cyclohexyl levulinate, b. p. 115° (3 mm.).

γ-Methyl-γ-octanolactone was synthesized from 430 g. (3.14 moles) of *n*-butyl bromide and 73.0 g. (3.00 gram atoms) of magnesium turnings in 800 ml. of dry ether, and 500 g. (3.52 moles) of ethyl levulinate in 3 liters of benzene. The crude product, after shaking with zinc dust, gave on fractional distillation 279.8 g. (60%) of the colorless lactone, b. p. 85–87° (2 mm.) (reported,[12] 120–123° (15 mm.)); $n^{20}_{\rm D}$ 1.4452; sp. gr. $^{20}_{20}$ 0.964; *MR* calcd.: 43.10; *MR* found: 43.11.

Anal. Calcd. for $C_9H_{16}O_2$: C, 69.19; H, 10.32. Found: C, 69.40; H, 10.53.

γ,δ-Dimethyl-γ-caprolactone (XI) was prepared from 1275 ml. (1684 g., 13.70 moles) of isopropyl bromide and 314 g. (12.9 gram atoms) of magnesium turnings in 3900 ml. of absolute ether and 1885 g. (13.08 moles) of ethyl levulinate in 6.5 liters of dry benzene. Fractional distillation of the crude product gave 274.9 g. (15.1%) of the lactone, b. p. 116° (16 mm.); $n^{20}_{\rm D}$ 1.4460; sp. gr. $^{20}_{20}$ 0.991; *MR* calcd., 38.49; *MR* found, 38.26.[13]

The Reaction of Lactones with Phosphorus Pentoxide.—The transformations were carried out similarly with all the lactones. One-fifth mole of phosphorus pentoxide was placed in a distilling flask equipped with a ground-glass joint. The lactone (0.27 mole) was then poured into the flask, which was immediately attached to a distilling column partially filled with glass helices. The mixture was heated gently with a flame to initiate reaction, the pressure was gradually reduced to 2–28 mm., and the products finally distilled directly from the dark reaction mixture by the use of a free flame. They were then redistilled.

2,3-Dimethyl-2-cyclopentenone (IV).—γ-Methyl-γ-caprolactone (in three runs totaling 101.6 g., 0.78 mole) gave 53.0 g. of distillate, b. p. 102–115° (28 mm.). Redistillation yielded 29.6 g. of starting material, b. p. 101–110° (25 mm.), and 18.8 g. (30.4% based on unrecovered lactone) of 2,3-dimethyl-2-cyclopentenone, b. p. 90–92° (25 mm.); $n^{20}_{\rm D}$ 1.4830; sp. gr. $^{20}_{20}$ 0.969; *MR* calcd., 31.89; *MR* found, 32.47; ultraviolet absorption maximum 235 mμ (log ε = 3.04). The semicarbazone of the product melted at 247–250° (dec.) (reported,[3] 247° (dec.)).

3-Methyl-2-*n*-propyl-2-cyclopentenone (V).—γ-Methyl-γ-octanolactone (in five runs totaling 210 g., 1.35 moles) gave 136.4 g. of distillate. Redistillation yielded 39.6 g. (32% based on unrecovered lactone) of 3-methyl-2-*n*-propyl-2-cyclopentenone of mint-like odor, b. p. 55–58° (2 mm.); $n^{20}_{\rm D}$ 1.4778; ultraviolet absorption maximum, 235 mμ (log ε = 3.04); and 71.2 g. of starting material, b. p. 82–88° (2 mm.). The semicarbazone of the product melted at 209–210.5° (reported,[3] 212°).

2,2,3-Trimethyl-4-cyclopentenone (XII) and 3,4-Dimethyl-2-cyclohexenone (XIII).—γ,δ-Dimethyl-γ-caprolactone (XI) was treated with phosphorus pentoxide in ten runs of 32 g. (0.23 mole) each to give 18.8 to 23.7 g. of slightly yellow distillate per run, $n^{20}_{\rm D}$ 1.4563–1.4621. All were combined to total 212.2 g., $n^{20}_{\rm D}$ 1.4601. Careful distillation through a thirty-six inch helix-packed column with a total reflux-partial takeoff head and reflux ratio 20:1 yielded 11.8 g. (6%, based on unrecovered lactone) of 2,2,3-trimethyl-4-cyclopentenone (XII) of camphor-like odor, b. p. 66–66.5° (19 mm.), 169.5–170° (740 mm.); $n^{20}_{\rm D}$ 1.4599; sp. gr. $^{20}_{4}$ 0.911; *MR* calcd., 36.50; *MR* found, 37.06; C-methyl[14] calcd. (2 methyls), 24.2%; found, 19.5, 19.7%; ultraviolet absorption maximum 221 mμ (log ε = 2.77). *Anal.* Calcd. for $C_8H_{12}O$: C, 77.37; H, 9.74. Found: C, 77.18; H, 9.80. The semicarbazone of this fraction, recrystallized from ethanol as shiny colorless needles, melted at 189–190°.

Anal. Calcd. for $C_9H_{15}N_3O$: C, 59.64; H, 8.34. Found: C, 59.38; H, 8.60.

Attempts to prepare a crystalline oxime were unsuccessful.

A second fraction, probably 3,4-dimethyl-2-cyclohexenone (XIII), weighed 11.0 g. (6%, based on unrecovered lactone), b. p. 100–101° (18 mm.); $n^{20}_{\rm D}$ 1.4779; C-methyl calcd. (2 methyls): 24.2%; found: 18.0, 17.4%; ultraviolet absorption maximum 231 mμ (log ε = 3.02). *Anal.* Calcd. for $C_8H_{12}O$: C, 77.37; H, 9.74. Found: C, 75.14, 74.91; H, 9.79, 9.78.

The semicarbazone, recrystallized from 40% ethanol as colorless platelets, melted at 183–184°.

Anal. Calcd. for $C_9H_{15}N_3O$: C, 59.64; H, 8.34. Found: C, 59.77; H, 8.48.

---

[10] Gillam and West, *J. Chem. Soc.*, 486 (1942).

[11] Microanalyses were carried out by Miss Theta Spoor, Miss Lillian Hruda and Miss Betty Alice Snyder.

[12] Wilson, This Journal, 67, 2161 (1945).

[13] Blaise, *Compt. rend.*, **130**, 1033 (1900).

[14] C-Methyl determinations were carried out by Mr. Howard Clark of the Illinois State Geological Survey.

This semicarbazone was shown to be different from that of 2,2,3-trimethyl-4-cyclopentenone (XII) by a depressed mixed m. p., 168–170°.

Attempts to prepare a solid oxime were unsuccessful.

As a higher-boiling fraction, 99.3 g. of the starting lactone was recovered.

2-*n*-Hexyl-2-cyclopentenone (VIII) and 2-*n*-Hexyl-4-cyclopentenone.—γ-Undecanolactone (commercial product of Givaudan–Delawanna, Inc., New York) (in two runs totaling 100.0 g., 0.54 mole) gave 25.3 g. of a mixture of ketones, b. p. 74–94° (2 mm.); $n^{20}\text{D}$ 1.4728. Redistillation yielded 15.7 g. (17.5%) of 2-*n*-hexyl-2-cyclopentenone, b. p. 97–100° (5 mm.); $n^{20}\text{D}$ 1.4675; sp. gr. $^{20}{}_{20}$ 0.910, *MR* calcd., 50.32; *MR* found, 50.72; ultraviolet absorption maximum 229 mμ (log ε = 2.70). The semicarbazone, recrystallized as a colorless powder from 40% ethanol, melted at 194.5–196° (reported,[9] 196°). A 4-g. lower-boiling fraction, b. p. 60–70° (5 mm.); $n^{20}\text{D}$ 1.4854; ultraviolet absorption maximum 212 mμ (log ε = 2.40), yielded a semicarbazone corresponding in melting point (192–193.5°) to that of Plattner and St. Pfau[9] (m. p. 189–190°) for 2-*n*-hexyl-4-cyclopentenone. A mixture with the semicarbazone of 2-*n*-hexyl-2-cyclopentenone melted at 186–187°.

Ozonolysis of 2,2,3-Trimethyl-4-cyclopentenone (XII).—Ozone was bubbled for twelve hours through a solution of 3.3 g. (0.027 mole) of 2,2,3-trimethyl-4-cyclopentenone in 35 ml. of glacial acetic acid. The solution was then added dropwise to 25 ml. of 11% aqueous hydrogen peroxide, the mixture being agitated by a stream of air bubbles, and refluxed for two hours. The acetic acid was removed by steam distillation and the residue evaporated to a volume of approximately 5 ml. To this was added 5 ml. of concentrated nitric acid, followed by reevaporation to 5 ml., the process being repeated three times. On standing the solution then deposited platelets of trimethylsuccinic acid, weighing 0.75 g. (18%) after recrystallization from concentrated nitric acid, m. p. 147.5–149° (reported,[15] 148–149°); neutral equivalent calcd., 80.1; found, 84.6.

Anal. Calcd. for $C_7H_{12}O_4$: C, 52.49; H, 7.55. Found: C, 52.22; H, 7.81.

Distillation of 0.25 g. of the acid gave a colorless solid melting *ca.* 30° (anhydride). On standing with an equimolar amount of *p*-toluidine in benzene this deposited crystals of the mono-*p*-toluidide of trimethylsuccinic acid. Recrystallization from 95% ethanol gave colorless needles melting at 125–126° (reported,[16] 127°).

Hydrogenation of 2,2,3-Trimethyl-4-cyclopentenone (XII).—Two grams of the ketone dissolved in 8 ml. of ethanol was hydrogenated over Raney nickel at room temperature and a pressure of 1900 lb. per square inch. The reaction was stopped after five minutes when one molar equivalent of hydrogen had been absorbed (estimated by pressure drop). The catalyst was removed by filtration and the semicarbazone and oxime prepared from the alcoholic solution. The semicarbazone, recrystallized from 40% ethanol, took the form of shiny plates, m. p. 197–198° (reported,[17] 210–212°).

Anal. Calcd. for $C_9H_{17}N_3O$: C, 58.99; H, 9.35. Found: C, 58.76; H, 9.15.

A mixed m. p. with the semicarbazone of 2,2,3-trimethyl-4-cyclopentenone (XII) was depressed, 184–185°.

The oxime, recrystallized from water or aqueous ethanol as colorless needles, melted at 103–104° (reported,[18] 104°).

Anal. Calcd. for $C_8H_{15}NO$: C, 68.05; H, 10.71. Found: C, 67.45; H, 10.56.

Ultraviolet Absorption Spectra.—Miss Ruth Johnston carried out the determinations using a Beckmann Model D Spectrophotometer. The ketones were dissolved in 95% ethanol, concentration 0.006 g. per liter of solution; $\log \epsilon = \log (1/cl) \cdot \log (I_0/I)$, in which c = g./100 ml. of solution, l = 1 cm.

Summary

γ-Methyl-γ-lactones having a methylene group adjacent to the *gamma* carbon atom are converted smoothly by action of phosphorus pentoxide to 2,3-disubstituted 2-cyclopentenones. This method is not applicable, however, for the preparation of 2-cyclopentenone and 3-methyl-2-cyclopentenone.

γ,δ-Dimethyl-γ-caprolactone, when treated with phosphorus pentoxide, is converted in low yield to 2,2,3-trimethyl-4-cyclopentenone and other products.

The ultraviolet absorption spectra of substituted 2-cyclopentenones are briefly discussed.

URBANA, ILLINOIS RECEIVED SEPTEMBER 10, 1947

[15] Auwers, *Ann.*, **292**, 142 (1896).

[16] Auwers and Umgemach, *Ber.*, **68**, 349 (1935).

[17] Blanc and Desfontaines, *Compt. rend.*, **136**, 1141 (1903).

[18] Noyes and Patterson, *Am. Chem. J.*, **27**, 427 (1902).

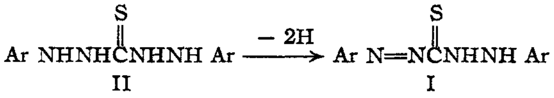
[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF ROCHESTER]

The Synthesis of Some Substituted Thiocarbazones[1]

BY D. S. TARBELL, C. W. TODD,[2a] M. C. PAULSON,[2b] E. G. LINDSTROM[2c] AND V. P. WYSTRACH[2d]

The observation[3] that thiocarbazones, especially di-(*p*-biphenyl)-thiocarbazone, were sensitive reagents for the detection of small amounts of arsenicals, led to the preparation and testing of a number of substituted thiocarbazones. The synthesis of these compounds, and their properties as arsenical detectors, are described in the present paper.

Thiocarbazones (I) are prepared by oxidation of the corresponding thiocarbazides (II) by air in alkaline solution or by hydrogen peroxide



$$\underset{\text{II}}{\text{Ar NHNH}\overset{\overset{\text{S}}{\|}}{\text{C}}\text{NHNH Ar}} \xrightarrow{-\,2\text{H}} \underset{\text{I}}{\text{Ar N=N}\overset{\overset{\text{S}}{\|}}{\text{C}}\text{NHNH Ar}}$$

Several methods were used for the preparation of the necessary thiocarbazides in our work.

---

[1] The work described in this paper was done under Contract OEM-sr-319, recommended by the National Defense Research Committee, between the Office of Scientific Research and Development, and the University of Rochester.

[2] Present address: (a) Experimental Station, E. I. du Pont de Nemours, Inc., Wilmington, Del.; (b) Research Laboratory, Grasselli Chemical Company, Cleveland, Ohio; (c) California Research Corporation, Richmond, Calif.; (d) Research Laboratory, American Cyanamid Company, Stamford, Conn.

[3] By Professor Weldon G. Brown of the University of Chicago.