[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, WASHINGTON UNIVERSITY]

Ring Enlargements. V. The Preparation of 2-Arylcycloheptanones and 2-Aryl-2-cycloheptenones[1]

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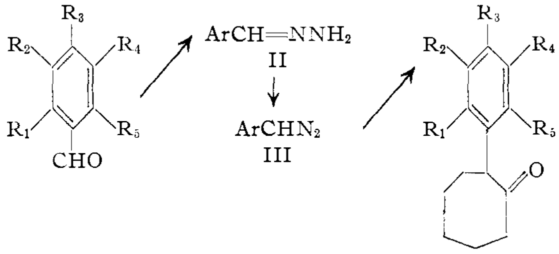
RECEIVED JUNE 20, 1955

Aryldiazomethanes can be prepared readily from the corresponding aromatic aldehyde by conversion to the hydrazone followed by oxidation to the diazo compound. Interaction of the diazo compound with cyclohexanone provides the 2-arylcycloheptanone in 20–48% over-all yield from the aldehyde; interaction with 2-chlorocyclohexanone provides the 2-aryl-2-cycloheptenone in *ca.* 25% over-all yield from the aldehyde. A variety of aryl groups have been tested in these reactions, including the 2,3,4-trimethoxyphenyl group which gives the difficultly obtainable 2-(2',3',4'-trimethoxyphenyl)-cycloheptanone and -cycloheptenone.

Preparation of 2-Arylcycloheptanones.—Paper III of this series[2] dealt with the reaction between cyclohexanone (in methanol solution) and various ethyl N-nitroso-N-benzylcarbamates carrying methyl and methoxyl substituents on the phenyl nucleus. In all of the cases studied, the ring enlargement product was contaminated with methyl arylmethyl ether resulting from participation of the solvent; in some cases this was the only product formed.[2,3] A reaction rationalization was presented which demanded, as one of several requirements, that phenyldiazomethane be unreactive toward methanol but very reactive toward cyclohexanone. It was the verification of this requirement that provided the impetus for the present work.

Although phenyldiazomethane has been reported previously,[4–7] it is a difficult and hazardous operation to obtain a pure sample. Of the several preparative methods investigated, that of Staudinger and Gaule[5] involving the mercuric oxide oxidation of benzalhydrazine proved to be the most suitable, and by this procedure it was possible to secure material which could be distilled under vacuum and obtained in a state of *ca.* 85% purity. In similar fashion a variety of substituted phenyldiazomethanes III were prepared from the appropriate aldehydes I by conversion to the corresponding hydrazone II and oxidation with mercuric oxide or silver oxide.[8] No attempt was made to distil these materials, however, for even IIIa, the lowest-boiling member of the series, sometimes detonated violently during purification by this means.

Phenyldiazomethane proved to be quite unreactive toward methanol, either alone or in the presence of potassium carbonate, and the slow reaction that did occur resulted in the formation of dibenzalhydrazine instead of methyl benzyl ether. Toward cyclohexanone in methanol, on the other hand, phenyldiazomethane was quite reactive and yielded 76% of 2-phenylcycloheptanone (IVa).[9] Thus, the requirement mentioned above was verified and, in addition, the high yield of IVa by this route suggested that the method might possess certain advantages over the one employing nitrosobenzylcarbamates. This proved to be true, and the reaction of various aryldiazomethanes with cyclohexanone gave the desired 2-arylcycloheptanone (IV) in all cases and in 20–48% over-all yield from the aldehyde I. Particularly interesting is the synthesis of 2-(2',3',4'-trimethoxyphenyl)-cycloheptanone (IVh) by this method. Previous attempts to prepare this ketone by ring enlargement of cyclohexanone with ethyl N-nitroso-N-(2,3,4-trimethoxybenzyl)-carbamate[3] failed completely whereas by the present sequence it is obtainable in 42% yield, the over-all process being somewhat simpler than that previously described.[10]



I IV

a, $R_1R_2R_3R_4R_5$ = H
b, R_1 = OCH_3, $R_2R_3R_4R_5$ = H
c, R_2 = OCH_3, $R_1R_3R_4R_5$ = H
d, R_3 = OCH_3, $R_1R_2R_4R_5$ = H
e, R_1R_2 = OCH_3, $R_3R_4R_5$ = H
f, R_1R_3 = OCH_3, $R_2R_4R_5$ = H
g, R_2R_3 = OCH_3, $R_1R_4R_5$ = H
h, $R_1R_2R_3$ = OCH_3, R_4R_5 = H
j, $R_2R_3R_4$ = OCH_3, R_1R_5 = H
k, $R_1R_3R_5$ = CH_3, R_2R_4 = H

Preparation of 2-Aryl-2-cycloheptenones.—2-Aryl-2-cyclohexenones and 2-aryl-2-cycloheptenones have received considerable attention in recent years as attractive intermediates in the field

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[1] This research was supported, in part, by a grant from the Office of Ordnance Research, U.S. Army (Contract No. DA-23-072-ORD-767).

[2] C. D. Gutsche and H. E. Johnson, THIS JOURNAL, **77**, 109 (1955). The reader's attention is called to an error in this paper. The numbers in the three columns on the right hand side of Table I are multiply juxtaposed, line for line. The correct data may be obtained by reference to the experimental section of the paper, by writing to the senior author for a correction tab, or by reference to the errata in THIS JOURNAL, **77**, 6827 (1955).

[3] C. D. Gutsche and H. E. Johnson, *ibid.*, **76**, 1776 (1954).

[4] A. Hantzsch and M. Lehmann, *Ber.*, **35**, 897 (1902).

[5] F. Staudinger and A. Gaule, *ibid.*, **49**, 1897 (1916).

[6] E. A. Werner, *J. Chem. Soc.*, **115**, 1093 (1919).

[7] A. F. McKay, W. L. Ott, G. W. Taylor, M. N. Buchanan and J. F. Crooker, *Canadian J. Research*, **28**, 683 (1950).

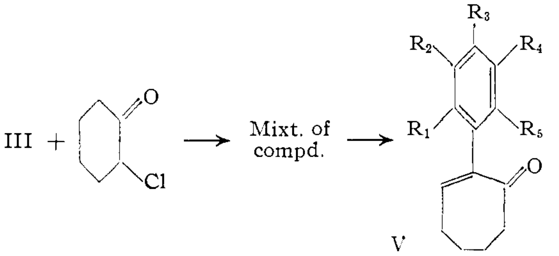
[8] W. Schroeder and L. Katz, *J. Org. Chem.*, **19**, 718 (1954), have reported the use of silver oxide in the preparation of diphenyldiazomethanes.

[9] In the hope of extending the method to the synthesis of 2-arylcyclohexanones, the reaction between phenyldiazomethane and cyclopentanone was carried out. With distilled phenyldiazomethane and a fivefold excess of cyclopentanone a 37% yield of 2-phenylcyclohexanone was achieved. However, when unpurified phenyldiazomethane was used the yield was considerably lower, and it does not appear that the method is particularly suitable for the preparation of this class of compounds.

[10] C. D. Gutsche and F. A. Fleming, THIS JOURNAL, **76**, 1771 (1954).

of morphine[11–13] and colchicine syntheses,[14,15] and several methods for their preparation have been described. The most widely used of these involves an allylic oxidation of the corresponding arylcycloalkene, and by this method 2-phenyl-2-cyclohexenone (35–40% yield),[12,13] 2-phenyl-2-cycloheptenone (25–45% yield),[15,16] 2-(2′,3′-dimethoxyphenyl)-2-cyclohexenone (15% yield),[17] 2-(2′,3′,4′-trimethoxyphenyl)-2-cyclohexenone (47% yield),[12] and 2-(2′,3′,4′-trimethoxyphenyl)-2-cycloheptenone (38% yield)[15] have been prepared. 2-Phenyl-2-cycloheptenone[15] and 2-(2′,3′-dimethoxyphenyl)-2-cyclohexenone[17] also have been prepared in 50 and 28% yield, respectively, from the aryl Grignard reagent and the corresponding cycloalkane-1,2-dione. 2-Phenyl-2-cyclohexenone has been synthesized in good yield from 2-phenylcyclohexanone by bromination followed by dehydrobromination.[11] To this list another method has now been added.

Aryldiazomethanes have been found to react with 2-chlorocyclohexanone to yield products which probably contain, *inter alia*, aryl-chloro-cycloheptanones. When the mixture obtained from 2-chlorocyclohexanone and phenyldiazomethane was refluxed with pyridine and distilled, 2-phenyl-2-cycloheptanone (Va) was produced in 24% over-all yield from benzaldehyde. In the case of the mixture obtained from 2-chlorocyclohexanone and 2,3,4-trimethoxyphenyldiazomethane, simple distillation sufficed to effect the conversion to 2-(2′,3′,4′-trimethoxyphenyl)-2-cycloheptenone (Vh) in 24% over-all yield from 2,3,4-trimethoxybenzaldehyde. The structures of the products were established by carbon and hydrogen analyses, by infrared spectral considerations, by comparison with reported data, and by hydrogenation to the known 2-arylcycloheptanones (IV). Although the over-all yield is relatively low, this method has certain advantages over several of those enumerated above in that the starting materials are, in most cases, readily available, and none of the intermediates require isolation or purification.



Experimental[18,19]

Phenyldiazomethane.—Benzalhydrazine was prepared according to the procedure of Lock and Stach[20] and obtained as a pale yellow material with m.p. 13–15° (reported[20] 13–14°). The oxidation was carried out in the manner described by Staudinger and Gaule.[5] From 18 g. of benzaldehyde there was obtained 16 g. of crude phenyldiazomethane (*ca.* 40% pure) which yielded 7.0 g. (35%) of distilled (caution: highly explosive) material as a red oil with b.p. 37–41° (1.5 mm.). Benzoic acid assay of the distilled product indicated a purity of 80%; reaction with cyclohexanone (*cf.* below) indicated a purity of 85%.

Reactions of "Pure" Phenyldiazomethane: (A) With Methanol.—A sample of distilled phenyldiazomethane was dissolved in methanol (with or without suspended potassium carbonate present). After 24 hours at room temperature very little reaction had taken place, but after 8 days a considerable amount of nitrogen had been evolved, and the isolated product consisted of dibenzalhydrazine, obtained in 92% yield. (B) **With Cyclohexanone**.—A 7.4-g. (0.063 mole) sample of distilled phenyldiazomethane was added to a solution of 11.2 g. (0.11 mole) of cyclohexanone in 30 ml. of methanol. The mixture was allowed to stand at room temperature for 24 hours during which time 85% of the theoretical amount of nitrogen was evolved. The solvents were then removed by evaporation, and the residue was distilled to give 9.0 g. (76%) of 2-phenylcycloheptanone; b.p. 93–97° (0.2 mm.), m.p. 18–23°. Recrystallization from petroleum ether (b.p. 32–37°) removed the small amount of dibenzalhydrazine contaminant and yielded colorless needles, m.p. 21–23° (reported[21] 21–23°). (C) **With Cyclopentanone**.—The reaction was carried out as described above with cyclopentanone (fivefold excess) in place of cyclohexanone. After standing at room temperature for 5 days the nitrogen evolution was complete, and the reaction mixture was worked up to yield 37% of 2-phenylcyclohexanone with b.p. 86–95° (0.3 mm.). Crystallization from petroleum ether (b.p. 63–69°) gave colorless crystals, m.p. 52–56° (reported 50–53°,[22] 62°[23]), which showed no depression in m.p. when admixed with an authentic sample. When less cyclopentanone was used or when crude phenyldiazomethane was used the yields were considerably lower.

Preparation of 2-Arylcycloheptanones. Method A (Preferred Method).—A 0.1-mole sample of the aldehyde was dissolved in 25 ml. of ether and added, over a period of one hour, to a stirred suspension of 6.4 g. (0.2 mole) of anhydrous hydrazine in 25 ml. of ether cooled to *ca.* 5°. During the addition of the aldehyde a slight to copious precipitate formed, but upon further stirring, first for one hour at 5° and then at room temperature for 5 hours or longer, the precipitate disappeared and a clear solution was obtained. The resulting solution was placed in a separatory funnel, and the lower layer of aqueous hydrazine was removed and extracted with two 10-ml. portions of ether. These extracts were added to the ether solution which was then washed twice with water and diluted with ether to a total volume of 100–150 ml. To this solution was added 25 g. of anhydrous sodium sulfate, 4 ml. of saturated alcoholic potassium hydroxide solution[24] and 30 g. (0.14 mole) of yellow mercuric oxide, the mixture being stirred and cooled during the addition of the mercuric oxide to keep the temperature below 30°. Stirring was continued at room temperature for 3–6 hours during which time the reaction mixture became dark red. After the oxidation was complete, the mercury and mercuric oxide were removed by filtration, and the filtrate was added to a solution of 69 g. (0.7 mole) of cyclohexanone (redistilled) in 50 ml. of methanol. The initially deep red solution was allowed to stand at room temperature until the color had changed to pale yellow and the nitrogen evolution had ceased (1–7 days). The volatile materials were removed under vacuum on the steam-bath, and the residue was distilled through a 4-inch Vigreux column to yield the 2-arylcycloheptanone.

Some minor variations of the above procedure were em-

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[11] W. E. Bachmann and L. B. Wick, THIS JOURNAL, **72**, 3388 (1950); W. E. Bachmann and E. J. Fornefeld, *ibid.*, **72**, 5529 (1950).

[12] R. Pappo and D. Ginsburg, *J. Chem. Soc.*, 516 (1951).

[13] C. F. Koelsch, THIS JOURNAL, **73**, 2951 (1951).

[14] D. Ginsburg and R. Pappo, *ibid.*, **75**, 1094 (1953).

[15] D. Ginsburg, *ibid.*, **76**, 3628 (1954).

[16] T. Nozoe, S. Ito and K. Sonobe, *Sci. Repts. Tohoku Univ. Series I*, **38**, No. 2 (1954).

[17] R. A. Barnes and D. F. Reinhold, THIS JOURNAL, **74**, 1327 (1952).

[18] All melting points are corrected; all boiling points are uncorrected.

[19] The microanalyses were performed by Drs. Weiler and Strauss, Oxford, England, and by Miss Charlotte Peterson, Washington University.

[20] G. Lock and K. Stach, *Ber.*, **76**, 1252 (1943).

[21] C. D. Gutsche, THIS JOURNAL, **71**, 3513 (1949).

[22] J. W. Cook, C. L. Hewett and C. A. Lawrence, *J. Chem. Soc.*, 71 (1936).

[23] I. R. Sherwood, S. W. F. Short and J. Woodcock, *ibid.*, 322 (1936).

[24] C. D. Nenitzescu and E. Solomonica, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 496, have prescribed the use of an alkaline catalyst in the hydrazone oxidation.

ployed in a few cases and may be generally applicable. Where the starting aldehyde was insufficiently soluble in ether alone, a mixture of ether and petroleum ether (b.p. 63–69°) was employed. In the example where a 7-day period was required for the reaction with cyclohexanone to be completed (Ik, IVk), refluxing the solution was found to shorten this time to 16 hours and to have little effect on the yield. In another case (Ia, IVa), the addition of an aqueous solution of lithium chloride to the reaction mixture containing the diazoalkane, cyclohexanone and methanol markedly decreased the reaction time.

The following 2-arylcycloheptanones were prepared by the general method described above:

2-Phenylcycloheptanone (IVa) was obtained in 48% over-all yield from benzaldehyde as a pale yellow oil, b.p. 115–118° (0.8 mm.), m.p. 18–23°, n^{25}D 1.5425.

2-(2′-Methoxyphenyl)-cycloheptanone (IVb) was obtained in 45% over-all yield from *o*-methoxybenzaldehyde as a pale yellow oil, b.p. 137–142° (0.8 mm.), n^{25}D 1.5440 (reported[2] n^{25}D 1.5407). The product formed a 2,4-dinitrophenylhydrazone, m.p. 178–179°, which showed no depression in m.p. when admixed with an authentic sample, m.p. 178–179°.

2-(3′-Methoxyphenyl)-cycloheptanone (IVc) was obtained in 39% over-all yield from *m*-methoxybenzaldehyde as a pale yellow oil, b.p. 148–152° (0.8 mm.), n^{25}D 1.5438 (reported[2] n^{25}D 1.5418). The 2,4-dinitrophenylhydrazone of IVc was obtained as yellow needles, m.p. 158–159°.

Anal. Calcd. for $C_{20}H_{22}N_4O_5$: C, 60.29; H, 5.57. Found: C, 59.99; H, 5.25.

The reported[2] m.p. for the 2,4-dinitrophenylhydrazone of IVc is 145–146°. A mixed m.p. of the two samples was 158–159° indicating that the 146° material is probably a metastable polymorphic modification of the 159° material.

2-(4′-Methoxyphenyl)-cycloheptanone (IVd) was obtained in 40% over-all yield from *p*-methoxybenzaldehyde as a pale yellow oil, b.p. 149–155° (0.8 mm.), which changed to a solid, m.p. 56–58° (reported m.p. 57–58°,[2] 60°[25]). A mixed m.p. of the ketone as well as its 2,4-dinitrophenylhydrazone derivative with authentic samples showed no depression in m.p.

2-(2′,3′,4′-Trimethoxyphenyl)-cycloheptanone (IVh) was obtained in 42% over-all yield from 2,3,4-trimethoxybenzaldehyde (*cf.* below for preparation) as a pale yellow oil, b.p. 173–178° (1.0 mm.), n^{25}D 1.5392 (reported[10] n^{25}D 1.5362). The 2,4-dinitrophenylhydrazone of IVh, m.p. 152–153°, showed no depression in m.p. when admixed with an authentic sample, m.p. 153–154°.

2-(2′,4′,6′-Trimethylphenyl)-cycloheptanone (IVk) was obtained in 20% over-all yield from 2,4,6-trimethylbenzaldehyde as a pale yellow oil, b.p. 145–151° (0.8 mm.), n^{25}D 1.5450.

Anal. Calcd. for $C_{16}H_{22}O$: C, 83.43; H, 9.63. Found: C, 82.96; H, 9.46.

The 2,4-dinitrophenylhydrazone of IVk was obtained as yellow needles, m.p. 202–203°, after several recrystallizations from ethanol.

Anal. Calcd. for $C_{22}H_{26}N_4O_4$: C, 64.37; H, 6.39. Found: C, 64.37; H, 6.30.

Method B.—A 0.1-mole sample of the aldehyde was dissolved in *ca.* 20 ml. of ether and treated with 4.0 g. (0.12 mole) of anhydrous hydrazine in 15 ml. of ether. The precipitate which formed was removed by filtration and suspended in 70 ml. of ether. The suspension was cooled to 0–5°, treated with 1 ml. of 10% aqueous sodium hydroxide followed by 21.6 g. (0.10 mole) of yellow mercuric oxide, added over a period of 3 hours. The remainder of the reaction proceeded as in method A. Method B offers no advantage over method A and, in fact, gives slightly lower yields of products. Furthermore, it is restricted to aldehydes which react with hydrazine to form stable precipitates.

The following 2-arylcycloheptanones were synthesized by the method described above:

2-(2′,3′-Dimethoxyphenyl)-cycloheptanone (IVe) was obtained in 45% yield (based on the isolated precipitate from the hydrazone preparation) as a pale yellow oil, b.p. 140–143° (0.3 mm.), n^{25}D 1.5397.

Anal. Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found: C, 72.84; H, 7.83.

The 2,4-dinitrophenylhydrazone of IVe was obtained as yellow needles after several recrystallizations from ethanol; m.p. 175–176°.

Anal. Calcd. for $C_{21}H_{24}N_4O_6$: C, 58.87; H, 5.65. Found: C, 58.90; H, 5.53.

2-(2′,4′-Dimethoxyphenyl)-cycloheptanone (IVf) was obtained in 25% over-all yield from 2,4-dimethoxybenzaldehyde as a pale yellow oil, b.p. 155–160° (0.4 mm.), n^{25}D 1.5470.

Anal. Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found: C, 72.64; H, 7.90.

The 2,4-dinitrophenylhydrazone of IVf was obtained as yellow needles after several recrystallizations from ethanol; m.p. 164–165°.

Anal. Calcd. for $C_{21}H_{24}N_4O_6$: C, 58.87; H, 5.65. Found: C, 58.36; H, 5.98.

2-(3′,4′-Dimethoxyphenyl)-cycloheptanone (IVg) was obtained in 40% over-all yield from 3,4-dimethoxybenzaldehyde as a pale yellow oil, b.p. 167–172° (1.0 mm.), n^{25}D 1.5528.

Anal. Calcd. for $C_{15}H_{20}O_3$: C, 72.55; H, 8.12. Found: C, 72.43; H, 7.97.

The 2,4-dinitrophenylhydrazone of IVg was obtained as yellow needles after several recrystallizations from ethanol; m.p. 191–192°.

Anal. Calcd. for $C_{21}H_{24}N_4O_6$: C, 58.87; H, 5.65. Found: C, 59.27; H, 5.33.

Method C.—The only essential difference between methods A and C was the use of silver oxide instead of mercuric oxide in the latter. However, if the preparation of the hydrazone is properly carried out (*i.e.*, to the point where a clear solution is obtained), mercuric oxide works just as well as silver oxide and has the advantage of being cheaper.

The following 2-arylcycloheptanone was prepared by the general method described above:

2-(3′,4′,5′-Trimethoxyphenyl)-cycloheptanone (IVj) was obtained in 39% over-all yield from 3,4,5-trimethoxybenzaldehyde as a pale yellow oil, b.p. 190–195° (1.5 mm.), which solidified on standing. Recrystallization from aqueous ethanol gave colorless needles; m.p. 59–60°.

Anal. Calcd. for $C_{16}H_{24}O_4$: C, 69.04; H, 7.97. Found: C, 69.16; H, 7.86.

Attempts to prepare a solid semicarbazone or 2,4-dinitrophenylhydrazone of IVj have been unsuccessful.

Preparation of 2-Aryl-2-cycloheptenones. 2-(2′,3′,4′-Trimethoxyphenyl)-2-cycloheptenone (Vh).—A 25.5-g. (0.13 mole) sample of 2,3,4-trimethoxybenzaldehyde (*cf.* below for preparation) was converted to the diazo compound by method A. The ethereal diazoalkane solution was then added dropwise, over a period of 5.5 hours, to a stirred mixture of 86 g. (0.65 mole) of 2-chlorocyclohexanone (redistilled immediately before use), 100 ml. of absolute methanol and 5 ml. of pyridine at 0–2°. The reaction mixture was allowed to stand for an additional 36 hours at 0° by which time the color had faded to a pale yellow and the total nitrogen evolution amounted to 2.2 liters (76% of theory). The volatile materials were removed under vacuum on the steam-bath, and the residue was distilled through a 4-inch Vigreux column to yield 72 g. of unreacted 2-chlorocyclohexanone, b.p. 90–95° (15 mm.), 5.4 g. of material with b.p. 125–180° (1 mm.), and 11.7 g. of material with b.p. 200–215° (2.5 mm.). The highest-boiling fraction was redistilled through the same column to yield 8.70 g. (24%) of a pale yellow oil, b.p. 192–196° (0.8 mm.), n^{25}D 1.5618, $\tilde{\nu}_{\max}^{\text{liq}}$ 1680 cm.$^{-1}$ for C═O.

Anal. Calcd. for $C_{16}H_{20}O_4$: C, 69.54; H, 7.30. Found: C, 69.07; H, 7.14.

The semicarbazone of Vh was obtained as colorless needles after two recrystallizations from ethyl acetate–petroleum ether (b.p. 63–69°), m.p. 183–184° dec. (reported[15] 174–175° dec.)

Anal. Calcd. for $C_{17}H_{23}N_3O_4$: C, 61.24; H, 6.95. Found: C, 61.21; H, 6.68.

Reduction of Vh at 75 atmospheres pressure of hydrogen in the presence of 5% palladium-on-charcoal catalyst yielded 2-(2′,3′,4′-trimethoxyphenyl)-cycloheptanone (IVh), identified by comparison with an authentic sample.

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(25) M. Tiffeneau, P. Weill, J. Gutmann and B. Tchoubar, *Compt. rend.*, **201**, 277 (1935).

2-Phenyl-2-cycloheptenone (Va).—A 53.5-g. (0.5 mole) sample of benzaldehyde was carried through the sequence described above but with the following additions to the procedure. The crude product from the first distillation was refluxed for 2 hours with 50 ml. of benzene and 20 ml. of concentrated hydrochloric acid (to remove dibenzalhydrazine), and the benzene layer was then separated, washed with water, and evaporated. The resulting material was treated with 15.8 g. (0.2 mole) of pyridine and refluxed for 3 hours. The residue remaining after the usual processing was distilled through a 4-inch Vigreux column to give 22 g. (24% over-all from benzaldehyde) of a pale yellow oil, b.p. 128–133° (1 mm.), $n^{25}\text{D}$ 1.5745. The carbon analysis of this material was *ca.* 1.5% low even after careful redistillation. It was necessary, therefore, to prepare a pure sample *via* the semicarbazone which, upon decomposition, yielded a colorless oil, $n^{25}\text{D}$ 1.5712 (reported[16] $n^{11}\text{D}$ 1.5720), $\bar{\nu}_{\max}^{\text{liq}}$ 1680 cm.$^{-1}$ for C=O.

Anal. Calcd. for $C_{13}H_{14}O$: C, 83.83; H, 7.58. Found: C, 83.81; H, 7.39.

The semicarbazone of Va was obtained as colorless plates, m.p. 178–179° (reported[14] 180–181°).

Hydrogenation of Va in the presence of 5% palladium-on-charcoal in ethyl acetate yielded 2-phenylcycloheptanone (IVa), identified by comparison with authentic material.

2,3,4-Trimethoxybenzaldehyde (Ih) was conveniently prepared on a large scale by a method patterned after that of Sommers, *et al.*[26] A 130-g. sample of 1,2,3-trimethoxybenzene was added to a mixture of 168 g. of phosphorus oxychloride and 144 g. of N-methylformanilide over a period of 2.5 hours. After stirring for an additional 3 hours, the reaction mixture was poured into 2 l. of ice-water and allowed to stand overnight. The product was then extracted into ether and the ether solution was treated with saturated sodium bisulfite solution. The bisulfite product was separated, washed with ether, and decomposed to yield 96 g. (64%) of Ih as a pale yellow oil, b.p. 121–124° (0.5 mm.). A 2,4-dinitrophenylhydrazone prepared from this product showed no depression in m.p. when admixed with a sample prepared by an alternate and unequivocal route.

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[26] A. H. Sommers, R. J. Michaels and A. W. Weston, THIS JOURNAL, **74**, 5546 (1952).

ST. LOUIS, MISSOURI

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, THE GEORGE WASHINGTON UNIVERSITY]

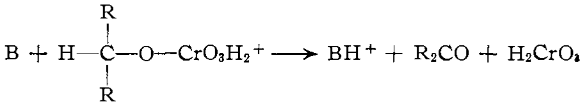
Oxidation of Triethylmethane and Other Hydrocarbons by Acidified Dichromate

BY W. F. SAGER AND ARTHUR BRADLEY[1]

RECEIVED AUGUST 24, 1954

Oxidation of triethylmethane by sodium dichromate in acidified aqueous acetic acid is shown to proceed through triethylcarbinol as the initial oxidation product. Evidence is presented which supports the view that hydrocarbon oxidations by this reagent result from electrophilic attack of the oxidant on the hydrocarbon to yield a carbonium ion.

This study was undertaken to identify the sequence of events which lead to the formation of ketones by oxidation of branched chain hydrocarbons with dichromate. The work reported here includes preliminary studies on the composition of the reaction mixture throughout the course of the oxidation and a more detailed analysis of the initial step. Identification of the means by which such a saturated system engages the oxidant is of special interest inasmuch as the esterification mechanism preferred by Westheimer and co-workers[2–5] for the oxidation of secondary alcohols cannot be paralleled. These authors demonstrated, in an exceptionally thorough investigation, that the transition state concentration was proportional to the alcohol, $HCrO_4^-$ and the square of the hydrogen ion concentration. Moreover, a study of deuteropropanol indicated that the hydrogen attached to the carbinol carbon is involved in the rate-determining step.[3] Finally, induced oxidation of the manganous ion showed the presence of tetravalent chromium in the reaction mixture.[5] This evidence was used to support the idea that chromium is reduced from a valence of six to four in an oxidation process which involves a base-initiated breakdown of a chromate ester.



$$B + H-\overset{\overset{\displaystyle R}{|}}{\underset{\underset{\displaystyle R}{|}}{C}}-O-CrO_3H_2^+ \longrightarrow BH^+ + R_2CO + H_2CrO_3$$

The lack of influence of oxygen[4,6] on chromic acid oxidations supports this conclusion.

Our approach to the similar questions connected with hydrocarbon oxidation followed three general lines: study of the reaction products, isotope effect on oxidation rate and effect of special structural features on the ease of C–H bond rupture. All studies concerned oxidations by sodium dichromate in aqueous acetic acid acidified with sulfuric acid, a useful agent for hydrocarbon oxidations. A general idea of the composition of the reaction mixture at various times was gained by analysis for ketone and dichromate. The other species, unreacted hydrocarbon, triethylcarbinol and propionic acid, could then be calculated, as indicated in the Experimental section, with the aid of the independently determined oxidation rate of triethylcarbinol and 3-pentanone. An analysis by fractional distillation for all components except the acid was used as a check on the other analytical results. Similar measurements were made on the oxidation of triethyldeuteromethane. Last of all the behavior of bicyclic systems was studied by measurements on the oxidation rate of camphane and the nature of its oxidation product.

Discussion

By the means mentioned previously the primary oxidation product of triethylmethane is clearly triethylcarbinol (Fig. 2). Moreover, these results were checked by a larger scale run of short duration which was analyzed by fractional distillation. It yielded 9% of unreacted hydrocarbon, 41% carbinol and 36% ketone.

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