for infrared analysis was prepared from the *p*-nitrocinnamoyl chloride–cyclopentadiene adduct as described above under the cinnamamide adduct.

***p*-Chlorocinnamic Acid and Cyclopentadiene.**—Most of the unreacted *p*-chlorocinnamic acid crystallized on cooling the toluene solutions. The iodolactone, prepared in the usual way, was reductively cleaved by zinc as described above. The *endo*-acid was obtained as a white solid in 81% yield, m.p. 138–139.5°.

The bromolactone was prepared from the pure *endo*-acid.

The filtrate from the iodolactonization produced a mixture of *p*-chlorocinnamic acid and the *exo* adduct. When treated with methanol, most of the remaining *p*-chlorocinnamic acid remained undissolved. The adduct was isolated from the filtrate by crystallization.

***p*-Methoxycinnamic Acid and Cyclopentadiene.**—No adduct could be detected in a reaction run at 55° for 5 weeks. Adducts were isolated from reactions in refluxing toluene, longer times giving higher yields. Unreacted *p*-methoxycinnamic acid crystallized on cooling.

The pure *endo* adduct was prepared by reductive cleavage of the iodolactone with zinc in 95% yield.

The *exo*-acid, obtained from the iodolactonization filtrate, was separated from the *p*-methoxycinnamic acid by two crystallizations.

Miscellaneous Experiments.—The adduct from methyl *p*-chlorocinnamate was an oil which did not crystallize and was heavily contaminated with cyclopentadiene polymers. No further investigation of it was made.

p-Dimethylaminocinnamic acid and its methyl ester did not form adducts at 55° for long times. The acid did not form an adduct at 110°, but the ester was not investigated.

ANN ARBOR, MICHIGAN

[CONTRIBUTION FROM THE RESEARCH LABORATORIES OF THE UPJOHN CO.]

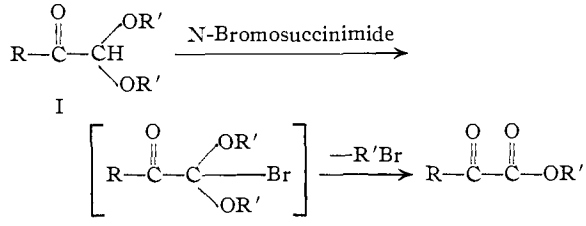
Reaction of Dialkylacetals of α-Ketoaldehydes with N-Bromosuccinimide. A New Synthesis for α-Ketoesters

BY JOHN B. WRIGHT

RECEIVED APRIL 27, 1955

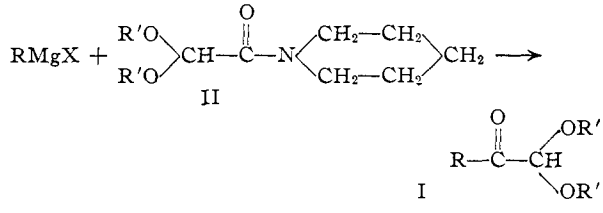
Dialkylacetals of α-ketoaldehydes (I), on treatment with N-bromosuccinimide, were found to be converted to α-ketoesters in very good yield.

We have found that acetals of α-ketoaldehydes react with N-bromosuccinimide to give the corresponding α-ketoesters in very good yield. Since the requisite acetals (I) can be prepared readily in



I

excellent yield by the reaction of Grignard reagents with dialkoxyacetylpiperidines[1] (II), this represents a convenient two-step synthesis of α-ketoesters from Grignard reagents.



II

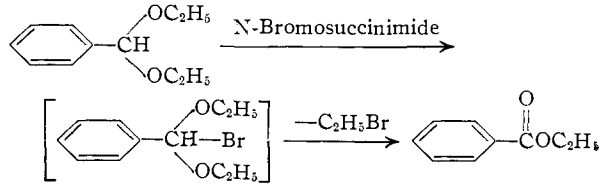
I

The reaction with N-bromosuccinimide was carried out with pyruvaldehyde diethylacetal (I, R = CH_3; R' = C_2H_5), pyruvaldehyde dibutylacetal (R = CH_3; R' = n-C_4H_9), *t*-butylglyoxal diethylacetal (R = $(CH_3)_3C$; R' = C_2H_5) and phenylglyoxal diethylacetal (R = C_6H_5; R' = C_2H_5). The yields varied from 72 to 78%. The reactions were carried out in the usual way using carbon tetrachloride as the solvent. When the reaction was complete, the solvent was removed and the residue distilled *in vacuo*.

(1) A. Wohl and M. Lange, *Ber.*, **41**, 3615 (1908); *cf.* also the Experimental part of paper.

In the case of the pyruvaldehyde acetals, bromination on the carbon not containing the alkoxy groups to give α-bromopyruvaldehyde dialkylacetals was possible. As a matter of fact, Mowat[2] has reported the preparation of α-bromopyruvaldehyde diethylacetal by the bromination of pyruvaldehyde diethylacetal with bromine. We have found, however, that when the bromination is carried out with N-bromosuccinimide in the presence of light the reaction proceeds in a different manner and essentially pure pyruvate esters are obtained.

Marvell and Joncich[3] have reported that benzaldehyde diethylacetal reacts with N-bromosuccinimide to give ethyl benzoate and they have postulated a somewhat analogous course for this reaction.



Experimental[4,5]

Bromination of Pyruvaldehyde Diethylacetal with N-Bromosuccinimide. Preparation of Ethyl Pyruvate.—In a flask fitted with an efficient reflux condenser equipped with a calcium chloride tube was added 57.5 g. (0.394 mole) of freshly distilled pyruvaldehyde diethylacetal, 70.2 g. (0.394 mole) of N-bromosuccinimide[6] and 288 ml. of dry carbon tetrachloride. The mixture was heated by a 250-watt drying lamp placed about 12 inches below the flask. As soon as the mixture began to reflux the light was turned

(2) J. H. Mowat, U. S. Patent 2,436,073.

(3) E. N. Marvell and M. J. Joncich, THIS JOURNAL, **73**, 973 (1951).

(4) All boiling points reported are uncorrected.

(5) We wish to thank Mr. W. A. Struck and his associates of these laboratories for the microanalytic data reported herein, Dr. J. L. Johnson for the infrared data, and Mr. A. Barton for technical assistance.

(6) Purchased from Arapahoe Chemical Co., Boulder, Colo.

off and switched on and off as required so that the mixture refluxed gently. As soon as the initial reaction was over, the light was raised closer to the reaction flask and the mixture was refluxed for 3 hours and allowed to stand overnight.

The succinimide was removed by filtration and was washed with dry carbon tetrachloride. The solvent was removed by slow distillation through a 7″ column packed with glass helices and the residue was distilled *in vacuo* through the same column. There was obtained 36.3 g. (78%) of ethyl pyruvate boiling at 48–52° (14 mm.).

To remove any traces of hydrogen bromide that might be present, the material was dissolved in ether and the ethereal solution extracted with 1% sodium bicarbonate solution, washed with water, dried (anhydrous $MgSO_4$) and redistilled.

The product was identified as ethyl pyruvate by (1) comparison of the infrared curve with that obtained from an authentic sample of ethyl pyruvate, (2) lack of depression of mixed melting points when the *oximes* derived from the product of the reaction and an authentic sample of ethyl pyruvate were mixed, and (3) identity of the infrared curves of the two *oximes* mentioned above.

Bromination of Pyruvaldehyde Dibutylacetal with N-Bromosuccinimide. Preparation of Butyl Pyruvate.—The procedure described above for the preparation of ethyl pyruvate was followed using an equivalent amount (79.5 g.) of pyruvaldehyde dibutylacetal.[7] There was obtained 40.8 g. (72%) of a colorless liquid boiling at 74–77° (15 mm.), $n^{25}D$ 1.4132.

Anal. Calcd. for $C_7H_{12}O_3$: C, 58.31; H, 8.39. Found: C, 58.77; H, 8.58.

***t*-Butylglyoxal Diethylacetal.**—To a stirred solution of *t*-butylmagnesium chloride, prepared from 61.0 g. (2.5 moles) of magnesium according to the method described in reference 8 and cooled to 5° was added over the course of about 5 minutes 215 g. (1 mole) of diethoxyacetylpiperidine.[1] The mixture was then stirred and refluxed for 20 hours and decomposed by the addition of 300 ml. of an ice-cold ammonium chloride solution. The ethereal layer was decanted off, the aqueous slurry extracted with ether and the combined ethereal solutions dried over anhydrous magnesium sulfate. The ether was removed and the residue distilled *in vacuo* through a 7″ helices-packed column. After a very small amount of forerun there was obtained 152.2 g. (82%) of a colorless liquid boiling at 80.5–82° (15 mm.), $n^{25}D$ 1.4128.

Anal. Calcd. for $C_{10}H_{10}O_3$: C, 63.79; H, 10.71. Found: C, 64.07; H, 10.99.

Bromination of *t*-Butylglyoxal Diethylacetal with N-Bromosuccinimide. Preparation of Ethyl α,α,α-Trimethylpyruvate.—Using an equivalent amount (74.1 g.) of *t*-butylglyoxal diethylacetal and using the procedure for the preparation of ethyl pyruvate there was obtained 48.4 g. (78%) of a colorless liquid boiling at 65–66° (15 mm.), $n^{25}D$ 1.4096.

Anal. Calcd. for $C_8H_{14}O_3$: C, 60.74, H, 8.92. Found: C, 60.82; H, 9.21.

Phenylglyoxal Diethylacetal.—Phenylmagnesium bromide was prepared from 30.5 g. of magnesium turnings and 196.3 g. of bromobenzene in 650 ml. of anhydrous ether. To the solution of the Grignard reagent cooled to 0° in an ice–salt-bath was added, with stirring, 107.5 g. (0.5 mole) of diethoxyacetylpiperidine. By the time the addition was completed a large amount of solid had formed making further stirring impossible. The mixture was then refluxed and stirred (as soon as it became possible to do this) for 18 hours.

The reaction mixture was decomposed by the gradual addition of 500 ml. of a 20% ammonium chloride solution. The ethereal layer was decanted from the aqueous slurry. To the aqueous layer was added an additional liter of a 20% ammonium chloride solution, and the mixture was then extracted twice with 1500-ml. portions of ether. The combined ethereal extracts were dried over anhydrous magnesium sulfate, the ether removed, and the residue distilled *in vacuo* through a 7″ column packed with glass helices. There was obtained 58.75 g. (56%) of a colorless liquid boiling at 147.5–150° (2.2 mm.), $n^{25}D$ 1.4992. Torrey, Kuch and Elderfield,[9] who prepared this material by a different method, give the boiling point as 129–132° (7 mm.), $n^{25}D$ 1.5012.

The Reaction of Phenylglyoxal Diethylacetal with N-Bromosuccinimide. Preparation of Ethyl Benzoylformate.—A mixture of 38.13 g. (0.183 mole) of phenylglyoxal diethylacetal, 49.8 g. (0.275 mole) of N-bromosuccinimide and 136 ml. of dry carbon tetrachloride was heated under reflux (using a heat lamp) for 18 hours. The succinimide was removed by filtration and the filtrate distilled through a 7″ Vigreux column to remove carbon tetrachloride. The residue was distilled *in vacuo* through a 7″ column packed with glass helices. There was obtained 23.9 g. (73%) of a colorless liquid boiling at 97° (2 mm.).

The material was purified further by dissolving it in ether and extracting the ethereal solution with a 1% sodium carbonate solution. The ethereal solution was then dried (anhydrous magnesium sulfate), the ether removed and the residue redistilled, $n^{25}D$ 1.5145.

Anal. Calcd. for $C_{10}H_{10}O_3$: C, 67.40; H, 5.66. Found: C, 67.73; H, 5.85.

The infrared spectrum of the product was identical to that obtained with an authentic sample of ethyl benzoylformate.

(7) H. R. Guest, L. G. McDowell and R. W. McNamee, U. S. Patent 2,421,559.

(8) H. Gilman and A. H. Blatt, "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., New York, N. Y., 1944, p. 254.

(9) J. V. Torrey, J. A. Kuck and R. C. Elderfield, *J. Org. Chem.*, **6**, 289 (1941).

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