

methylfuran (10.8 g.) and unchanged methylfuran (16.1 g.) from an input of 41 g.

Isolation and Analysis of Products.—The products from the reaction chamber were caught in a trap at -78° and freed from water either by filtering with exclusion of atmospheric moisture through a small sintered glass funnel kept very cold or by using anhydrous magnesium sulfate. Distillation was effected at atmospheric pressure with a 12-plate fractionating column. Methylfuran constituted most of the fraction, b. p. $60-70^{\circ}$. The amount was checked by conversion into the maleic anhydride adduct using benzene as solvent. Tetrahydromethylfuran was present in the fraction b. p. $70-90^{\circ}$ (most $79-80^{\circ}$); 2-pentanone distilled mainly between 101 and 103° , the fraction being collected between 90 and 110° . This fraction was shaken with saturated aqueous bisulfite and correction applied for the small amount of non-ketonic material. The distillation residue contained 2-pentanol, usually too little for separation by distillation. The material from several experiments was collected, any ketone removed by bisulfite and the material shown by distillation to contain 80% of b. p. $117-120^{\circ}$. The figures for 2-pentanol are perhaps the least accurate of those recorded.

The 2,4-dinitrophenylhydrazone of 2-pentanone after recrystallization from ethyl alcohol had m. p. $146-147^{\circ}$. The 3,5-dinitrobenzoate of 2-pentanol recrystallized from ligroin, b. p. $90-120^{\circ}$, had m. p. $61-62^{\circ}$.

Reduction of 2-Pentanone.—The ketone (15 g.) was passed with hydrogen (15 l./hr.) during thirty minutes over the nickel catalyst at 100° . The product consisted of unchanged pentanone (20 g.) and 2-pentanol (12.3 g.).

Dehydrogenation of 2-Pentanol.—The alcohol (10 g.) was passed over the nickel catalyst at 225° together with hydrogen (30 l./hr.). The product contained 95% ketone. Similar results were obtained at 250° .

Tetrahydromethylfuran.—The cyclic ether, b. p. $80-81^{\circ}$ (30 g.), was passed during one hour together with hydrogen (30 l./hr.) over nickel at 250° . No ketone was

produced but there was considerable gas formation. At 100° the compound was recovered unchanged.

Reaction of Methylfuran with Dinitrophenylhydrazine.—Methylfuran (1 g.) and 2,4-dinitrophenylhydrazine dissolved in hydrochloric acid (2 *N*) were shaken for several days. The yellow precipitate (1.3 g.) was filtered off, washed with water and hot ethyl alcohol. It was insoluble in all ordinary solvents but was crystallized from dimethylformamide forming dark red prisms, m. p. 231° (dec.).

Anal. Calcd. for $C_{11}H_{16}O_2N_2$: C, 44.3; H, 3.5; N, 24.2. Found: C, 44.4; H, 3.5; N, 24.2.

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Summary

The variation of products with temperature in the reaction of methylfuran vapor with hydrogen over a nickel catalyst has been studied. At 100° the main product was tetrahydromethylfuran while above this temperature 2-pentanone was formed in large amounts. The yield of ketone was a maximum at 185° . Along with the ketone small amounts of 2-pentanol were also formed and at the higher temperatures quantities of gaseous materials.

Other catalysts containing cobalt, copper and iron also resulted in ketone formation but a detailed study of their behavior was not made.

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

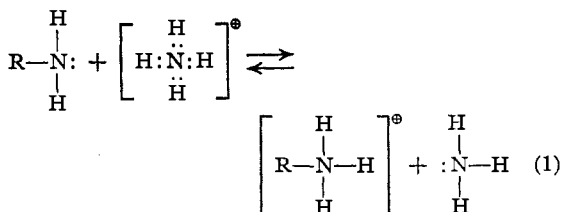
A Low Pressure Reductive Alkylation Method for the Conversion of Ketones to Primary Amines¹

BY ELLIOT R. ALEXANDER AND ALICE LOUISE MISEGADES²

It is well known that carbonyl compounds can be hydrogenated in the presence of ammonia to produce mixtures of primary, secondary, and tertiary amines.³ Originally the reaction was carried out by the hydrogenation of the carbonyl compound in ethanol, saturated with ammonia, at low pressure over a nickel catalyst.^{3a} Better yields and more reproducible results, however, have been obtained over Raney nickel with hydrogen pressures of 20 to 150 atmospheres at temperatures ranging from 40 to 150° .^{3b,3c} This technique, while readily carried out, requires high pressure apparatus which is not always available. Accordingly, it was the object of this work to improve Mignonac's low pressure reductive alkyl-

ation reaction for the preparation of primary amines.

It appeared that this might be done by taking advantage of the fact that a primary amine is more basic than ammonia. If ammonium ions were introduced into the reaction mixture, the following reaction should occur in which the position of equilibrium should favor the products on the right.



(1) Taken from a thesis by Alice Louise Misegades submitted to the faculty of the University of Illinois in partial fulfillment of the requirements for the degree of bachelor of science.

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(3) (a) Mignonac, *Compt. rend.*, **172**, 223 (1921); (b) Schwoegler and Adkins, *This Journal*, **61**, 3499 (1939); (c) Winans, *ibid.*, **61**, 3566 (1939).

Since the alkylammonium ion no longer has an electron pair available for combination with the carbonyl group, the process should tend to stop at the formation of primary amines.

In Table I are summarized the yields which were obtained from a number of reductive alkylations which were carried out in the presence of excess ammonium chloride. The reaction medium was methanol saturated with ammonia and the catalyst was platinum oxide.

TABLE I
REDUCTIVE AMMONIATION OF CARBONYL COMPOUNDS IN THE PRESENCE OF AMMONIUM CHLORIDE

Ketone or aldehyde used in preparation ^a	Primary amine prepared	Yield, %
Isobutyraldehyde	Isobutyl-	10
Methyl isopropyl ketone	1,2-Dimethylpropyl-	32
Cyclohexanone	Cyclohexyl-	44-50
Methyl isobutyl ketone	1,3-Dimethylbutyl- ^b	57-65
Benzaldehyde	Benzyl- ^c	14
Dipropyl ketone	1-Propylbutyl-	38-59
Diisopropyl ketone	1-Isopropylisobutyl- ^d	55
Methyl <i>n</i> -amyl ketone	1-Methylhexyl-	40
Acetophenone	1-Phenylethyl-	69
Propiophenone	1-Phenylpropyl-	65
Phenylacetone	1-Benzylethyl-	52
Methyl β -naphthyl ketone	1- β -naphthylethyl- ^e	53
Benzophenone	Benzhydryl-	34

^a Freshly distilled commercial products were used in all cases. ^b Mailhe, *Compt. rend.*, 172, 693 (1921). ^c The bulk of the product (71%) was dibenzylamine. ^d Reference 3b. ^e Blicke and Maxwell, *THIS JOURNAL*, 61, 1781 (1939).

It will be observed that the method was only partially successful in preventing the formation of secondary products but that the yields from ketones are quite comparable to those obtained at higher pressures and temperatures.^{3b} In the case of isobutyraldehyde, benzaldehyde, methyl isopropyl ketone, cyclohexanone, methyl *n*-amyl ketone, and phenylacetone, considerable amounts of secondary amines were observed. With less reactive ketones such as methyl isobutyl, di-*n*-propyl, diisopropyl, acetophenone, propiophenone, methyl β -naphthyl, and benzophenone there appeared to be very little secondary amine formation. Presumably, the formation of a secondary alcohol was a competing reaction although this point was not investigated.

The improvement ammonium chloride made upon the yield of primary amine can be illustrated with acetophenone and methyl isobutyl ketone. When the reaction was carried out in the absence of ammonium chloride yields of 37 and 49%, respectively, were obtained. Table I shows that yields of 69 and 57-65% were obtained for the same reactions in the presence of ammonium chloride.

Experimental

Reductive Alkylation of Ammonia with Ketones.—An apparatus similar to the one described by Adams and Voorhees⁴ was used for the reaction. The carbonyl compounds were all redistilled before use.

In a 300-ml. reduction bottle containing 10 ml. of distilled water, 0.2 g. of platinum oxide⁵ was reduced to platinum by shaking in an atmosphere of hydrogen for about ten minutes.⁶ The ketone (0.3 mole), ammonium chloride (20.0 g., 0.37 mole), 225 ml. of absolute methanol saturated with ammonia, and 25 ml. of aqueous ammonia were added and the mixture was reduced by shaking with hydrogen at one to three atmospheres. Hydrogenation was continued until a constant pressure reading indicated that reduction had ceased. The shaker was then stopped, the bottle was vented, and the catalyst was allowed to settle. The platinum was removed by filtering the mixture through a Hirsch funnel into a one-liter round-bottomed flask and any salt which collected on the filter was rinsed down with water or methanol. The flask and contents were then removed to a hood and refluxed under a condenser for one hour to remove the excess ammonia.

When the excess ammonia had been removed, the solution was cooled, acidified to congo red paper with concentrated hydrochloric acid, and evaporated to about one-half of its volume under vacuum. Water (200 ml.) was added and the solution extracted with three 25-ml. portions of benzene. The benzene extracts were discarded. The aqueous solution was then made strongly basic with 50% sodium hydroxide solution, the two layers which formed were separated and the water layer was extracted three or four times with ether. The ether extracts and the oily layer were then combined, washed with water and dried over potassium hydroxide. The primary amine was purified by distillation through a 13-cm. column packed with glass helices. The boiling points found agreed well with those recorded in the literature.

In the case of the runs with benzaldehyde, phenylacetone, methyl β -naphthyl ketone, and benzophenone, insoluble salts were formed on acidification. With these compounds the procedure was modified to the extent that the mixture was cooled, the salts filtered with suction and washed thoroughly with water. The filtrate was then extracted with benzene as before and the salts were recombined with it before basing the solution with aqueous sodium hydroxide.

Summary

Experimental conditions have been described for the low pressure hydrogenation of a mixture of a ketone and ammonia to the corresponding primary amine. The reduction was carried out over platinum oxide in methanol saturated with ammonia in the presence of excess ammonium chloride. In general the yields were comparable to those obtained with high pressure equipment.

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(4) Adams and Voorhees, "Organic Syntheses," John Wiley and Sons, Inc., New York, N. Y., 1941, p. 61.

(5) Obtained from the American Platinum Works, Newark, N. J.

(6) When an attempt was made to omit this step a long induction period occurred and reduction appeared to proceed much more slowly than normally.