THE CATALYTIC SYNTHESIS OF HOMOLOGS OF PYRROLIDINE FROM FURAN AMINES

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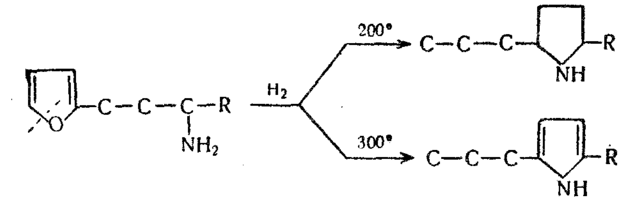
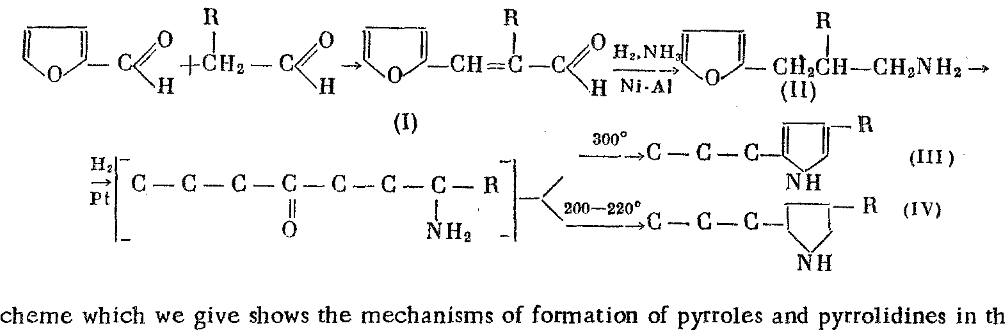
The condensation of furfural with aliphatic carbonyl compounds leads to furylacroleins or furfurylidene ketones which contain the carbonyl group in position 3 with respect to the furan ring. This fact is important for further syntheses, since the carbonyl group can be easily converted into hydroxyl or amino groups. If furan alcohols and furan amines of this structure are hydrogenated under conditions in which there is hydrogenolysis of the furan ring, there are first formed1,4-alkanediols or 1,4-amino alcohols which are cyclized with especial ease with evolution of water into new five membered heterocyclic compounds: tetrahydrofurans [1], pyrroles, and pyrrolidines [2]. There is a simple temperature relation between the pyrroles and pyrrolidines under conditions of catalytic vapor phase hydrogenation: at low temperatures pyrroles are hydrolyzed into pyrrolidines, while at higher temperatures the reverse reaction occurs [3]. This fact is very important, since it determines the temperature conditions under which pyrroles or pyrrolidines are formed from furan amines. We have obtained experimental data on this from hydrogenation of 1-furyl-3-aminoalkanes on platinum in the vapor phase at 200 and 300°; in the first case we obtained pyrrolidines, in the second, pyrroles [2]

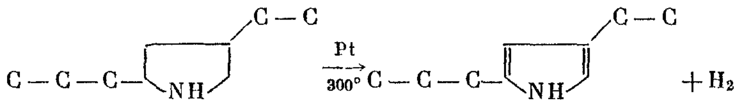


1-Furyl-3-aminoalkanes, which are products of the reduction of aminated furfurylidene ketones, form pyrroles or pyrrolidines which belong to the series of 2,5-dialkyl substituted homologs of these heterocycles. On the other hand, evidently furfural and aliphatic aldehydes can give β-furylacroleins (I) which in the general case contain alkyl groups in the α-position. It was found that furan amines (II) obtained from α-alkyl-β-furylacroleins are catalytically hydrogenated in the vapor phase over platinum at 300° and converted to 2-n-propyl-4-alkylpyrroles (III)



The scheme which we give shows the mechanisms of formation of pyrroles and pyrrolidines in the hydrogenation of furan amines in the vapor phase. It is known that as a result of hydrogenolysis of the furan ring, depending on the temperature, there forms from the ether oxygen,carbonyl or hydroxyl groups. Therefore it is natural to assume that the conversion of furan amines into pyrroles occurs through an intermediate stage of formation of 1,4-amino ketones, and the conversion into pyrrolidines through a stage of 1,4-amino alcohols. In all probability, 1,4-amino ketones and 1,4-amino alcohols are converted into pyrroles and pyrrolidines without desorption from the catalyst surface and hence do not exist in the free state. In this case, the question of the mechanism of formation of pyrroles and pyrrolidines as proposed in this form is not actually as significant as when we consider the reversible reaction of hydrogenation of pyrroles into pyrrolidines.

In the present work we have studied the conversion of 1-furyl-2-alkyl-3-aminopropanes (II) into 2-n-propyl-4-alkylpyrrolidines (IV). The considerations discussed above determine the conditions under which such a conversion can occur. Temperature and catalyst play decisive roles. The latter should be effective for hydrogenolysis of the furan ring. As in our previous experiments, we have used platinum on charcoal or asbestos, which is an excellent catalyst for conversion of 1-furyl-2-alkyl-3-aminopropanes into 2,4-dialkylpyrrolidines; at a temperature of 200-220° the latter are formed with yields of 85-90%. We have obtained two dialkylpyrrolidines with alkyl substituents in the α- and β-positions: 2-n-propyl-4-methylpyrrolidine and 2-n-propyl-4-ethylpyrrolidine. The starting compounds for their synthesis were on the one hand furfural, and on the other, propionic and butyric aldehydes. The scheme of the successive reactions leading to the 2,4-dialkylpyrrolidines is given above. One of our pyrrolidines, 2-n-propyl-4-ethylpyrrolidine, was submitted to dehydrogenation on platinized asbestos at 300°. The reaction occurred smoothly and the dehydrogenation product, 2-n-propyl-4-ethylpyrrole, was obtained with a yield of about 95%



This fact shows once more the temperature limits for the conversion of furan amines into pyrroles and pyrrolidines.

EXPERIMENTAL

2,4-Dialkylpyrrolidines were synthesized from furfural and aliphatic aldehydes in the following three steps: 1) condensation of furfural with the aldehydes with formation of α-alkyl-β-furylacroleins; 2) reductive amination of α-alkyl-β-furylacroleins; 3) conversion of the furan amines into 2,4-dialkylpyrrolidines.

Synthesis of α-alkyl-β-furylacroleins. We placed in a flask 1 liter of water, 400 ml of alcohol, and 20 g of sodium hydroxide. We poured into this mixture from a dropping funnel, with stirring and ice cooling, first 2 M of furfural, then 2.5 M of propionic or butyric aldehyde. After addition of aldehyde (this took 5-6 hours) the reaction mixture was stirred at room temperature for two hours and then neutralized with acetic acid. The dark oil which precipitated was washed with water and distilled at reduced pressure. α-Methyl-β-furylacrolein had b.p. 92-94° (8 mm), and α-ethyl-β-furylacrolein 93-95° (6 mm).

Conversion of α-alkyl-β-furylacroleins into 1-furyl-2-alkyl-3-aminopropanes. α-Alkyl-β-furylacroleins were converted into 1-furyl-2-alkyl-3-aminopropanes by reductive amination in the liquid phase in the presence of a skeletal nickel-aluminum catalyst. The reaction was carried out in an autoclave in which we placed 125 g of α-alkyl-β-furylacrolein, 360 ml of methanol, saturated with ammonia at 0°, and 15 g of Ni-Al catalyst. Then hydrogen was introduced into the autoclave to a pressure of 100-120 atm. The autoclave was heated to 80°, the reaction was complete when absorption of hydrogen stopped. The catalyzate after distillation of the methanol was vacuum distilled. 1-Furyl-2-alkyl-3-aminopropanes had the following properties: 1-furyl-2-methyl-3-aminopropane, b.p. 53-54° (3 mm), n_D^{20} 1.4848; d_4^{20} 0.9750; 1-furyl-2-ethyl-3-aminopropane, b.p. 78-79° (5 mm), n_D^{20} 1.4841; d_4^{20} 0.9684.

Catalysts. For the reductive amination of α-alkyl-β-furylacroleins we used a skeletal nickel-aluminum catalyst prepared by treatment of a Ni-Al alloy with a 10% solution of alkali with ice cooling. The catalyst was washed free of alkali with water (reaction to phenolphthalein) and placed in the autoclave after washing with methanol.

The platinum catalysts were prepared by depositing platinum on activated charcoal or asbestos which had first been treated with alkali and hydrochloric acid with heating, and then washed with water. After drying, the charcoal and asbestos were soaked in a solution of chloroplatinic acid and placed in the reaction tube where they were reduced with hydrogen at 250-300° for 12 hours.

The furan amines were converted into 2,4-dialkylpyrrolidines by their hydrogenation over platinum catalysts in a flowing system at 200-220°. The resulting catalyzate was saturated with alkali, separated from the water, and dried with ignited potassium hydroxide. Then the catalyzate was fractionated in an effective column. The separated pyrrolidines were again distilled over sodium from a flask with a fractionating column; they had the following properties: 2-n-propyl-4-methylpyrrolidine, b.p. 162-164°, n_D^{20} 1.4457; d_4^{20} 0.8413. Found: MR 40.30. $C_8H_{17}N$. Calculated: MR 40.55; 2-n-propyl-4-ethylpyrrolidine, b.p. 55-56° (5 mm), n_D^{20} 1.4475; d_4^{20} 0.8457. Found: MR 44.98. $C_9H_{19}N$. Calculated: MR 45.16; 2-n-propyl-4-ethylpyrrolidine was dehydrogenated over platinized asbestos at 300°. As a result we obtained 2-n-propyl-4-ethylpyrrole, b.p. 97-98° (16 mm), n_D^{20} 1.4876; d_4^{20} 0.8982. Found: MR 43.98. $C_9H_{15}N$. Calculated: MR 44.23.

SUMMARY

1-Furyl-2-alkyl-3-aminopropanes are converted by hydrogenation on platinum in a flowing system at 200-220° to 2-n-propyl-4-alkyl-pyrrolidines with yields of 85-90%.

LITERATURE CITED

1. I. F. Bel'skii and N. I. Shuikin, Dokl. AN SSSR 128, 945 (1959).
2. I. F. Bel'skii and N. I. Shuikin, Dokl. AN SSSR 137, 331 (1961).
3. N. D. Selinsky and J. K. Jurjew, Ber. 64, 101 (1931).