CATALYTIC SYNTHESIS OF DIAZINES FROM 1,3-DIAMINOPROPANE AND 3-AMINO-1-PROPANOL

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The transformations of 1,3-diaminopropane and 3-amino-1-propanol under pulse conditions over tungsten trioxide in an inert atmosphere at 300-500°C were investigated. The transformation of 1,3-diaminopropane leads to the formation of saturated pyrimidine bases; the maximum selectivity of the formation of hexahydropyrimidine bases at 300°C is 60%, while the selectivity of the formation of tetrahydropyrimidine bases is 20% (400°C). In the case of 3-amino-1-propanol the overall yield of heterocyclic bases was less than 5%, and piperazine and pyrazine derivatives were observed as the cyclic products; the formation of pyrimidine bases was not observed.

It has been previously shown [1, 2] that ethylenediamine is converted to piperazine bases in the gas phase on oxides; depending on the nature of the oxide and the temperature in the catalyst layer, deamination is accompanied by processes that involve redistribution of hydrogen and lead to the formation of pyrazine and its derivatives and acyclic products of hydrogenolysis. Intermolecular dehydration of aminoethanol, which leads to the formation of piperazine, competes with reactions that take place with cleavage of the C-C bond [3]. However, the transformation of 4-aminio-1-butanol on catalysts with similar compositions leads to the selective formation of five-membered nitrogen heterocycles [4]. Data relative to the behavior of 1,3-diaminopropane and 3-amino-1-propanol on oxides are not available. It has been established that 1,3-diaminopropane is converted to 2-ethyl- and 2-methylpyrimidine in 50 and 10% yields, respectively, on metals of the platinum group applied to aluminum trioxide in the presence of hydrogen and water vapors [5].

In this paper we present data on the conversion of 1,3-diaminopropane and 3-amino-1-propanol to cyclic diazines on tungsten oxide and catalysts based on it, which display high selectivity in the cyclization of 4-amino-1-butanol to pyrrolidine [4].

Transformations of 1,3-Diaminopropane

Hexahydropyrimidine, 2-methyl- and 2-ethyl-substituted hexahydropyrimidines, and a number of the simplest alkylamines are formed at 300-500°C from 1,3-diaminopropane on tungsten trioxide applied to Chromosorb W (Table 1). The conversion of 1,3-diaminopropane and the overall yields of the heterocycles and alkylamines increase when the temperature is raised. The temperature curve of the selectivity of the formation of 2-methylhexahydropyrimidine and hexahydro pyrimidine passes through a maximum at 400-420°C as a consequence of the fact that products of partial dehydrogenation, viz., 1,4,5,6-tetrahydropyrimidine and 2-methyl-1,4,5,6-tetrahydropyrimidine, appear in the reaction products at the same temperature.

The introduction of modifying additives such as phosphoric and silicic anhydrides in 2% amounts with respect to tungsten trioxide into the composition of the catalyst leads to a decrease in both the activity (Tables 2-4) and overall yields of the pyrimidine bases. The addition of phosphoric and silicic anhydrides changed the catalytic activity to a lesser extent, and the overall yields of pyrimidine bases on these catalysts at 340-380°C are approximately the same but decrease as the temperature is raised further (to a greater degree for the catalyst with added phosphoric anhydride). The catalyst consisting of tungsten trioxide with 1% boron trioxide and 3% cobalt oxide, on which the transformations of 1,3-diaminopropane takes place at higher temperatures, displays the greatest differences in catalytic activity as compared with tungsten trioxide; the formation of tetrahydropyrimidine was not established in this case.

Institute of Organic Synthesis, Academy of Sciences of the Latvian SSR, Riga 226006. Translated from Khimiya Geterotsiklicheskikh Soedinenii, No. 7, pp. 967-973, July, 1982. Original article submitted December 16, 1981. It should be noted that the largest fraction of tetrahydro derivatives in the sum of the pyrimidine bases (~40% at 380-460°C) is observed for the catalyst modified with phosphorus pentoxide, while the yield of tetrahydro derivatives is lower on unmodified tungsten oxide and on tungsten trioxide with silicon dioxide and approaches 40% only at 500°C.

The formation of 2-ethylhexahydropyrimidine can be represented by the following scheme:



In fact (see Table 1), the formation of dipropylenetriamine, the yield of which decreases as the temperature is raised (to 0% at 420°C), is observed on tungsten trioxide even in the case of a relatively low degree of conversion of 1,3-diaminopropane. On all of the investigated catalysts the selectivity of the formation of 2-ethylhexahydropyrimidine decreases sharply as the temperature is raised; this is due to the formation of other reaction products. In addition to 2-ethylhexahydropyrimidine, methylhexahydropyrimidine and hexahydropyrimidine, the yields of which increase with the temperature and the formation of which includes not only a step involving intermolecular deamination but also a step involving hydrogenolysis at the C-C bond, were also detected in the catalyzate.

$$CH_{3}CH_{2}NH_{2} + \underbrace{-NH_{3}}_{HN} 2 NH_{2}CH_{2}CH_{2}CH_{2}NH_{2} - \underbrace{-NH_{3}}_{HN} + CH_{3}NH_{2}$$

The amount of methyl- and ethylamine corresponds precisely to the amount of the corresponding hexahydro- and tetrahydropyrimidines formed at 340-420°C on tungsten trioxide (Table 1) and even up to 460°C on the modified catalyst. Partially unsaturated pyrimidine bases appear in the catalysate at the same temperature. Since we were unable to observe hydrogen evolution in this case, it may be assumed that intermolecular redistribution of hydrogen, as was also noted for the catalytic transformation of ethylenediamine [1, 2], occurs on the catalyst.

In comparing the yields of tetrahydropyrimidine bases at 500°C it is apparent that the formation of 1,4.5,6-tetrahydropyrimidine itself proceeds more selectively than the formation of the 2-methyl or 2-ethyl derivative. This can be explained by the fact that the alkyl substituent in the 2 position creates steric hindrance in the dehydrogenation of the hexahydro derivative to the tetrahydropyrimidine base.

The intensified dehydrogenation of the hexahydropyrimidine bases is responsible for the hydrogenolysis of the molecules of the starting diamine, the products of which are alkyla-mines:

 $2 \text{ NH}_{2}\text{CH}_{2}\text{CH}_{2}\text{CH}_{2}\text{NH}_{2} \xrightarrow{+2 \text{ H}_{2}} \text{HN}(\text{CH}_{2}\text{CH}_{2}\text{CH}_{3})_{2} + 2 \text{ NH}_{3}$ NH_{2}\text{CH}_{2}\text{CH}_{2}\text{CH}_{2}\text{NH}_{2} \xrightarrow{+ \text{H}_{2}} \text{CH}_{3}\text{CH}_{2}\text{CH}_{2}\text{NH}_{2} + \text{ NH}_{3}

In addition, as in the formation of 2-methylhexahydropyrimidine and hexahydropyrimidine, hydrogenolytic cleavage of the C-C bond also occurs at higher temperatures also in the molecule of the starting diamine:

$$\mathrm{NH}_{2}\mathrm{CH}_{2}\mathrm{CH}_{2}\mathrm{CH}_{2}\mathrm{NH}_{2} \xrightarrow{\mathrm{+H}_{2}} \mathrm{CH}_{3}\mathrm{NH}_{2} + \mathrm{CH}_{3}\mathrm{CH}_{2}\mathrm{NH}_{2}$$

The presence of allylamine in the catalysate constitutes evidence that the intramolecular deamination of 1,3-diaminopropane can also be realized without the participation of hydrogen; however, this reaction takes place to a significant extent only at 460-500°C and is most pronounced on unmodified tungsten trioxide.

$$NH_2CH_2CH_2CH_3NH_2 \longrightarrow CH_2=CHCH_3NH_2 + NH_3$$

| Compound | Composition of the catalysate in percent at | | | | | | | | |
|--|---|-----------------------|---|---|---|--|--|--|--|
| | 300°C | 340°C | 380°C | 420°C | 460°C | 500°C | | | |
| 2-Methylhexahydropyrimidine 2-Ethylhexahydropyrimidine Hexahydropyrimidine 1,4,5,6-Tetrahydropyrimidine 2-Methyl-1,4,5,6-tetrahydropyrimidine 2-Ethyl-1,4,5,6-tetrahydropyrimidine Ammonia Methylamine Ethylamine Ethylamine Propylamine Dipropylamine Dipropylenetriamine 1,3-Diaminopropane | 2,0 1,2 1,3 | 2,4 1,5 1,3 | $\begin{array}{c} 4,1\\ 1,7\\ 1,5\\ 2,1\\\\ 1,4\\ 1,3\\ 1,9\\ 1,0\\ -\\ 0,4\\ 1,0\\ 83,6\\ \end{array}$ | 8,1 2,5 3,6 3,2 1,6 3,3 3,6 3,6 0,5 | $ \begin{array}{c} 11,6\\3,2\\4,7\\9,9\\1,2\\\\5,0\\3,4\\5,1\\3,0\\4,8\\1,5\\\\46,6\end{array}\right) $ | $\begin{array}{c} 12,1\\ 3,2\\ 10,1\\ 13,0\\ 1,3\\ 1,0\\ 6,0\\ 8,6\\ 18,4\\ 10,8\\ 2,0\\ 3,0\\ \hline \\ 10,5\\ \end{array}$ | | | |

TABLE 1. Dependence of the Composition of the Catalysate on the Temperature in the Transformation of 1,3-Diaminopropane over 1% $\rm WO_3$

TABLE 2. Dependence of the Percentage of Products of Transformation of 1,3-Diaminopropane in the Catalysate on the Temperature over 0.98% WO₃ + 0.02% P_2O_5

| Compound | Composition of the catalysate in percent at | | | | | | | | |
|---|---|---|--|--|---|---|--|--|--|
| - | 380 ° C | 420°C | 440 [¢] C | 460 ° C | 480°C | 500°C | | | |
| 2-Methylhexahydropyrimidine 2-Ethylhexahydropyrimidine Hexahydropyrimidine 1,4,5,6-Tetrahydropyrimidine 2-Methyl-1,4,5,6-tetrahydropyrimidine Ammonia Methylamine Ethylamine Propylamine Dipropylamine 1,3-Diaminopropane | | $ \begin{array}{c} 3\\2\\1\\4\\1\\12\\-\\-\\1\\-\\75\end{array} $ | $\begin{array}{c c} 4\\ 2\\ 2\\ 4\\ 1\\ 13\\ \hline \\ 1\\ 1\\ \hline \\ 70 \end{array}$ | $ \begin{array}{r} 4 \\ 2 \\ 3 \\ 6 \\ 1 \\ 12 \\ 1 \\ 1 \\ 2 \\ \overline{68} \end{array} $ | $ \begin{array}{c} 5 \\ 2 \\ 4 \\ 3 \\ 1 \\ 5 \\ 3 \\ 4 \\ 3 \\ -60 \end{array} $ | $ \begin{array}{c} 6 \\ 2 \\ 6 \\ 3 \\ 1 \\ 21 \\ 7 \\ 8 \\ 7 \\ 2 \\ 37 \\ \end{array} $ | | | |

TABLE 3. Dependence of the Percentage of Products of Transformation of 1,3-Diaminopropane in the Catalysate on the Temperature over 0.98% WO_3 + 0.02% SiO_2

| Compound | Composition of the catalysate in percent at | | | | | | | | |
|---|---|---|--|---|--|--|--|--|--|
| <u>-</u> | 340°C | 380°C | 420°C | 460°C | 500°C | | | | |
| 2-Methylhexahydropyrimidine 2-Ethylhexahydropyrimidine Hexahydropyrimidine 1,4,5,6-Tetrahydropyrimidine 2-Methyl-1,4,5,6-tetrahydropyrimidine Ammonia Methylamine Ethylamine Propylamine Allylamine Dipropylamine 1,2-Diaminopropane | 3 | $ \begin{array}{c} 5 \\ -3 \\ -4 \\ -1 \\ -87 \end{array} $ | $ \begin{array}{c} 6 \\ - 1 \\ - 4 \\ - 6 \\ 2 \\ 2 \\ $ | $9 \\ 3 \\ 4 \\ 5 \\ 1 \\ 3 \\ 4 \\ 2 \\ 5 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7 \\ 7$ | $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$ | | | | |

The formation of allylamine was not observed on the catalyst modified with phosphorus pentoxide or boron trioxide and cobalt oxide.

Thus the data presented above constitute evidence that 1,3-diaminopropane undergoes cyclization primarily via a bimolecular scheme and in the process undergoes a significnat amount of hydrogenolysis, which is responsible for the formation of 2-methylhexahydropyrimidine and hexahydropyrimidine in addition to 2-ethylhexahydropyrimidine. Dehydrogenation occurs when the temperature is raised to 380-420°C and involves only one strictly determined

| TABLE 4 | . Depe | endenc | e of | the | Pe | rcent | age | of | Produc | ets c | of Tra | ansform | na- |
|---------|---------|--------|------|-------------------------------|----|-------|------|-----|--------|-------|--------|---------|-----|
| tion of | 1,3-Di | lamino | prop | ane i | in | the C | atal | ysa | te on | the | Temp | erature | е |
| over 0. | 96% WO: | , + 0. | 01% | B ₂ O ₃ | + | 0.03% | CoO | 1 | | | | | |

| Compound | Composition of the catalysate in percent at | | | | | | | | |
|--|---|-------|-------|-------|-------|--|--|--|--|
| Compound | 380°C | 420°C | 440°C | 460°C | 480°C | 500°C | | | |
| 2-Methylhexahydropyrimidine 2-Ethylhexahydropyrimidine Hexahydropyrimidine 1,4,5,6-Tetrahydropyrimidine Ammonia Methylamine Ethylamine Propylamine Dipropylamine | | 3 | | | | $ \begin{array}{c c} 3 \\ 1 \\ 2 \\ 0,4 \\ 7 \\ 2 \\ 2 \\ 0,2 \\ \end{array} $ | | | |
| 1.3-Diaminopropane | 98 | 96 | 95 | 92 | 86 | 80 | | | |





bond in the hexahydropyrimidine bases. Cyclic products of intramolecular deamination were not observed on any of the investigated catalysts under the indicated conditions.

Transformation of 3-Amino-1-propanol

On tungsten trioxide 3-amino-1-propanol primarily forms unsaturated products, viz., allylamine and methylpyrazine, small amounts of which are detected in the catalysate obtained at 340°C. The formation of allylamine can be conceived of as being the result of intramolecular dehydration of the starting amino alcohol, as was assumed for the formation of allylamine from 1,3-diaminopropane.

Propane, methylamine, and ethylamine were also detected in the catalysate at 380° C along with the compounds already cited; this constitutes evidence for hydrogenolysis and ammonolysis

 $HOCH_{2}CH_{2}CH_{2}NH_{2} \xrightarrow{+2H_{2}} CH_{3}CH_{2}CH_{3} + NH_{3}$ $HOCH_{2}CH_{2}CH_{2}NH_{2} \xrightarrow{+NH_{3}} CH_{3}NH_{2} + CH_{3}CH_{2}NH_{2}$

The hydrogenolysis of 3-amino-l-propanol may also lead to the formation of ethanol and methylamine, which are actually observed in the catalysate obtained at 400°C and higher temperatures:

$$\text{HOCH}_2\text{CH}_2\text{CH}_2\text{NH}_2 \xrightarrow{+\text{H}_2} \text{HOCH}_2\text{CH}_3 + \text{CH}_3\text{NH}_2$$

The reaction of the resulting amines among themselves and with the starting amino alcohol is responsible for the formation of both saturated and unsaturated diazines and morpholine:

$$HOCH_{2}CH_{2}CH_{2}NH_{2} + CH_{3}CH_{2}NH_{2} \xrightarrow{-4H_{2}-H_{2}O} N_{N}CH_{3}$$

$$CH_{3}CH_{2}OH + 2CH_{3}CH_{2}NH_{2} \xrightarrow{-H_{2}O, -2H_{2}} N_{N}CH_{3}CH_{2}CH_{3}$$

$$CH_{3}CH_{2}OH + CH_{3}CH_{2}NH_{2} \xrightarrow{-2H_{2}} N_{N}CH_{3$$

Certain amounts of (~1%) of 2-methylaziridine, the formation of which, as in the case of allylamine (see above), is a consequence of intramolecular elimination of a molecule of water, are detected in the catalysate commencing at 400°C:

$$HOCH_2CH_2CH_2NH_2 \xrightarrow{-H_2O} CH_3 \xrightarrow{} H$$

The condensation of two molecules of 2-methylaziridine with opening of the three-membered ring can be regarded as one of the steps in the formation of 2,5-dimethylpyrrole:

$$2 CH_3 - \bigvee_{H} - NH_3, -2 H_2 - CH_3 - \bigvee_{H} CH_4$$

We were unable to detect other products of the transformation of 3-amino-1-propanol; this may be due to both processes involving the profound decomposition of the starting compound as a consequence of its strong adsorption on the surface and rapid decomposition of azetidine, the formation of which is extremely likely, although it was not detected in the catalysate. A study of the transformations of azetidine under similar conditions showed that the reactivity of azetidine differs little from that of 3-amino-1-propanol (Fig. 1); the reaction products were the same as in the transformation of 3-aminopropanol. It may be assumed that the following equilibrium is established under heterogeneous reaction conditions:

$$HOCH_2CH_2CH_2NH_2 \xrightarrow{-H_2O} NH_1$$

Thus the presence of a hydroxy group in the molecule of the starting amino compound is responsible for the occurrence of dehydrogenation and hydrogenolysis to a greater degree than in the transformation of the diamine. Thus profoundly dehydrogenated heterocycles, viz., aromatic diazines, were detected along with completely hydrogenated heterocycles in the reaction products in the transformation of 3-amino-1-propanol, whereas hexahydropyrimidines were accompanied only by tetrahydropyrimidines in the reaction products in the transformation of the diamine.

The results of the catalytic transformation of 3-amino-1-propanol are in agreement with the results of a study of the hydrogenolytic cleavage of diamines and amino alcohols on Pt catalysts under conditions of "chromatography of the carbon skeleton," in which it was shown that the presence of a hydroxy group in the aminoalkanol molecule is responsible for cleavage of the C--C bond at a relatively low temperature [6]. It is also possible that covering of the surface of the oxide catalyst with reaction water potentiates the hydrogenolytic and dehydrogenating properties of the catalyst.

EXPERIMENTAL

The catalytic transformations of 1,3-diaminopropane and 3-amino-1-propanol were carried out under chromatographic conditions with an AGK-6 analytical reaction gas chromatograph by the method in [4]; the amount of catalyst in all cases was 0.4 g.

The structures of the 1,3-diazines isolated from the catalysates by preparative gasliquid chromatography (GLC) (the column was 4 m by 0.4 cm and was filled with 25% Apiezon M on Cellite 545 impregnated with 0.5% KOH, the column temperature was 100-220°C, the temperature-rise rate was 6 deg/min, the carrier gas was helium, and the flow rate was 90 ml/min) were confirmed by the IR and PMR spectra (in $CDCl_3$), by "chromatography of the carbon skeleton" [6], and the mass spectra.

<u>2-Methylhexahydropyrimidine</u>. PMR spectrum: 1.14 (3H, d, J = 5,6 Hz, CH₃), 1.38 (2H, s, NH), 1.4 (2H, m, 5-H), 2.7-3.1 (4H, m, 4- and 6-H), and 3.60 ppm (1H, q, J = 5.6 Hz, 2-H).

<u>2-Methyl-1,4,5,6-tetrahydropyrimidine</u>. PMR spectrum: 1.79 (2H, q, J = 5.8 Hz, 5-H), 1.92 (3H, s, CH_3), 3.34 (4H, t, J = 5.8 Hz, 6- and 4-H), and 4.27 ppm (1H, s, NH).

<u>2-Ethylhexahydropyrimidine</u>. PMR spectrum: 0.92 (3H, t, J = 6 Hz, CH₃), 1.1-1.5 (6H, m, 5-H and α -CH₂, NH), 2.7-3.1 (4H, m, 4- and 6-H), and 3.38 ppm (1H, t, J = 5.9 Hz, 2-H).

Hexahydropyrimidine. Mass spectrum, m/z (relative intensity, %): 85 (13), 84 (34), 71 (67), 70 (82), 69 (14), 68 (17), 67 (15), 58 (17), 57 (36), 56 (100), 55 (9), 54 (9), 44 (21), 43 (22), 42 (59), 41 (60); hydrogenolysis products: CH₄, C₃H₈.

<u>1,4,5,6-Tetrahydropyrimidine</u>. Mass spectrum, m/z (relative intensity, %): 83 (3), 82 (17), 69 (63), 68 (70), 54 (100); hydrogenolysis products: CH₄, C₃H₈. IR spectrum (film): 1640 cm⁻¹ (very strong, C=N).

Qualitative analysis of the remaining reaction products was carried out by gas chromatography on the basis of the Kovats indexes determined on two stationary phases with different polarities [4].

The quantitative compositions of the catalysates were determined by gas-chromatographic methods: by the internal-standard (benzene) method [4] for the catalysates of 1,3-diaminopropane and azetidine and with the aid of an external standard (1-heptanol) [7] for the cataly-sates of 3-amino-l-propanol.

LITERATURE CITED

- 1. A. A. Anderson, S. P. Yurel', and M. V. Shimanskaya, Izv. Akad. Nauk Latv. SSR, Ser. Khim., No. 6, 683 (1968).
- S. P. Yurel', and A. A. Anderson, and M. V. Shimanskaya, Izv. Akad. Nauk Latv. SSR, Ser. Khim., No. 6, 729 (1974).
- 3. A. A. Anderson, D. K. Kurgan, S. A. Giller, and M. V. Shimanskaya, in: Piperazine [in Russian], Zinatne, Riga (1965), p. 25.
- Ya. F. Oshis, A. A. Anderson, and M. V. Shimanskaya, Izv. Akad. Nauk Latv. SSR, Ser. Khim., No. 4, 408 (1981).
- 5. J. Okada, S. Morita and M. Tsuchiya, Yakugaku Zasshi, No. 6, 801 (1976).
- Ya. F. Oshis, A. A. Anderson, and M. V. Shimanskaya, Izv. Akad. Nauk Latv. SSR, Ser. Khim., No. 4, 445 (1978).
- Ya. F. Oshis, A. A. Anderson, and M. V. Shimanskaya, Izv. Akad. Nauk Latv. SSR, Ser. Khim., No. 3, 333 (1979).