POSITION OF THE EQUILIBRIUM DURING THE MIGRATION OF DOUBLE BONDS IN THE PYRAZOLINE RING

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Data characterizing the position of the equilibrium between Δ^2- and Δ^1-pyrazolines with alkyl substituents in different positions, which is established under the influence of potassium tert-butoxide in tert-butyl alcohol at 90°C, were obtained. 3-Alkyl-Δ^2-pyrazolines are thermodynamically more stable than their isomers with different positions of the double bond, so that the fraction of the latter in equilibrium mixtures does not exceed 1-2%, and they are practically completely isomerized to the 3-Alkyl-Δ^2-substituted derivatives. If the position of the side chains excludes the possibility of the formation of 3-alkyl-Δ^2-pyrazolines by migration of the double bond (4-alkyl- and 5,5-dialkyl-substituted compounds), the fraction of Δ^1-pyrazolines in the equilibrium rises appreciably and reaches 12% for 3,3-diethyl-Δ^1-pyrazoline.

In connection with the observations of interconversions of nitrogen-unsubstituted Δ^2-pyrazolines with side chains in different positions [1], their isomerization to Δ^1-pyrazolines [2], and the formation of mixtures of isomeric pyrazolines during the reaction of hydrazine with unsaturated carbonyl compounds [3], data on the comparative thermodynamic stability of pyrazolines with double bonds located in different positions in the ring are of interest. Although the conversion of Δ^2-pyrazolines to Δ^1-isomers was long ago assumed as an intermediate step in their decomposition to cyclopropane hydrocarbons, and even the equilibrium interconversion of Δ^2- and Δ^1-5,5-dimethylpyrazolines had been accomplished [2], there are no data at all regarding the position of the $\Delta^2 \rightleftharpoons \Delta^1$ equilibrium. The conversion of 5-substituted Δ^2-pyrazolines to 3-substituted derivatives [1, 4-6] are also known, but the reversibility and equilibrium character of these transformations are as yet unproved.

In the closest acyclic analogs of the Δ^2- and Δ^1-pyrazolines – aliphatic hydrazones and azo compounds – the position of the equilibrium set up during the catalytic action of strong bases (potassium tert-butoxide) was determined by gas-chromatographic analysis [7]. Under absolutely similar conditions, we subjected a number of Δ^2- and Δ^1-pyrazolines with different alkyl substituents to isomerization at 90°, with gas-chromatographic analysis every 5 h. Most of the pyrazolines (except for 3-methyl-, 3,5-dimethyl-, and 3,5,5-trimethyl-Δ^2-pyrazolines) were isomerized, but the gradual accumulation of some different reaction products, probably formed as a consequence of slow cleavage of the pyrazolines by the alkaline catalyst, was observed on prolonged heating. The amount of these side products did not exceed several percent in experiments with 0.05 M solutions of potassium tert-butoxide, but in those cases where the approach to equilibrium was realized from both sides (5,5-dimethyl-Δ^2- and Δ^1-pyrazolines and 5-methyl-Δ^2- and 3-methyl-Δ^1-pyrazolines), similar compositions of the reaction mixtures were obtained, * such that the data presented can be considered to be a sufficiently convincing characteristic of the equilibrium position of the isomerization, although they were not obtained under strictly equilibrium conditions.

The results presented in Table 1 show that the highest concentration of the Δ^1-isomers – from 6 to 12% – is obtained in the isomerization of 5,5-dialkylpyrazolines. Equilibrium is practically established in 5 h at 90° for pyrazolines with alkyl substituents in this position. When there are no substituents in the 5 and 3 positions (4-ethyl-Δ^2-pyrazoline), the fraction of the Δ^1-isomer falls to 3-4%, apparently due to an increase (double) in the rate of the reverse isomerization ($\Delta^1 \rightarrow \Delta^2$), since the attack of the base-catalyst

*The deviations in the concentrations of the components in counter-experiments were 0.5-1.5%.

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TABLE 1. Isomerization of Pyrazolines by Heating with Catalytic Amounts of Potassium tert-Butoxide in tert-Butyl Alcohol at 90°C

Starting pyrazoline	Components of the mixture formed	Percent fraction of total amount of pyrazolines after heating for			
		5 h	10 h	15 h	20 h
5-Methyl-Δ^2	3-Methyl-Δ^1-pyrazoline	—	0,4	0,4	0,7
	3-Methyl-Δ^2-pyrazoline	—	97,2	97,1	96,5
	5-Methyl-Δ^2-pyrazoline	—	2,4	2,5	2,8
3-Methyl-Δ^2	3-Methyl-Δ^1-pyrazoline	1,8	1,4	1,8	2,1
	3-Methyl-Δ^2-pyrazoline	96,9	97,5	97,1	96,7
	5-Methyl-Δ^2-pyrazoline	1,3	1,1	1,1	1,2
4-Ethyl-Δ^2	3-Ethyl-Δ^1-pyrazoline	—	4,1	3,7	2,2
	4-Ethyl-Δ^2-pyrazoline	—	93,5	92,6	95,9
	Unidentified	—	2,4	3,7	1,9
3-Ethyl-Δ^1	3-Ethyl-Δ^1-pyrazoline	4,4	3,1	3,4	3,5
	4-Ethyl-Δ^2-pyrazoline	94,1	95,2	95,0	95,3
	Unidentified	1,5	1,7	1,6	1,2
3,5-Dimethyl-Δ^2	3,5-Dimethyl-Δ^1-pyrazoline *	1,0	1,8	1,1	1,0
	3,5-Dimethyl-Δ^2-pyrazoline	99,0	98,2	98,9	99,0
3,4-Dimethyl-Δ^2	3,4-Dimethyl-Δ^1-pyrazoline	0,6	2,0	1,9	2,9
	3,4-Dimethyl-Δ^2-pyrazoline	97,9	96,0	96,1	93,6
	Unidentified	1,5	2,0	2,0	3,5
4,5-Dimethyl-Δ^2*	3,4-Dimethyl-Δ^1-pyrazoline	—	2,2	—	2,1
	3,4-Dimethyl-Δ^2-pyrazoline	—	96,9	—	96,3
	4,5-Dimethyl-Δ^2-pyrazoline	—	0,6	—	0,8
	Unidentified	—	0,3	—	0,8
5,5-Dimethyl-Δ^2	3,3-Dimethyl-Δ^1-pyrazoline	6,8	6,5	6,2	6,3
	5,5-Dimethyl-Δ^2-pyrazoline	93,2	93,5	93,8	93,7
3,3-Dimethyl-Δ^1	3,3-Dimethyl-Δ^1-pyrazoline	—	—	6,8	6,6
	5,5-Dimethyl-Δ^2-pyrazoline	—	—	93,2	93,4
5,5-Diethyl-Δ^2	3,3-Diethyl-Δ^1-pyrazoline	11,7	12,5	11,9	11,8
	5,5-Diethyl-Δ^2-pyrazoline	88,3	87,5	88,1	88,2
3,3-Diethyl-Δ^1	3,3-Diethyl-Δ^1-pyrazoline	12,9	12,1	12,2	11,9
	5,5-Diethyl-Δ^2-pyrazoline	87,1	87,9	87,8	88,1

*A mixture of stereoisomers.

necessary for this conversion can be realized at both of the CH_2 groupings adjacent to the $-N=N-$ fragment and becomes twice as probable as attack in the 5,5-disubstituted compounds. The concentrations of the Δ^1-isomers prove to be less when one or both carbon atoms adjacent to the nitrogen atom have alkyl substituents. 3-Alkyl-Δ^2-pyrazolines, which are apparently much more thermodynamically stable than the 5-substituted Δ^2-pyrazolines and Δ^1-isomers, participate in the equilibrium for such skeletal structures. After 10 h of heating with tert-butoxide in alcohol, 5-methyl-Δ^2-pyrazoline is converted to 97% of 3-methyl-Δ^2-pyrazoline, and less than 1% of the Δ^1-isomer is formed. The degree of isomerization of 4,5-dimethyl-Δ^2-pyrazoline proves to be just as profound: an equilibrium mixture contains less than 1% of it along with 2% of the Δ^1-isomer and 96% of 3,4-dimethyl-Δ^2-pyrazoline. 5-Alkyl-Δ^2-pyrazolines are thus by no means less inclined to conversion to 3-substituted compounds than 5-aryl-Δ^2-pyrazolines, and the formation of a conjugated system should not be considered to be the major factor in determining the direction of isomerization.

The migration of the double bond in 5-alkyl-substituted Δ^2-pyrazolines through the nitrogen atom toward the substituent is completely analogous to the conversion of propionaldehyde isopropylhydrazone to acetone propylhydrazone [7], which is observed under similar conditions. The equilibrium between isomers with double bonds in different positions that prevails in the simplest pyrazolines is generally very similar to the equilibrium of aliphatic hydrazones and azo compounds [7]. The inclusion of azo or hydrazone fragments in a five-membered ring has comparatively little effect on the relative stability of the corresponding forms: in all cases, the $-NH-N=\underset{\displaystyle C}{\overset{|}{C}}-C,$ structure is the most stable form, and the $C-N=N-C$ and $-NH-N=CH-C$ structures are less favorable forms.

EXPERIMENTAL

Δ^2-Pyrazolines. These compounds were obtained from unsaturated carbonyl compounds and hydrazine hydrate. Twice-distilled preparations, the characteristics of which were presented in a previous paper [3], were subjected to isomerization.

Δ^1-Pyrazolines. Preparations obtained from the Δ^2-isomers [8] were used.

Isomerization. The isomerization was carried out in solutions of potassium tert-butoxide in tert-butyl alcohol prepared by dissolving potassium in anhydrous alcohol with mp 24.5°. The potassium tert-butoxide concentration was monitored by titration with 0.02 N hydrochloric acid. (A mixture of methylene blue and methyl red was used as the indicator.) Equal volumes of 10% (by weight) solutions of the pyrazolines in tert-butyl alcohol and a 0.05 M solution of potassium tert-butoxide were mixed and poured into 1-ml ampuls, which were sealed and held in a thermostat at 90± 0.1°. The samples for analysis were removed at 5 h intervals. (Each sample was doubled.)

Gas-Chromatographic Analysis. The conditions described in [3] were used. Since the amounts of some isomers did not exceed several percent, the sensitivity was increased by a factor of three to ten with respect to the sensitivity in the detection of the base peak in order to obtain more accurate results. The quantitative analysis was carried out by multiplying the heights by the retention times. The deviations during repeated chromatography did not exceed ± 0.4 absolute %, while the deviations in parallel samples did not exceed ± 0.7 absolute %.

In those cases where we did not have access to pure preparations of the isomers (3-methyl-, 3,4-dimethyl-, and 3,5-dimethyl-Δ^1-pyrazolines), the peaks were assigned from the retention times [3].

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