INDOLE DERIVATIVES

L*. CATALYTIC TRANSFORMATIONS OF N-(β-HYDROXYETHYL) ANILINE AND N,N'-DIPHENYLETHYLENEDIAMINE

N. N. Suvorov, N. N. Mitina,
and L. I. Zamyshlyaeva

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The catalytic cyclization of N-(β-hydroxyethyl)aniline and N,N'-diphenylethylene diamine on oxide catalysts based on alumina and silica gel and on activated carbon has been studied in the temperature range from 300-500°C. The following cyclization products have been isolated and identified: N-phenylpyrrole, indole, N-methyl- and 3-ethylindoles, N,N'-diphenylpiperazine, and N,N'-diphenylimidazoline.

A number of attempts at the catalytic synthesis of indole from ortho- and N-substituted anilines has been described in the literature, for example: the cyclization of N-(β-hydroxyethyl)aniline [2], o-ethylaniline [3, 4] and o-ethylnitrobenzene [5]; the reaction of aniline with acetylene has also been studied [6, 7]. In the majority of the processes studied, indole is only one of the components of a complex mixture of products. It is accompanied, frequently in predominating amount, by pyrrole, piperazine, and, particularly, quinoline compounds. In addition, considerable resinification takes place which shows the intermediate formation of unsaturated substances, especially vinylaniline [2, 7]. In the final account, the synthetic indole obtained by the method described in the literature requires such laborious purification that it cannot compete with coal-tar indole. Consequently, the question of the industrial synthesis of indole still remains an urgent one. We considered it desirable to use for the closure of the ring reactions taking place under milder conditions than, for example, the dehydrocyclization reaction, although, according to the literature, the latter also gives satisfactory yields of indole [3, 4].

We have studied the cyclization of N-(β-hydroxyethyl)aniline and of N,N'-diphenylethylenediamine on the oxides Al_2O_3 and SiO_2 (pure and with addition of oxides of chromium, cadmium, nickel, titanium, thorium, and zirconium) and on activated carbon.

As a rule, none of the starting material was recovered. The catalysate contained aniline and cyclic products, the compositions and limiting temperatures of which are shown in Table 1.

All the products were isolated and identified on the basis of elementary analysis, melting point, and UV, IR and PMR spectra (Table 2).

EXPERIMENTAL

N-(β-Hydroxyethyl)aniline was obtained by known method [8] and the following constants: bp 140-141°C (1 mm); n_D^{20} 1.5791; mp of the picrate 124-125°C (from ethanol); mp of the N-benzoyl derivative 93-94°C, which corresponds to literature data [9].

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*For Communication XLIX, see [1].

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TABLE 1. Composition of the Cyclization Products

Starting material	Catalyst	Cyclization temperature, °C	Cyclization products		
			compound	name	yield,* wt.%
N-(β-Hydroxyethyl)aniline	Al_2O_3	300—350	I	N,N'-Diphenylpiperazine	10,0
The same	„	350—400	II	N-Phenylpyrrole	14,0
			III	Indole	6,8
			IV	3-Ethylindole	11,1
„ „	SiO_2	350—450	II	N-Phenylpyrrole	следы
			III	Indole	2,0
N,N'-Diphenylethylenediamine	Al_2O_3	400—450	II	N-Phenylpyrrole	10,0
			III	Indole	7,6
The same	$Al_2O_3+ThO_2$	420	I	N,N'-Diphenylpiperazine	4,0
„ „	SiO_2	400—470	II	N-Phenylpyrrole	8,5
			III	Indole	14,6
			V	1-Methylindole	5,0
„ „	SiO_2+ThO_2	400—450	II	N-Phenylpyrrole	7,0
			III	Indole	20,0
			V	1-Methylindole	4,5
			IV	3-Ethylindole	5.0
„ „	AG-2 activated carbon	410—430	VI	N,N'-Diphenylimidazolidine	12,5
„ „	ThO_2 on carbon	410	I	N,N'-Diphenylpiperazine	16,0

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* Calculated on the substance passed.

N,N'-Diphenylethylenediamine was obtained by our modification of Bennett's method [10], mp 63°C; mp of the diacetyl derivative 158°C, which corresponds to literature data [11]. The elementary analysis and IR spectra of the product itself and of its diacetyl derivative correspond to the composition and spectra of the required compound.

Performance of the Experiments. The experiments were performed in a flow-through catalytic apparatus with an inclined furnace. The diameter of the tube was 35 mm. The bulk volume of the catalyst was 150 ml. The temperature was measured by means of a thermocouple located within the layer of catalyst. The starting material in the form of a benzene solution (ratio of the weight of the substance to that of benzene 1:3) was added uniformly to the catalyst tube by means of an automatic doser. The space velocity was varied from $6.5 \cdot 10^{-4}$ to $13.0 \cdot 10^{-4}$ mole/ml · h. Nitrogen or carbon dioxide (at a rate of 8 liters/h) was used as the carrier gas. The catalysate was collected in a water receiver and the gaseous products passed into a gasometer (at atmospheric pressure).

Isolation and Identification of the Reaction Products. The catalysate obtained was dissolved in a two- to threefold amount of benzene and was washed free from aniline with dilute sulfuric acid. The benzene solution containing the indole and pyrrole compounds was dried with magnesium sulfate; the residue after the benzene had been driven off was vacuum-distilled to free it from resinous impurities. The fraction collected at 55-100°C (1 mm) was separated in a column of alumina for chromatography of activity grade II (the results of the separation are given in Table 3). When their amount in the catalysate was more than 15%, the N,N'-diphenylethylenediamine and N,N'-diphenylpiperazine were isolated by the recrystallization from 50% ethanol of the mixture of reaction products washed free from amines. When they were present in smaller amounts, the two substances were extracted from the still residue after vacuum distillation of the cyclization products by crystallization from ethanol or acetone. N,N'-Diphenylimidazolidine was extracted from the catalysate with methanol and purified by recrystallization from methanol.

TABLE 2. Identification of the Cyclization Products

Compound*	Mp, °C	Mp of the picrate, °C	Mp of the trinitrobenzene derivative, °C	UV spectrum		IR spectrum		PMR spectrum	
				λ, nm	log ε	ν, cm^{-1}	assignment of the absorption bands	ppm on the τ scale	assignment of the chemical shifts
II	61	—	—	255	4,15	690 730	Five adjacent C—H's of a phenyl ring	2,65—2,75	Proton of C_6H_5
						765	The same	3,00—3,20	Protons at C-2,5
						1470 1520 1610	Aromatic systems of bonds	3,85	Protons at C-3,4
III	52—53	181	187	270 280 288	4,45 3,79 3,64	730 755 770	Four C—H's of a phenyl ring	—	—
						1460	Aromatic systems of bonds		
						3420	N—H		
IV	21—22	115	149—150	274 282 290	4,46 3,82 3,74	760 785	Four C—H's of a phenyl ring	—	—
						1466 1560 1600	Aromatic systems of bonds		
						2895 2950 2995 3430	Methyl and methylene groups N—H		
V	—	148	—	272 280 294	4,43 3,80 3,72	750 770	Four C—H's of a phenyl ring	2,60—2,70	Protons of C_6H_4
						1470 1520 1600	Aromatic systems of bonds	3,26—3,30 3,75—3,78	Proton at C-2 Proton at C-3
						2960 3070	C—H of a methyl group	6,42	Protons of a methyl group
VI	123	—	—	255 290	4,58 3,68	700	C—H of phenyl groups	2,80—2,95	Protons of two phenyl groups
						750	The same		
						755 1460 1510 1610	Aromatic systems of bonds	3,50—3,55 5,44	Protons of a CH_2 group
						2850	C—H of methylene groups	6,45	Protons of 2,2'-CH_2 groups
I	163	173	171	255 292	4,40 3,60	700 770	C—H of phenyl rings	3,32	Protons of a piperazine ring
						1500 1580 1600	Aromatic systems of bonds	6,80	Protons of two phenyl groups
						2852	C—H of methylene groups	7,35	

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*For the names of the compounds, see Table 1.

TABLE 3. Chromatographic Separation of the Cyclization Products on Alumina*

Eluent system	Component eluted	Content of the component in the fraction, wt., %	R_f
Petroleum ether (light)	N-phenylpyrrole	39,1	0,363
Petroleum ether–diethyl ether (10:1)	Oily product	4,3	0,655
Petroleum ether–diethyl ether (8:1)	3-Ethylindole	17,3	0,500
Petroleum ether–diethyl ether (from 5:1 to 2:1)	Indole	30,4	0,820

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*2.3 g of the substance was subjected to separation.

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