215. *Liquid-phase Reactions at High Pressures. Part IV. The Autocondensation of* cyclo*Hexanone, and its Condensation with Aniline.*

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The autocondensation of *cyclo*hexanone under pressure in the absence of a catalyst has been studied further, and the yield of 2-Δ^1-*cyclo*hexenyl*cyclo*hexanone found to be dependent upon the temperature and pressure. Silica reaction tubes gave the same results as glass ones.

With aniline, the ketone gave both anil and autocondensation product. Calculation of the equilibrium concentrations showed both reactions to be favoured by pressure but to have opposite temperature coefficients. At 5000 atm. the autocondensation product underwent a measurable amount of condensation to its anil above 60°.

IN Part I (J., 1937, 876) the autocondensation of *cyclo*hexanone in the absence of a catalyst was recorded. At 4500 atm. pressure and 60° the ketone, in the presence of 1 mol. of diluent, gave some 2% of 2-Δ^1-*cyclo*hexenyl*cyclo*hexanone. This condensation has been investigated further, and the maximum yields of unsaturated ketone obtained at 60° and 100° at pressures up to 5000 atm. are given in Table I.

TABLE I.

Autocondensation of cyclo*hexanone* (*no condensing agent*) :

$$2C_5H_{10}:CO \rightleftharpoons C_6H_9\cdot C_5H_9:CO + H_2O$$

Temp.	20°	20°	60°	60°	60°	100°	100°	100°	100°
Pressure (atm.)	1	5000	1	3500	5000	1	2000	3500	5000
Molar concn. of unsat. ketone	* Nil	Nil	Nil	0·021	0·033	Nil	0·084	0·212	0·361

* No measurable yield.

Comparative experiments with glass and silica reaction tubes at 100° and 5000 atm. pressure showed that autocondensation in the absence of a base is not essentially due to alkalinity of the glass under pressure conditions. Maximum yields of 36·1% and 36·0% condensation were obtained for glass and silica respectively, and the rate of reaction was approximately the same in both cases. The yields were estimated by standardised fractionation of a known weight of reaction mixture as described in the experimental section.

Condensation with Aniline.—Since pressure facilitates the condensation between *cyclo*hexanone and cyanoacetic ester in the presence of piperidine (Part I, *loc. cit.*), we have investigated the autocondensation of the ketone in the presence of aniline, which proved a suitable base for isolation of the product of condensation between ketone and base. Table II shows the yields of anils obtained from equimolar mixtures of aniline with various ketones at atmospheric and at 3500 atm. pressure in the absence of a condensing agent. *cyclo*Hexanone showed the greatest response to pressure, and neither methyl ethyl ketone nor diethyl ketone reacted with the base. Formation of *cyclo*hexanoneanil in the absence of a condensing agent is quite rapid at atmospheric pressure and 20° (see Table II), an observation apparently not made hitherto. Reddelein and Meyn (*Ber.*, 1920, **53**, 345) obtained the anil (b. p. 138—142°/19 mm.) by reaction at 155° with zinc chloride (cf. Hoch, *Compt. rend.*, 1934, **199**, 1428).

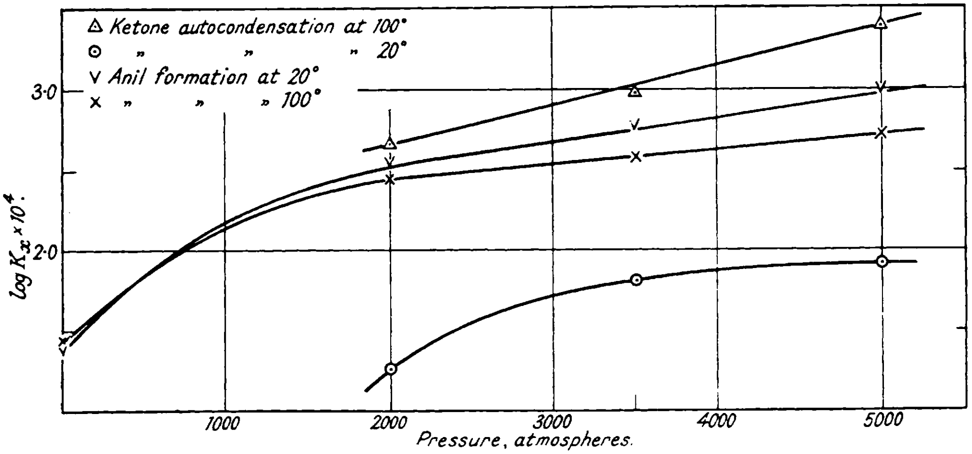

TABLE II.

Anil formation (*no condensing agent*).

Ketone.	Press. (atm.).	Temp.	Time (hrs.).	Concn. of anil.	Ketone.	Press. (atm.).	Temp.	Time (hrs.).	Concn. of anil.
*cyclo*Hexanone	1	20°	2	0·103	a-Methyl*cyclo*-hexanone	1	100°	66	0·112
	,,	100	2	0·121		3500	60	,,	0·138
	3500	60	2	0·161	Acetophenone	1	100	66	0·040
	,,	,,	66	0·180		3500	,,	2	0·106
*cyclo*Pentanone	1	100	66	0·082		,,	,,	66	0·105
	3500	60	,,	0·123					

A series of experiments was made at temperatures up to 130° and at pressures up to 5000 atm. The yields, obtained from both forward and reverse reactions, were determined by a standardised fractionation under reduced pressure, and in Table III are expressed as % (by wt.) of the reaction mixture after correction for free aniline in the weighed fraction. 2-Δ^1-*cyclo*Hexenyl*cyclo*hexanone was isolated and identified by means of its semicarbazone. Experiments at 5000 atm. gave a high-boiling fraction when the reaction temperature was 100° or higher. This on hydrolysis gave aniline and 2-Δ^1-*cyclo*hexenyl*cyclo*hexanone, and was no doubt the anil of that ketone.

TABLE III.

Condensation of cyclo*hexanone and aniline* (*equimolar mixture*) :

$$C_5H_{10}{:}CO + NH_2Ph \rightleftharpoons C_6H_{10}{:}NPh + H_2O;\quad 2C_5H_{10}{:}CO \rightleftharpoons C_6H_9{\cdot}C_5H_9{:}CO + H_2O.$$

Press. (atm.).	Temp.	Total condn. product (% by wt. of reaction mixture). A.*	B.*	Mean.	Press. (atm.).	Temp.	Total condn. product (% by wt. of reaction mixture). A.*	B.*	Mean.
1	20°	12·3	12·4	12·35	2000	20°	14·9	15·1	15·0
	60	12·1	12·2	12·15		60	14·9	14·9	14·9
	100	12·9	12·9	12·9		130	16·5	16·8	16·65
3500	20	17·7	17·7	17·7	5000	20	21·7	21·3	21·5
	60	18·1	18·0	18·05		60	21·2	21·3	21·25
	100	17·5	17·8	17·65		100	20·0 (1·4†)	19·9 (1·4†)	19·95 (1·4)
	130	16·7	16·7	16·7		130	16·5 (5·3†)	16·7 (5·4†)	16·6 (5·35)

* A = from forward reaction (mean of 2 expts.); B = from reverse reaction (mean of 2 expts.).
† Fraction b. p. 200—210°/15 mm.

The proportions of anil and unsaturated ketone were determined in the case of experiments at 20° and 100°, as described in the experimental section, and from the molar concentrations at equilibrium K_x was calculated for each pressure at the two temperatures. The values are given in Table IV, and in the figure log $K_x \times 10^4$ is plotted against pressure. The two reactions have opposite temperature coefficients, but are both promoted by pressure.

TABLE IV.

Condensation of cyclo*hexanone and aniline.*

Temp.	Press. (atm.).	$K_x \times 10^4$, calc. for Anil.	Unsatd. ketone.	Temp.	Press. (atm.).	$K_x \times 10^4$, calc. for Anil.	Unsatd. ketone.
20°	1	25·2	—	100°	1	27·1	—
	2000	337	18·2		2000	282	454
	3500	573	64·3		3500	379	972
	5000	944	82·3		5000	530	2470

EXPERIMENTAL.

*cyclo*Hexanone was redistilled through an 18″ column, and the fraction, b. p. 156°/760 mm., was used, being frequently redistilled throughout the series of experiments. "AnalaR" Aniline was redistilled under reduced pressure, the first and the last quarter being rejected, and the collected fraction was stored out of contact with light. Reaction mixtures were freshly made up by weighing for each experiment, the mixture being inverted in a glass tube over mercury and placed in the pressure vessel—heated to the desired temperature—or in a thermostat in the case of atmospheric pressure experiments. The mercury used was agitated several times with dilute nitric acid, washed, filtered, and dried in a vacuum. The apparatus used has been fully described in Part I (*loc. cit.*).

The mixture after reaction was weighed into a 50 c.c. Claisen flask and carefully fractionated under reduced pressure. The fraction boiling from 146°/15 mm. was collected and weighed. The results given in Table I are calculated from the weight of the fraction corrected for some 6% of *cyclo*hexanone present. The same apparatus and procedure were always used, and duplicate experiments showed the method to be satisfactory.

The crude fraction was converted into semicarbazone, which was recrystallised by the method of Kon and Nutland (J., 1926, 3101). It had m. p. 192° either alone or admixed with an authentic specimen of 2-Δ^1-*cyclo*hexenyl*cyclo*hexanonesemicarbazone (m. p. 192°). After redistillation, the ketone had b. p. 106—107°/0·1 mm., $n_D^{25°}$ 1·4988, *M* (cryoscopic in benzene) 176·0 (Calc. : 178). Kon and Nutland found b. p. 145°/17 mm. and $n_D^{15·1°}$ 1·50692 for the pure ketone regenerated from its semicarbazone.

The reaction mixtures from condensations of the ketone with aniline were fractionally distilled as above, and the fraction boiling from 135°/15 mm. was weighed. Analyses of the products from several pressure experiments showed the presence of oxygenated material, and 2-Δ^1-*cyclo*hexenyl*cyclo*hexanone was isolated and identified from the product of an experiment at 5000 atm. and 100° as follows. The fraction collected was shaken for 15 mins. with 100 c.c. of cold 12% sulphuric acid and then extracted with ether. The extract was washed with fresh cold acid and with water, dried, filtered, and evaporated. The residue was distilled from a micro-Claisen flask. The first fraction was *cyclo*hexanone, from its anil by hydrolysis, and the second, b. p. 100—106°/0·1 mm., had $n_D^{25°}$ 1·4998. It was converted into semicarbazone which, recrystallised from alcohol, had m. p. 192°, unchanged by mixture with an authentic specimen of 2-Δ^1-*cyclo*hexenyl*cyclo*hexanonesemicarbazone or with that obtained from pressure experiments without aniline (Found : C, 66·5, 66·3; H, 8·9, 8·8; N, 17·9, 17·6. Calc. : C, 66·35; H, 8·9; N, 17·9%).

The proportion of anil to autocondensation product was estimated as follows. Duplicate weighed amounts (0·4—0·5 g.) of the fraction, b. p. 135—145°/15 mm., were gently boiled in open conical flasks with 20 c.c. of 10% hydrochloric acid for 30 mins., care being taken to avoid concentration below about 10 c.c. The cooled residual liquor was diluted to about 30 c.c., and the aniline titrated with N/2-bromate–bromide solution. The method was tested with known mixtures of *cyclo*hexanoneanil and *cyclo*hexenyl*cyclo*hexanone to find whether any ketone had not been driven off during the boiling and so gave rise to errors in the estimation. Results showed the method to be satisfactory. It was then necessary to apply a correction for free aniline carried over during the distillation and weighed in the collected fraction. By distilling mixtures of aniline and pure anil, collecting the fraction of b. p. 135—145°/15 mm., hydrolysing it, and estimating the aniline as above, the necessary figure was found.

High-boiling fraction from 5000-*atm. experiments.* This fraction, b. p. 200—210°/15 mm., was collected separately, and a sample was investigated as follows. It was refractionated at 0·1 mm. in a micro-apparatus, and the main fraction, b. p. 170—180°, collected. It was a thick yellow oil, $n_D^{25°}$ 1·5454. Reddelein and Meyn (*loc. cit.*) reported b. p. 212—214°/18 mm. for *cyclo*hexylidene-2-*cyclo*hexanoneanil. 0·4 G. of the fraction was hydrolysed in the cold, and the ketone, after removal of aniline, was converted into semicarbazone. This, when recrystallised, had m. p. 194°; when mixed with an authentic specimen of 2-Δ^1-*cyclo*hexenyl*cyclo*hexanonesemicarbazone or with the semicarbazones obtained from pressure experiments it melted at 192—193°.

The acid extract from the hydrolysis gave tribromoaniline on bromination.

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