terol extracted, the average volume of liquid ammonia and the average solubility of the cholesterol in milligrams per 100 cc. of liquid ammonia.

TABLE I

THE SOLUBILITY OF NON-RADIATED CHOLESTEROL IN LIQUID AMMONIA

Temperature, °C.	Av. vol. of ammonia, Cc.	Av. wt., mg.	Av. solubility, mg. per 100 cc.
—38	4.00	0.00	0.00
0	4.05	0.25	6.16
7	4.13	0.83	20.2
14	4.05	1.10	27.2
21	3.30	2.40	72.6
28	3.20	3.75	117.2
35	3.70	8.60	232.2
42	3.25	9.80	301.2
49	3.95	21.55	545.0

The assistance of a grant from the National Research Council for the study of the isolation and purification of the female sex hormone is gratefully acknowledged.

Summary

1. The solubility of cholesterol in liquid ammonia at temperatures ranging from —38 to +49° has been determined.

2. The solubility at —38° is beyond the sensitiveness of the Liebermann-Burchardt test.

3. Liquid ammonia can be used to separate certain preparations from cholesterol.

DENVER, COLORADO

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF PRINCETON UNIVERSITY]

THE REARRANGEMENT OF ACID AZIDES AND HYDROXAMIC ACIDS OF GEOMETRICAL ISOMERS

BY LAUDER W. JONES AND J. PHILIP MASON[1]

RECEIVED MAY 4, 1927 PUBLISHED OCTOBER 5, 1927

In an article by Jones and Wallis[2] an account of the rearrangements of compounds with optically active radicals was presented. It was shown that *d*-benzylmethylacetazide, dissolved in benzene, rearranged at room temperatures (10–35°) and that an optically active product, *d*-benzylmethyl methyl isocyanate, $(C_7H_7)(CH_3)CH.N{=}C{=}O$, and nitrogen (97%) were formed. These results suggested the experiments described in the following article.

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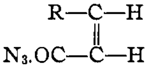
[1] This paper is based upon a thesis submitted by J. Philip Mason to the Faculty of the Graduate School of Princeton University in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

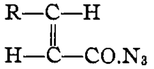
[2] Jones and Wallis, THIS JOURNAL, **48,** 169 (1926).

The problem may be stated as follows. If geometrical isomers in which the radicals of *cis* and *trans* configurations are directly attached to the group —CO.Nxy in such derivations as hydroxamic acids or acid azides undergo rearrangement, will the *cis* and *trans* configurations of their radicals be retained in the organic products of rearrangement?

Two pairs of *cis-trans* isomers, namely, cinnamic acid and allocinnamic acid, and crotonic and isocrotonic acids, were chosen for investigation. It was found that the azides offered less experimental difficulty than the hydroxamic acids. The two space isomers are represented by the formulas

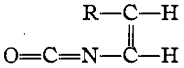


$$\begin{array}{r} \text{R—C—H} \\ \| \quad \\ \text{N}_3\text{.OC—C—H} \end{array}$$

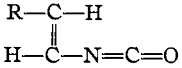


$$\begin{array}{l} \text{R—C—H} \\ \quad \| \\ \text{H—C—CO.N}_3 \end{array}$$

If these pairs of isomers, in which R stands for C_6H_5 or CH_3, rearrange and the configurations of the styryl and *iso*-allyl radicals persist, then two different isocyanates should result in each case

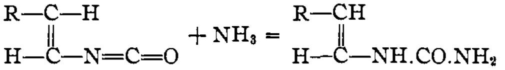


$$\begin{array}{r} \text{R—C—H} \\ \| \quad \\ \text{O=C=N—C—H} \end{array}$$



$$\begin{array}{l} \text{R—C—H} \\ \quad \| \\ \text{H—C—N=C=O} \end{array}$$

Furthermore, addition of ammonia to these isocyanates should yield *two pairs of space isomeric monosubstituted ureas*, for example,



$$\begin{array}{l} \text{R—C—H} \\ \quad \| \\ \text{H—C—N=C=O} \end{array} + \text{NH}_3 = \begin{array}{l} \text{R—CH} \\ \quad \| \\ \text{H—C—NH.CO.NH}_2 \end{array}$$

But if the styryl and *iso*-allyl radicals change and the "labile" configuration gives place to the "stable" configuration, only one isocyanate would result in each case and consequently *only one urea* would be formed from each pair of isomeric azides.

Results of the Study of Azides

The azides of the four different acids were prepared by the action of powdered sodium azide upon the acid chlorides dissolved in absolute ether or in benzene. The azide of cinnamic acid has been described by Forster.[3] It is a solid which melts at 86°, accompanied by decomposition. A solution of this azide in benzene did not evolve nitrogen until a temperature between 75 and 80° was reached. In contrast to this behavior, the azide of allocinnamic acid, during its preparation by the action of sodium azide upon the acid chloride dissolved in ether, lost nitrogen at room temperature continuously; about 100 cc. of nitrogen was collected during the course of the reaction (six–seven hours). The azide of cinnamic acid may be crystallized from boiling ether without suffering any decomposition. No attempt was made to isolate the azide of allocinnamic acid, because every precaution was being taken to prevent a change to the more stable cinnamic form, and at the temperature necessary to cause

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[3] Forster, *J. Chem. Soc.*, **95**, 437 (1909).

sodium azide and the acid chloride to react decomposition was unavoidable and a mixture of azide and isocyanate was always obtained.

The behavior of ether solutions of the azides described above seems to justify the conclusion that the azide of allocinnamic acid existed in solution and decomposed to give nitrogen and an isocyanate at a temperature appreciably lower than that required to affect the azide of cinnamic acid.

The azides obtained from crotonic and isocrotonic acids did not show so pronounced a difference in reactivity.

The conversion of the isocyanates into monosubstituted ureas, a reaction carried out by passing the calculated amount of ammonia gas into cold ether solutions of the isocyanates, seemed to offer the best chemical method of determining whether or not the radicals in the isocyanates had retained their original configurations. When these experiments were performed, only *one monostyryl urea*, $C_6H_5CH{=}CH{-}NH{-}CO{-}NH_2$ (m. p. 142–143°), was obtained and, similarly, from crotonic and isocrotonic azides only *one mono-iso-allyl urea*, $CH_3{-}CH{=}CH{-}NH{-}CO.NH_2$ (m. p., 122°), resulted.

These observations lead to the conclusion that during rearrangement the labile radicals assume the more stable configurations; for it is not likely that the action of ammonia at 0° upon the isocyanates would cause the radicals to change their configurations from *cis* to *trans*.

Results of the Study of Hydroxamic Acids

Mention has been made of complications encountered in experiments with hydroxamic acids. Cinnamhydroxamic acid has been studied by several investigators.[4] The potassium salt of the benzoyl ester of this hydroxamic acid, $C_6H_3CH{=}CH{-}CO.NKO.CO.C_6H_5$, was prepared and a solution of it in water was heated to cause rearrangement. In reactions of this kind, the isocyanates first produced are usually hydrolyzed and *sym.*-disubstituted ureas are obtained as the chief product of the reaction. It was hoped that these ureas might be employed to answer the question concerning the behavior of the radicals discussed above.

When the experiment was performed, no *sym.*-distyryl urea, $(C_6H_5CH{=}CH{-}NH)_2CO$, could be isolated. However, when the azide of cinnamic acid was heated with water, it behaved normally; the chief product of the reaction was *sym.*-distyryl urea.

Thiele and Pickard[5] stated that the potassium salt of this benzoyl ester of cinnamhydroxamic acid heated with water gave "no definable transformation product." We have isolated a perfectly definite compound, a colorless solid which melted at 152°. It was not the disubstituted urea. The nitrogen content was almost exactly that required for cinnamhydrox-

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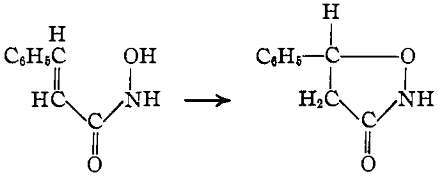
[4] Rostoski, *Ann.*, **178**, 214 (1875). Thiele and Pickard, *Ann.*, **309**, 189 (1899). Velardi, *Gazz. chim. ital.* [2] **34**, 66 (1904).

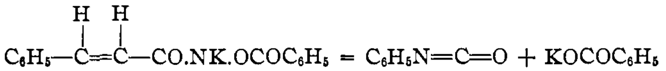
[5] Thiele and Pickard, *Ann.*, 309, 189 (1899).

amic acid, but the properties of the two compounds were totally different. At first it was thought that it might be γ-phenyl-α-isoxazolone, which melts at 152°.

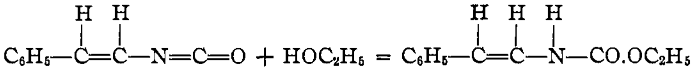
The percentage of nitrogen in the compound was found to be almost exactly that required by this isoxazolone. But it is difficult to see how this particular isoxazolone could be formed in the reaction. It is evident that by intramolecular addition cinnamhydroxamic acid might yield α-phenyl-γ-dihydro-isoxazolone; but the isoxazolones possess very pronounced acid properties and are readily soluble in solutions of the alkalies in the cold, whereas our compound was not soluble even in boiling alkalies. We hope to be able to identify the substance later.



In this connection, it is interesting to note that the potassium salt of the benzoyl ester of cinnamhydroxamic acid dissolved in boiling absolute alcohol shows a normal behavior; styryl urethan is formed by addition of alcohol to the isocyanate. This observation was also made by Thiele and Pickard.



$$C_6H_5-\overset{H}{C}=\overset{H}{C}-CO.NK.OCOC_6H_5 = C_6H_5N=C=O + KOCOC_6H_5$$



$$C_6H_5-\overset{H}{C}=\overset{H}{C}-N=C=O + HOC_2H_5 = C_6H_5-\overset{H}{C}=\overset{H}{C}-\overset{H}{N}-CO.OC_2H_5$$

Experimental Part

I. Rearrangement of the Azide of Cinnamic Acid

Preparation of the Azide.—The method employed was similar to the one used by Forster.[6]

Sodium azide (Kahlbaum) was purified by dissolving it in the minimum amount of water and reprecipitating it by the addition of acetone. Then, 20 g. of dry, finely-powdered azide (60% excess) was suspended in 120 cc. of absolute ether and 20 g. of cinnamyl chloride was added. This mixture was stirred for eight or ten hours at room temperature. The solid material was collected on a filter and washed with water to remove sodium chloride and sodium azide, and the azide was purified by crystallization from ligroin (b. p. 60–80°). Evaporation of the ether filtrate to one-half its original volume gave additional crystals of the azide. In all about 2.5 g. of pure azide (m. p. 86°) was obtained.

Preparation of Styryl Isocyanate: $C_6H_5CH=CH-N=C=O$.—A solution of 5 g. of cinnamic acid azide in 25 cc. of benzene dried over sodium was placed in a flask connected with a reflux condenser protected at the top by a calcium chloride tube. The

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[6] Forster, *J. Chem. Soc.*, **95,** 437 (1909).

solution was heated to a temperature just below the boiling point until no more nitrogen was evolved. After removing the benzene, the isocyanate was distilled under diminished pressure (12 mm.). It boiled at 107°. About 3 g. of pure isocyanate was obtained.

sym.-**Distyryl Urea:** $(C_6H_5CH{=}CH{-}NH)_2C{=}O$. *Action of Water upon the Isocyanate.*—Several grams of styryl isocyanate was suspended in water heated to 50°. The isocyanate was decomposed slowly. A white solid was formed which, after crystallization several times from dil. alcohol, melted at 214°. It was soluble in alcohol and in ethyl acetate and insoluble in ether and ligroin.

Anal. Subs., 0.3723 g.: N, 35.5 cc. (29°, 758 mm.). 50% KOH used. Calcd.: N, 10.6. Found: 10.7.

Rearrangement of Cinnamic Acid Azide in the Presence of Water.—A suspension of 3 g. of the azide in 75 cc. of water was heated nearly to boiling for half an hour. A yellow solid was formed and the solution became turbid. The solid weighed 2.2 g. Treatment of it with ether removed the yellow color and recrystallization from dil. alcohol gave *sym.*-distyryl urea; m. p., 214°.

The turbid solution filtered from the solid was extracted with ether and the ether evaporated. This gave a yellow, gummy product which possessed the peculiar aldehyde odor noticed in the rearrangement of the benzoyl ester of cinnamhydroxamic acid described in the latter part of this article. The yellow material finally became solid. It was treated with a small amount of benzene to remove the yellow color and recrystallized from dil. alcohol. This gave distyryl urea; m. p., 213°.

The rearrangement of the azide in water was also carried out in an atmosphere of carbon dioxide in order to measure the nitrogen evolved. Bubbles of nitrogen were not observed until the temperature of the water reached 75 to 80°. Thus, 0.3135 g. of the azide gave 42.8 cc. of nitrogen at 22° and 743 mm. over 50% potassium hydroxide. This corresponds to 94.8% of the nitrogen required for complete decomposition according to the equation.

Monostyryl Urea: $C_6H_5CH{=}CH{-}NH{-}CO{-}NH_2$.—A solution of 1.6 g. of the azide of cinnamic acid in 10 cc. of dry benzene was heated to bring about the rearrangement of the azide. The benzene was removed and the isocyanate dissolved in 10–15 cc. of dry ether. The flask containing the solution was cooled by ice water, and dry ammonia gas passed into the ether. A pale yellow precipitate formed; wt., 1.1 g.; m. p., 140–143°. Recrystallization of it from dil. alcohol gave a colorless solid which melted at 143°. It was soluble in acetone, in alcohol and in ethyl acetate, and insoluble in water and in ether.

Anal. Subs., 0.2815: N, 41.5 cc. (21°, 757.5 mm.). 50% KOH used. Calcd.: N, 17.3. Found: 16.9.

II. Rearrangement of the Azide of Allocinnamic Acid

Preparation of Allocinnamic Acid.—Allocinnamic acid was prepared according to the method of Liebermann and Scholz[7] and of Michael[8] by the reduction of α-bromo-allocinnamic acid. The starting material in the preparation was cinnamic acid. The yield of allocinnamic acid (m. p. 67°) was small; not more than 7 g. of pure substance was obtained from 100 g. of cinnamic acid in any of our experiments.

Preparation of Allocinnamic Acid Azide.—The chloride of allocinnamic acid was made by treating the acid (3.3 g.) dissolved in a small amount of ether with an excess of thionyl chloride at 0°. The mixture stood for half an hour in an ice-bath. Ether and excess of thionyl chloride were removed by evaporation in a vacuum desiccator.

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[7] Liebermann and Scholz, *Ber.*, **25,** 950 (1892).

[8] Michael, *Ber.*, **34,** 3648 (1901).

The acid chloride could not be distilled without being converted into the more stable chloride of cinnamic acid, so it was used directly. Finely powdered sodium azide (5 g.) was suspended in absolute ether contained in a 3-necked flask, which was connected with a carbon dioxide generator and also with an azotometer charged with a 50% solution of potassium hydroxide. After the system was thoroughly filled with carbon dioxide, an ether solution of the acid chloride (3.5 g.) was introduced through a dropping funnel.

This mixture was stirred for six or seven hours. During this time about 100 cc. of nitrogen gas collected in the azotometer. This implied that the azide of allocinnamic acid had formed and suffered decomposition and rearrangement at room temperature; the azide of cinnamic acid did not yield nitrogen under these conditions.

The Monostyryl Urea.—The ether solution which contained the isocyanate was filtered from the solids. It was cooled and treated with ammonia gas. A white precipitate weighing about 0.3 g. was collected and washed with water to remove any ammonium chloride. After crystallization from dil. alcohol it melted at 142°.

It is probable that the decomposition of the azide was not complete. The evolution of nitrogen took place slowly at room temperature. It did not seem desirable to hasten decomposition by increasing the temperature since this might cause a conversion of the allocinnamic form.

These results show that the same monosubstituted urea was obtained in the two experiments. It seems probable, therefore, that the isocyanates were identical.

III. Rearrangement of the Azide of Crotonic Acid

Preparation of the Azide: $CH_3CH{=}CH{-}CO.N_3$.—Crotonyl chloride was made by the action of thionyl chloride upon an excess of crotonic acid, first at room temperature and finally at 50–60°. It was separated by fractional distillation (b. p., 124°).

An ether solution of 21 g. of crotonyl chloride in which 23 g. of sodium azide was suspended was stirred mechanically for two days. An azotometer was connected with the flask containing the mixture. No nitrogen was evolved during the reaction. The ether solution was filtered and evaporated in a current of dry air. This gave 14 g. of the azide. It was a clear liquid possessing a sharp odor.

A sample of it was placed in a melting-point tube and, after inserting a glass thread, was heated slowly. At 30–40° an occasional bubble of gas was given off; at 75–85°, the evolution of nitrogen became very rapid.

To test the purity of the liquid, a weighed sample dissolved in benzene was decomposed in an apparatus from which air had been displaced by carbon dioxide, and the nitrogen was collected in an azotometer over a solution of potassium hydroxide. A correction was made for the vapor pressure of benzene.

Anal. Subs., 0.2470: N, 44.3 cc. (18°, 745 mm.). Vapor pressure of benzene at 18°, 68.9 mm. Calcd.: N, 49.8 cc. Found: 37 cc.; 74.2% azide in liquid.

Mono-*iso*-allyl Urea, $CH_3{-}CH{=}CH{-}NH{-}CO{-}NH_2$.—Seven g. of the impure liquid azide was placed in a clean, dry flask, attached to a reflux condenser, and heated on a water-bath until no more nitrogen was evolved. The liquid, chiefly *iso*-allyl isocyanate, possessed a very acrid and suffocating odor. Absolute ether was added to the residue and a current of dry ammonia gas was then passed through the solution as long as a precipitate was obtained. The white precipitate, collected on a filter and dried, weighed 2 g. Recrystallized from a mixture of hot ethyl acetate and chloroform by the addition of ligroin, it formed pure white crystals which melted at 122°.

It is very soluble in alcohol and in acetone, quite soluble in ethyl acetate, in chloroform and in warm water, from which it does not separate in good crystalline form. It is insoluble in ligroin, in benzene and in ether.

Anal. Subs., 0.1211: N, 30.4 cc. (32.5°, 757.3 mm.). 50% KOH used. Calcd.: N, 28. Found: 27.8.

IV. Rearrangement of the Azide of Isocrotonic Acid

Isocrotonic acid (Kahlbaum) purified according to the method suggested by Wislicenus[9] was converted into isocrotonyl chloride by the action of a little less than the calculated amount of thionyl chloride upon an ether solution of the acid. Isocrotonyl chloride cannot be distilled at atmospheric pressure without isomerization to give the more stable crotonyl chloride. To avoid any change of this kind the ether was removed carefully and the acid chloride obtained from 10 g. of isocrotonic acid used directly.

Preparation of the Azide of Isocrotonic Acid.—An ether solution of this chloride treated with 14 g. of sodium azide was stirred for two days. During the first 12 hours the mixture was kept at a temperature between 15 and 20°. No nitrogen was formed so the temperature was increased to 25–28°. This caused a slow evolution of nitrogen.

Mono-*iso*-allyl Urea.—After two days the ether solution was filtered, cooled and treated with dry ammonia gas. This gave a small amount of colorless solid which was recrystallized from a mixture of ethyl acetate and chloroform by the addition of ligroin. It melted at 122° and was identical with the urea obtained from the azide of crotonic acid as described above.

V. Rearrangement of Cinnamhydroxamic Acid

Preparation of Cinnamhydroxamic Acid.—Although this compound has been prepared by several investigators,[4] we found it more satisfactory to prepare it by the method used by Jones and Hurd in other preparations.[10]

The acid chloride of cinnamic acid was prepared by warming the acid with a 10% excess of thionyl chloride at 50°. When the reaction was complete, the liquid, still warm, was transferred to a distilling flask, the excess of thionyl chloride drawn off by means of a water pump, and the acid chloride distilled; b. p., 101° (2 mm.).

Free hydroxylamine was prepared by the method of Lecher and Hofmann[11] with the apparatus similar to that used by Hurd and Brownstein.[12]

A solution of 24 g. of cinnamic acid chloride in 60 cc. of dry benzene was added slowly to a suspension of 12 g. of free hydroxylamine in 100 cc. of dry benzene, while the flask was shaken and cooled in ice water. The reaction took place immediately; a white, viscous substance was formed. After all of the chloride was added the mixture was shaken for a few minutes and then filtered. The precipitate was washed twice by suspending it in water. It was collected and dried in a vacuum desiccator; wt., 24 g. The acid was recrystallized from hot ethyl acetate by the addition of ligroin. The first crystallization usually yielded an oil which solidified readily as it became cool. The melting point was finally raised to 119.5°. Thiele and Pickard gave 111° as the melting point.

Anal. Subs., 0.4749: N, 37.6 cc. (22.5°, 754 mm.). 50% KOH used. Calcd.: N, 8.95. Found: 9.03.

As a further check upon the constitution of the compound, a sample was hydrolyzed by heating it with 6 *M* hydrochloric acid. The ratio of cinnamic acid to hydroxylammonium chloride formed was found to be 1 : 1.

An attempt to prepare the hydroxamic acid by adding a few drops of water to an ether solution of the acid chloride in which equivalent quantities of sodium carbonate

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[9] Wislicenus, *Vierteljahrsschr. Naturforsch. Ges. Zürich*, **41**, 270–293 (1897).

[10] Jones and Hurd, THIS JOURNAL, **43**, 2439 (1921).

[11] Lecher and Hofmann, *Ber.*, **55B**, 912 (1922).

[12] Hurd and Brownstein, THIS JOURNAL, **47**, 68 (1925).

and hydroxylammonium chloride were suspended resulted in the formation of a mixture of the mono- and dicinnamhydroxamic acids.

Preparation of the Benzoyl Ester of Cinnamhydroxamic Acid.—The best method for the benzoylation of the hydroxamic acid was found to be that of Heidelberger and Jacobs.

A solution of 6.55 g. of cinnamhydroxamic acid in a mixture of 30 cc. of glacial acetic acid and 30 cc. of a saturated solution of sodium acetate was shaken with 6 cc. of benzoyl chloride added in small portions, while the flask was immersed in ice water. After a short time the benzoyl ester separated as a white solid. One crystallization of it from hot ethyl acetate with addition of ligroin gave 8.5 g. of benzoyl ester, which melted at 150–152°. Further recrystallization from hot ethyl acetate and ligroin, or from hot dil. alcohol, yielded pure white crystals which melted sharply at 156.5°. Thiele and Pickard gave 144° as the melting point.

Preparation of the Potassium Salt of the Benzoyl Ester of Cinnamhydroxamic Acid.—The benzoyl ester was only slightly soluble in cold alcohol and less soluble in ether. On this account, the ordinary method of preparing a potassium salt of this class was not satisfactory. Acetone was found to be the most suitable solvent. In a typical experiment, 7.95 g. of benzoyl ester was dissolved in 130 cc. of warm, dry acetone, and a cold solution made by dissolving 1.02 g. of potassium in 30 cc. of absolute methanol was added. The potassium salt formed immediately as a white precipitate. The mixture was cooled rapidly by shaking the flask in ice water. Addition of about 100 cc. of dry ether increased the yield; weight of dry salt, 8.2 g. The sodium salt was prepared by the same method.

Anal. Subs., 0.0561: Na_2SO_4, 0.0140. Calcd. for $C_{16}H_{12}O_3NNa$: Na, 7.96. Found: 8.08.

Rearrangement of the Potassium Salt in Water.—The potassium salt was only slightly soluble in water at room temperature, 2.5 g. dissolving in about 150 cc. of water. When this solution was heated, it became turbid at 40–45°. The precipitate could not be coagulated completely by any of the usual methods. By filtration, only a very small amount of a white precipitate was obtained. When it was crystallized from hot ethyl acetate or hot benzene, it melted at 152°. The same product was obtained when dicinnamhydroxamic acid was treated with an equivalent amount of sodium carbonate dissolved in water. During the rearrangement, a peculiar odor resembling that of benzaldehyde was noticed, but no aldehyde was ever detected when the solution was tested.

Anal. Subs., 0.0368: N, 2.7 cc. (21°, 760 mm.). 50% KOH used. Found: N, 8.5.

Summary

The azides of two pairs of *cis-trans* isomers, namely, cinnamic acid and allocinnamic acid, crotonic and isocrotonic acids have been prepared and caused to undergo rearrangement. The isocyanates formed by rearrangement were converted into monosubstituted ureas by addition of ammonia. Only one monostyryl urea and one *iso*-allyl urea could be obtained. This seems to indicate that during rearrangement the configurations of the styryl and *iso*-allyl radicals are changed and only the stable *trans* configuration appears in the ureas and undoubtedly, also, in the first product of rearrangement, the isocyannates.

The rearrangement of the potassium salt of the benzoyl ester of cinnamhydroxamic acid was studied. A definite product (m. p., 152°) was

obtained. It was not the *sym.*-disubstituted urea expected. It has not been identified.

PRINCETON, NEW JERSEY

[CONTRIBUTION FROM THE FIXED NITROGEN RESEARCH LABORATORY, BUREAU OF CHEMISTRY AND SOILS, WASHINGTON, D. C.]

THE USE OF NITROGEN TETROXIDE IN PLACE OF NITRIC ACID IN ORGANIC NITRATIONS[1]

BY L. A. PINCK

RECEIVED MAY 5, 1927 PUBLISHED OCTOBER 5, 1927

It has been previously observed that when nitrogen tetroxide is allowed to react with organic substances, oxidation, nitration or diazotization may take place. In general, the experience of previous workers has been that both oxidation and nitration take place when a solution of nitrogen tetroxide in an organic substance is allowed to stand either in the dark or in sunlight for several weeks to several months. With nitro arylamines,[2] nitrogen tetroxide acts as a diazotizing reagent. It has also been found that solutions of nitrogen tetroxide in toluene and benzene form explosive mixtures.[3]

The reactions of oxides of nitrogen with organic substances described in the literature, as well as some preliminary experiments conducted in the course of this investigation, indicate that the direct nitration of organic substances with oxides of nitrogen is neither safe nor economically feasible, the chief objections being: (1) slowness of nitration at moderate temperature, (2) oxidation and (3) possible explosions at higher temperatures.

The present paper describes a study of the conditions governing the nitration of a number of aromatic compounds with nitrogen tetroxide in the presence of sulfuric acid.

Theoretical

The fact that nitric acid oxidizes and only partially nitrates an organic substance, whereas a mixture of nitric and sulfuric acids yields a complete nitration, led to the belief that oxidation and explosion hazard might be avoided by using sulfuric acid in conjunction with the oxides of nitrogen. Sulfuric acid mixed with nitrogen tetroxide serves a purpose quite distinct from its use in the mixed acid nitration, for not only does it function as a dehydrating reagent, but it has the additional function of forming nitric acid *in situ* as shown in the following equation

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[1] Presented before the Division of Organic Chemistry at the 73rd Meeting of the American Chemical Society, Richmond, Virginia, April 11–16, 1927.

[2] Houston and Johnson, THIS JOURNAL, **47**, 3011 (1925).

[3] Raschig, *Z. angew. Chem.*, **35**, 117 (1922).