

On the Beckmann Rearrangement. IV.

Acyl Derivatives of the Substituted Imido-Acids.

By

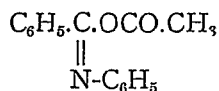
Mitsuru Kuhara and Kanoichiro Suitsu.

(Received July 6, 1914.)

It is almost evident that the intermediate formation of the acyl derivatives of the substituted imido-acids is a necessary condition of the Beckmann rearrangement of the ketoximes by the acid chlorides, acids, etc., as has been often mentioned in the previous articles¹ by one of us (M.K.) and his collaborators. Expecting that the isolation and synthesis of such compounds, if possible, may throw some more light upon the nature of the Beckmann rearrangement, an investigation for such a direction has been attempted as a subject of particular interest.

Wheeler and Johnson² have explained the formation of diacylanilides by the action of acyl chlorides upon the silver salts of acylanilides. Mumm³ has synthesized several acylbenzanilides by shaking an ethereal solution of phenylbenzimidochloride (benzanilidimide chloride)⁴ together with the aqueous solutions of the sodium salts of several organic acids. The actual isolation, however, of the acyl derivatives of the substituted imido-acids (pseudoamides), which would seem to be the intermediate products of the reactions, has not been effected.

Carrying out an experiment suggested by one of us (M.K.), Kodama has succeeded to isolate a compound which may be considered to be formed from diphenylketoxime through the Beckmann rearrangement by acetyl chloride, and must possess the constitution corresponding to phenylbenzimidacetate⁵.



¹ Mem. Coll. Sci. Engin., Kyoto, 1, 254 (1903-1908); 2, 367 (1909-1910); 6, 1 (1913).

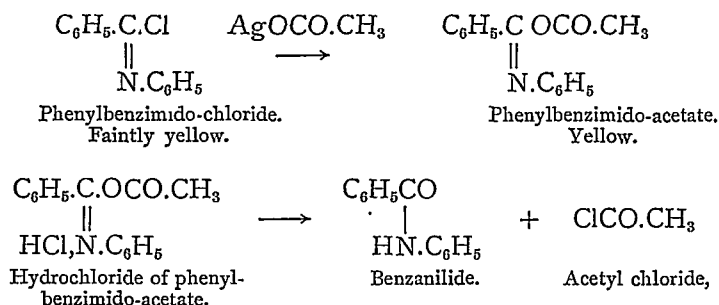
² Amer. Chem. J., 19, 188 (1897). Refer *ibid.*, 18, 381 (1896).

³ Ber. D. chem. Ges., 43, 886, 3336 (1910).

⁴ Lieb. Ann., 184, 97 (1777).

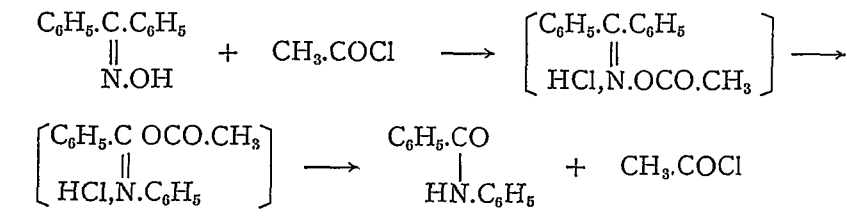
⁵ Mem. Coll. Sci. Engin., Kyoto, 2, 395 (preliminary communication).

by treating an ethereal solution of phenylbenzimidochloride with silver acetate. The substance is a thick yellow oil of unstable nature, and forms its hydrochloride as a canary yellow precipitate by passing dry hydrochloric acid through its ethereal solution cooled with a freezing mixture, but by the excess of the acid changes to acetylbenzanilide,¹ probably by the secondary reaction. The hydrochloride dissolved in chloroform and heated above 60° yields benzanilide at once. When sodium acetate is used for its preparation instead of silver acetate, the product always consists entirely of acetylbenzanilide. Then, the reactions for the formation of phenylbenzimidacetate and for the decomposition of its hydrochloride into benzanilide shall be represented as follows :



And the production of acetylbenzanilide may be the result of the secondary reaction or of the intramolecular rearrangement noticed by Mumm.²

Now the last phase of the Beckmann rearrangement of diphenylketoxime by acetyl chloride is highly probable to be due to the above-mentioned decomposition of the hydrochloride of phenylbenzimidacetate which is assumed to be formed as an intermediate product in the rearrangement of diphenylketoxime acetyl ester formed in reaction, being inferred from its behaviours ; so for convenience the whole scheme of the Beckmann rearrangement, as it is assumed, shall be stated again :

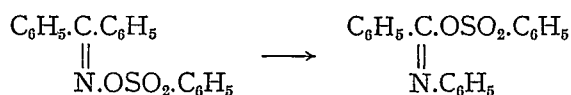


¹ Amer. Chem. J., 18, 546 (1896).

² Loc. cit.

It is, however, not possible to isolate phenylbenzimidido-acetate as an intermediate product from diphenylketoxime acetyl ester by its intramolecular rearrangement, as the latter does not undergo the rearrangement by itself even by the rise of temperature, on account of the weak negative character of the acetic acid residue present, but always the aid of hydrochloric acid is needed for its rearrangement as has been often stated. When hydrochloric acid is present, therefore, phenylbenzimidido-acetate formed would yield its hydrochloride, and its decomposition may progress until the extreme so that its isolation as an intermediate product is not possible.

Nevertheless, diphenylketoxime benzenesulphonyl ester actually undergoes the spontaneous rearrangement without the aid of any reagent, owing to the presence of the strong negative acid residue, with the formation of phenylbenzimidido-benzenesulphonate whose isolation is possible, the scheme of rearrangement being represented here again:



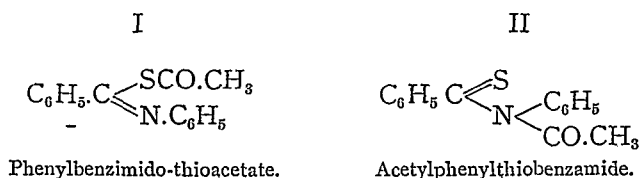
In fact, phenylbenzimidido-benzenesulphonate has been isolated by one of us (M. K.) and Matsunami from diphenylketoxime benzenesulphonyl ester by rearrangement, and an account has been preliminarily communicated to the Memoirs of the College of Science and Engineering¹.

As has been already mentioned, it is not only difficult to isolate phenylbenzimidido-acetate as an intermediate product of the rearrangement of diphenylketoxime by acetyl chloride, but also it is a hard task to prepare it synthetically in a perfectly pure state by the action of metallic acetate upon phenylbenzimidido-chloride without exception, often resulting only in the production of benzanilide and acetylbenzanilide; so we are not able to catch a just right condition for the constant formation of the yellow oil or phenylbenzimidido-acetate. The authors, have, therefore, attempted to synthesize the other esters of the same type by the action of the metallic salts of the other acids upon phenylbenzimidido-chloride, in order to see if the actual isolation of the esters of such a kind as phenylbenzimidido-acetate is possible. For this purpose, at first the synthesis of phenylbenzimidido-thioacetate was carried out, fortunately with success. In this experiment, potassium thioacetate,

¹ Mem. Coll. Sci. Engin., Kyoto, 6, 7 (1913).

KS.CO.CH_3 was made to react with phenylbenzimidochloride, dissolved in petroleum ether in presence of anhydrous potassium carbonate at the ordinary temperature, by which process the yellow coloration of the solution was at first observed, followed by its gradual change to orange red. On allowing the solution to stand for several days, yellow crystals were found to deposit mixed with some orange red crystals; and two substances were separated by fractional crystallization and each analysed. Both substances possess the same composition corresponding to the empirical formula $\text{C}_{15}\text{H}_{13}\text{NOS}$.

It is now concluded that the yellow compound would be phenylbenzimidothioacetate possessing the constitution represented by the formula I, and the orange red substance would be acetylphenylthiobenzamide having the formula II:



interpreting from the facts which will be described hereinafter:

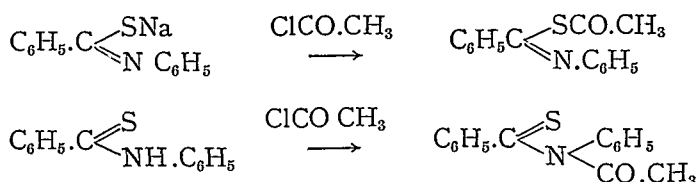
1. When the perfectly pure phenylbenzimidochloride is allowed to interact with potassium thioacetate, the yellow compound alone is formed, not a trace of the orange red compound being observed to be formed.

2. The yellow compound changes to the orange red isomer, when comes in contact with phosphorus oxychloride, acetyl chloride, benzoyl chloride, alkali, etc., or when kept in a vessel filled with hydrochloric acid gas. It is then assumed that the yellow compound is the primary reaction-product of phenylbenzimidochloride and thioacetate, which may secondarily change to the orange red isomer by the aid of the acid possibly present in the chlorides used or by alkali:

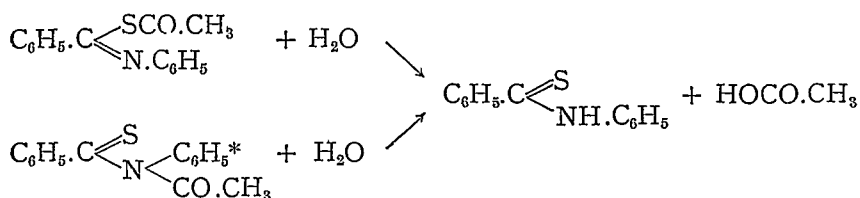
3. The formula I indicates the presence of a chromophoric group, $>\text{C}=\text{N.C}_6\text{H}_5$, which is assumed to give rise to the manifestation of yellow colour.¹

4. Acetyl chloride, when react with sodium salt of thiobenzanilide suspended in xylene, yields a considerable amount of the yellow compound, while in a dry etherial solution of thiobenzanilide in presence of anhydrous potassium carbonate it produces the orange red compound; the reactions in both cases should be represented as follows:

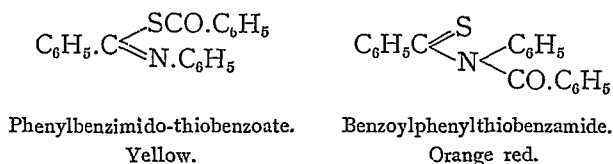
¹ Mem. Coll. Sci. Engin., Kyoto, 2, 366 (1909-1910).



5. Subjecting both yellow and orange red compounds to hydrolysis by means of dilute acid or alkali, they are decomposed yielding the same products, that is, thiobenzanilide and acetic acid. Such phenomena of decomposition may be shown by the following scheme :



Continuing experiment further with potassium (or silver) thiobenzoate and phenylbenzimidochloride under the same condition, it has also been noticed that both yellow and orange red compounds are produced as in the other case. Their behaviours are similar with those of the corresponding thio-compounds above mentioned; hence by analogy their respective constitutional formulas should be represented as follows :



In conclusion it may be said that the existence of the esters of the types, $\text{C}_6\text{H}_5\cdot\text{C}(\text{OCOR})\text{:N}\cdot\text{C}_6\text{H}_5$, $\text{RC}(\text{OSO}_2\cdot\text{C}_6\text{H}_5)\text{:NR}$ and $\text{C}_6\text{H}_5\cdot\text{C}(\text{SCOR})\text{:N}\cdot\text{C}_6\text{H}_5$ (in which $\text{R}=\text{C}_6\text{H}_5$ or CH_3) is possible, and that the esters corresponding to the first two formulas would be formed as the intermediate products of the Beckmann rearrangement of the respective ketoximes by the respective acid chlorides, inferring from their behavi-

* In the mixed diacylanilides, the lower acyl group is removed according to Wheeler, Smith and Warren's view.—*Amer. Chem. J.*, **19**, 758 (1897).

ours as well as from their actual isolation in the course of rearrangement. Especially, the investigation with regard to the rearrangement of benzenesulphonyl esters of ketoximes is now going on in our laboratory.

EXPERIMENTAL PART.

I *Action of Silver Acetate upon Phenylbenzimidochloride.*

A slight excess of finely powdered anhydrous silver acetate over an equivalent quantity was added by small quantities to a well cooled ethereal solution of phenylbenzimidochloride (benzanilidimide chloride) prepared according to Wallach's statement,¹ with constant and vigorous shaking of the mixture. At the beginning of reaction the white silver salt turned yellow on its surface, but the liquor soon got yellow, gradually increasing in depth, as the yellow substance formed passes into solution. The ethereal solution was then filtered, and ether removed by evaporation quickly passing a current of dry air. In the course of evaporation, there separated out at first some platy crystals which were confirmed to be benzanilide by its characteristic properties, soon followed by the deposition of colourless needle-shaped crystals and finally there remained a thick yellow oil. The needle-shaped crystals purified by repeated recrystallization from petroleum ether and also from dilute alcohol were found to melt at 63.5° and to possess all the properties of acetylbenzanilide already obtained by Wheeler and McFarland². The oil was then treated with petroleum ether for its purification, and the solution, was allowed to evaporate by passing a current of dry air. Its analysis has not been conducted, as the substance is very difficult to be obtained in a perfectly pure state on account of its changeable character, yet the substance should undoubtedly be phenylbenzimidate-acetate, $C_6H_5.C(OCO.CH_3):N.C_6H_5$, being inferred from its behaviours.

By passing a current of dry hydrochloric acid through an ethereal solution of the oil cooled with a freezing mixture, its hydrochloride separated out as a canary yellow precipitate which can be reconverted into the original substance by means of anhydrous potassium carbonate. The hydrochloride, when exposed to moist air, soon changed reddish brown, with the formation of benzanilide, aniline and acetic acid as its

¹ Lieb. Ann., 184, 79 (1877).

² Amer. Chem. J., 18, 546 (1896).

decomposition products. Heating the hydrochloride dissolved in dry chloroform in a sealed tube above 60° for about half an hour, it was found to be transformed into benzanilide. The oil itself alone dissolved in chloroform or benzene, when heated in a sealed tube at 160 – 170° for about two hours showed no perceptible change. It readily decomposes by acid and alkali splitting up into acetic acid (or its salt) and benzanilide.

2. *Action of Sodium Acetate and of Silver Benzoate upon Phenylbenzimidochloride.*

Gently warming an ethereal solution of phenylbenzimidochloride mixed with some powdered anhydrous sodium acetate, and then evaporating the solution, the residue was extracted with petroleum ether, by which process acetylbenzanilide¹ was isolated without the intermediate formation of the yellow isomer.

By the action of silver benzoate upon phenylbenzimidochloride dissolved in ether, a yellow oil and needle-shaped crystals were isolated besides benzanilide and some benzoic acid. The needle-shaped crystals were found to be dibenzoylanilide², as it possesses the melting point of 155° (Losanitsch) and all its characteristic properties. The yellow oil should be phenylbenzimidobenzoate, since its formation and decomposition are wholly analogous with those of the acetyl ester obtained from silver acetate and phenylbenzimidochloride.

The formation of acetyl- and dibenzoylanilides in those cases above described may be due to the rearrangement noticed by Mumm.

3. *Action of Potassium Thioacetate upon Phenylbenzimidochloride.*

Finely powdered anhydrous potassium thioacetate was added to a dry petroleum ether solution of phenylbenzimidochloride previously mixed with some anhydrous potassium carbonate in order to avoid the action of acid which is possible to be present, and the mixture was constantly shaken for a while at the ordinary temperature. At the beginning of reaction, the surface of potassium thioacetate was covered

¹ Loc. cit.

² Refer Beilstein II, 1171. Ber. D. chem. Ges., 43, 886 (1910).

with a yellow coating, but the solution soon changed pink, followed by the gradual increase of the depth of colour. On allowing the mixture to stand for a few days with occasional shaking, the yellow coloured phenylbenzimidio-thioacetate was found to deposit, mixed with the orange red crystals of acetylphenylbenzamide. The mixture was filtered, and the residue treated with warm petroleum ether and the solution concentrated by distillation under a diminished pressure. Letting the concentrated solution stand for a while there separated out a mass of granular orange red crystals. The substance purified by recrystallization from dry petroleum ether, consists of deep orange red coloured needles, and melts at $78.5-79.5^{\circ}$. It is soluble in common organic solvents with dark orange red colouration. Its analysis gave the following values for sulphur :

- I. 0.2384 grm. substance gave 0.222 grm. BaSO_4 .
 II. 0.2576 " " " 0.237 " "
 III. 0.1860 " " " 0.171 " "

	Calculated for		Found	
	$\text{C}_6\text{H}_5\cdot\text{C}(\text{N}\cdot\text{C}_6\text{H}_5\cdot\text{CO}\cdot\text{CH}_3)\text{:S}$	I	II	III
Sulphur	12.57	12.75	12.64	12.63

Warming with dilute acid or alkali, it is readily transformed into thio-benzanilide melting at $97.5-98.5^{\circ}$.

The last residue left after extracting with petroleum ether was treated with chloroform, and the solution thus obtained was allowed to evaporate by passing a current of dry air; the residue consisting of phenylbenzimidio-thioacetate was repeatedly washed with cold absolute alcohol and then dissolved in a mixture of chloroform and ether. On allowing the solution to stand for a while there deposited a lot of monoclinic amber-yellow coloured crystals.

The analysis of the substance gave the following values for sulphur :

- I. 0.1530 grm. substance gave 0.1406 grm. BaSO_4 .
 II. 0.2402 " " " 0.2172 " "

	Calculated for		Found	
	$\text{C}_6\text{H}_5\cdot\text{C}(\text{SCO}\cdot\text{CH}_3)\text{:N}\cdot\text{C}_6\text{H}_5$	I	II	
Sulphur	12.57	12.62	12.41	

¹ Ber. D. chem. Ges., 43, 886, 3336 (1910).

Phenylbenzimidio-thioacetate is of rather stable nature, difficultly soluble in alcohol, ether, petroleum ether, benzene and acetone, but readily in chloroform. By boiling with alcohol or warming with acid or alkali it is transformed into thiobenzanilide with more difficulty than its isomer, acetylphenylthiobenzamide. The yellow crystals of phenylbenzimidio-thioacetate, when heated, melt to a deep orange red liquid which solidifies to the original yellow substance when cooled. The substance being brought in contact with phosphorus oxychloride, acetyl chloride, benzoyl chloride or caustic alkali, or being kept under a desiccator filled with dry hydrochloric acid gas, is transformed into the orange red isomer. In the latter case, the reaction progresses until the extreme so as to produce thiobenzanilide, when it is allowed to stand for several days. On boiling the substance with water no perceptible change is observed to take place. Purer the phenylbenzimidio-chloride used is, the less acetylphenylthiobenzamide is produced; thus when potassium thioacetate is allowed to react with the well purified phenylbenzimidio-chloride, phenylbenzimidio-thioacetate alone is observed to be formed without the addition of potassium carbonate. From such a relation, it is almost evident that phenylbenzimidio-thioacetate formed as a primary product of reaction would change to isomeric acetylphenylthiobenzamide by the action of acid, which is probable to be mixed with the impure phenylbenzimidio-chloride, being derived from phosphorus oxychloride, acid chlorides, etc. used.

4. *Action of Acetyl Chloride upon Thiobenzanilide and upon its Sodium Salt.*

On adding an ethereal solution of an equivalent quantity of the purified acetyl chloride to an ethereal solution of thiobenzanilide in presence of anhydrous potassium carbonate, the solution was soon observed to alter deep orange red under the evolution of carbon dioxide. Evaporating the solution by passing a current of dry air through it, there was left an orange red substance; and from the petroleum ether solution of the latter the orange red coloured crystals separated out and were found to possess all the properties of acetylphenylthiobenzamide, $C_6H_5.C.(N.C_6H_5.COCH_3):S$.

1 gram of metallic sodium was added to 9 grams of thiobenzanilide dissolved in 100 grams of dry xylene, and the mixture was heated for 15 hours in a flask provided with an inverted condenser over an oil

bath at the temperature of 110–120°. When the reaction ended, the whole contents were cooled, and 20 c.c. of 1 molar solution of acetyl chloride in xylene were gradually added from a burette. At first there deposited some phenylbenzimidio-thioacetate alone, then the solution getting orange red. Driving off xylene from the mother liquor by continually passing a current of dry air for several days, phenylbenzimidio-thioacetate was left as a residue together with some orange red isomer and colourless crystals. The whole residue, by treating with cold absolute alcohol, left the yellow crystals of phenylbenzimidio-thioacetate undissolved. The solubility, crystalline form and chemical properties of the substance show that it is identical with phenylbenzimidio-thioacetate, $C_6H_5.C.(SCO.CH_3):N.C_6H_5$, obtained from phenylbenzimidio-chloride and sodium thioacetate.

5. *Action of Potassium Thiobenzoate upon Phenylbenzimidio-chloride.*

By the action of potassium thiobenzoate upon phenylbenzimidio-chloride dissolved in dry petroleum ether in presence of anhydrous potassium carbonate at the ordinary temperature, there deposited some yellow compound at first, followed by the gradual increase of the depth of red colour of the mother liquor. Allowing the mixture to stand for a month, a lot of yellow compound was found to crystallize out together with some orange crystals. Two compounds were separated by the similar treatment as in the case of two analogous acetyl derivatives of thiobenzanilide mentioned before.

The orange red compound is soluble in common organic solvents, melts at 110–111° and decomposes into thiobenzanilide and benzoic acid by heating with dilute acid or alkali. The analysis of the substance gave the following value for sulphur :

0.2371 grm. substance gave 0.1684 grm. $BaSO_4$.

Calculated for		
$C_6H_5.C.(SCO.C_6H_5):N.C_6H_5$		
Sulphur	10.11	Found 9.76

Accordingly the orange red compound would be no doubt benzoyl-phenylthiobenzamide, and as the yellow one is similar to phenylbenzimidio-thioacetate in all respects, so it should be phenylbenzimidio-thiobenzoate, $C_6H_5.C.(SCO.C_6H_5):N.C_6H_5$.