crude material contained a trace of adenine which was readily removed by the one recrystallization. The nucleoside was then chromatographically homogeneous and travelled at R_{Ad} 1.44 in solvent A and R_{Ad} 0.76 in solvent B[12]; $[\alpha]_D^{28}$ −36.9° (0.4% in H_2O).

Anal. Calcd. for $C_{11}H_{15}N_5O_4$: C, 47.0; H, 5.38; N, 24.9. Found: C, 46.7; H, 5.35; N, 24.8.

The nucleoside, in agreement with structure XV, consumed 0.78 mole-equivalent of periodate in 66 hr. The rate curve was then approaching about 0.85 mole-equivalent asymptotically.

2,6-Diacetamido-9-(2′-O-acetyl-3′,5′-di-O-benzoyl-6′-deoxy-α-L-idofuranosyl)purine (XIII). Condensation of X, prepared from 2.50 g. (5.5 mmoles) of diacetate (VII), with 2.20 g. (4.69 mmoles) of chloromercuri-2,6-diacetamidopurine[11] as described for XI gave 2.47 g. (72%) of crude blocked nucleoside; λ_{max}^{film} 3.00, 3.10 μ (NH), 5.78 μ (ester C=O), 6.14, 6.22, 6.68, 6.85 μ (NH and aromatic rings), 7.80, 8.98 μ (benzoate C—O—C), 8.09 μ (acetate C—O—C), 9.10, 9.32, 9.72 μ (C—O—C).

2,6-Diamino-9-(6′-deoxy-α-L-idofuranosyl)purine (XIV). A solution of 2.47 g. (3.90 mmoles) of XIII in 20 ml. of reagent methanol was treated with 5 ml. of *N* methanolic sodium methoxide and heated at reflux for 3 hr. The solution was then processed to the picrate as described for XV. Recrystallization from 20 ml. of water gave 248 mg. of the picrate of XIV as yellow crystals, m.p. 195–205° (dec.). Regeneration to the free nucleoside with 2.0 g. of Dowex 2 (CO_3) and 10 ml. of water in the usual fashion[6,11] gave 102 mg. (6.5%) of a white solid, m.p. 184–190°. Recrystallization from ethanol afforded white crystals, m.p. 210–211°; λ_{max}^{KBr} 2.92, 3.08 μ (NH, OH), 6.10, 6.23, 6.60, 6.75 μ (NH and aromatic rings), 9.22, 9.42 μ (C—O); $[\alpha]_D^{27}$ −50.8° (1.0% in H_2O). Both the crude and recrystallized products were chromatographically homogeneous and travelled at R_{Ad} 0.88 in solvent A and R_{Ad} 0.36 in solvent B as compared with R_{Ad} 0.54 and R_{Ad} 0.39, respectively, for 2,6-diaminopurine.

Anal. Calcd. for $C_{11}H_{16}N_6O_4 \cdot {}^1/_2H_2O$: C, 43.2; H, 5.58; N, 27.5. Found: C, 43.2; H, 5.88; N, 27.6.

Acknowledgments. The authors owe thanks to Dr. Peter Lim for interpretation of the infrared spectra, to O. P. Crews, Jr., and group for large-scale preparation of intermediates, and to Dr. L. K. Moss and group for the chromatography, periodate data, and optical rotations.

MENLO PARK, CALIF.

[CONTRIBUTION OF THE FULMER CHEMICAL LABORATORY, THE STATE COLLEGE OF WASHINGTON]

Schiff Bases and Related Substances. IV. Reaction of Acyclic and Heterocyclic α-Amino Sulfides with Phenyl Isocyanate. Comparative Reactions with Phenyl Isothiocyanate[1]

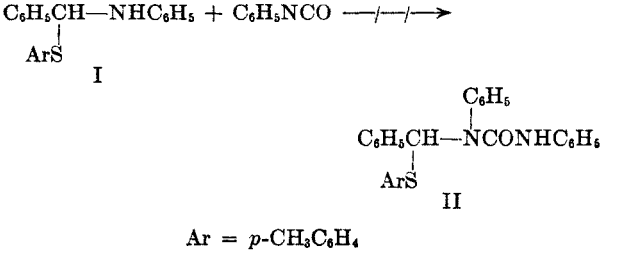
GARDNER W. STACY, PHILIP A. CRAIG,[2] AND RICHARD I. DAY[3]

Received March 12, 1958

When the Schiff base–thiol adduct, *N*-[α-(*p*-tolylthio)benzyl]aniline (I), is treated with phenyl isocyanate, none of the expected phenylurea derivative is obtained. Instead, the mercaptal, α,α-bis(*p*-tolylthio)toluene (III), *N*-benzylideneaniline (IV), carbanilide (V), and *p*-tolyl phenylthiolcarbamate (VI) are isolated from the reaction mixture. On the other hand, the adduct I fails to react with phenyl isothiocyanate under similar conditions. A possible explanation for the formation of the products III–VI is suggested. Related cyclic systems containing the S—C—NH group are shown to react with phenyl isocyanate to form phenylurea derivatives and none of the unusual behavior associated with the adduct I is observed. Phenyl isothiocyanate also reacts with most of the cyclic systems which were studied (the products in these cases are the corresponding phenylthiourea derivatives). However, in the case of 2,2-pentamethylenebenzothiazoline (XII), no reaction occurs with phenyl isothiocyanate under a variety of conditions, thus paralleling the result with I.

The reaction of the Schiff base–thiol adduct, *N*-[α-(*p*-tolylthio)benzyl]aniline (I), with acetylating agents has been shown to proceed only in part to give the expected acetyl derivative.[1] To a greater extent, cleavage of I occurred to yield acetanilide and the corresponding mercaptal III or *p*-tolyl disulfide. The behavior of I with phenyl isocyanate and phenyl isothiocyanate, respectively now has also been investigated and is reported in the present paper.

Unlike the acetylation reaction,[1] none of the corresponding *N*-acyl derivative (in this case the phenylurea derivative II) was isolated when I was heated with phenyl isocyanate; instead, a cleavage reaction occurred extensively to form the mercaptal



(1) Presented in part before the Oregon Section of the American Chemical Society, Salem, Ore., May 21, 1955, and in part before the Division of Organic Chemistry at the 132nd Meeting of the American Chemical Society, New York, N. Y., Sept. 10, 1957. Paper III. G. W. Stacy, R. I. Day, and R. J. Morath, *J. Am. Chem. Soc.*, **80**, 3475 (1958).

(2) To be presented in part as a thesis by Philip A. Craig in partial fulfillment of the requirements for the Degree of Master of Science, the State College of Washington.

(3) In part abstracted from a thesis submitted by Richard I. Day in partial fulfillment of the requirements for the degree of Doctor of Philosophy, the State College of Washington, June 1957.

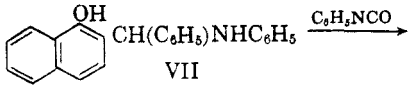
III, *N*-benzylideneaniline (IV), and carbanilide (V), all isolated in good yield. In addition, however, a small amount of *p*-tolyl phenylthiolcarbamate (VI) was isolated.

$$\text{I} \xrightarrow{C_6H_5NCO} \underset{\text{III}}{C_6H_5CH(SAr)_2} + \underset{\text{IV}}{C_6H_5CH{=}NC_6H_5} + \underset{\text{V}}{(C_6H_5NH)_2CO} + \underset{\text{VI}}{C_6H_5NHCOSAr}$$

The identity of VI followed from the elemental analysis and comparison with a sample of a synthetic product prepared directly from *p*-toluenethiol. Preparation or compound VI has been reported by Gilman and King;[4] these authors found that *p*-toluenethiol did not react directly with phenyl isocyanate but that VI could be obtained by employing *p*-tolylmercaptomagnesium iodide. However, since the recent work of Dyer and Glenn[5] had demonstrated that thiols will react with phenyl isocyanate if triethylamine is employed as catalyst, this direct method was applied successfully to the present independent preparation of VI. In an additional observation of interest, it was found that phenyl isothiocyanate reacts in a similar manner with *p*-toluenethiol under the influence of triethylamine.

Because of the catalytic effect of triethylamine on the reactions of *p*-toluenethiol with phenyl isocyanate and with phenyl isothiocyanate, it was questioned as to whether a different result from that already described might be observed if I were treated with phenyl isocyanate in the presence of triethylamine. And, indeed, under these conditions, products III and V were not obtained, while IV and VI were isolated in good yield as the exclusive products.

Although no previous studies of the reaction of phenyl isocyanate on Schiff base–thiol adducts, such as I, have been reported, Neri[6] observed a similar reaction with the secondary amine VII. However, this was an anomalous result in the work of this author, for he did obtain exclusively the phenylurea derivative corresponding to the 2-hydroxy-1-naphthyl isomer of VII,[6] as well as in several other instances,[6,7] whereas in no case have we been able to obtain the expected phenylurea derivatives in our work.



$$\underset{\text{V}}{(C_6H_5NH)_2CO} + \underset{\text{VIII}}{C_6H_5CH(C_{10}H_6OH\text{-}1,2)_2} + C_6H_5CHO$$

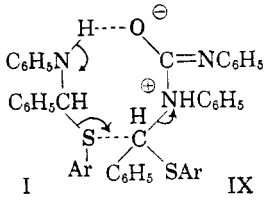
(4) H. Gilman and W. B. King, *J. Am. Chem. Soc.*, **47**, 1136 (1925).

(5) E. Dyer and J. F. Glenn, *J. Am. Chem. Soc.*, **79**, 366 (1957).

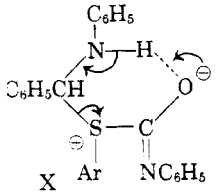
(6) A. Neri, *Gazz. chim. ital.*, **61**, 681, 815 (1931); *Chem. Abstr.*, **26**, 1277, 1922 (1932).

(7) A. Neri, *Gazz. chim. ital.*, **64**, 420 (1934); *Chem. Abstr.*, **28**, 6436 (1934).

An explanation of the formation of the products, III–V, as a result of the action of phenyl isocyanate on I, might involve the concerted interaction of the complex IX (formed from I and phenyl isocyanate) with a molecule of I.[8] The formation of VI, on the other hand, might result from complexing of phenyl isocyanate with the sulfur atom rather than the nitrogen atom of I with subsequent decomposition of the intermediate complex X into VI and *N*-benzylideneaniline (IV).



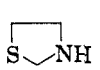
I IX



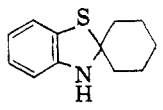
X

In order to determine if a less reactive reagent might react with I to form a derivative, rather than causing the decomposition that occurred in the case of phenyl isocyanate, I was treated with phenyl isothiocyanate. However, no reaction was observed under a variety of conditions.

Because of the unusual results obtained when I was treated with phenyl isocyanate and with phenyl isothiocyanate, it seemed desirable to study the action of these reagents on some better known systems containing the S-C-NH group. Because such known systems are cyclic, it seemed that they very likely would not decompose in the same manner as I but would tend to form phenylureas and phenylthioureas with the reagents in question.[9] Further, the possibility of obtaining some qualitative information on comparative reactivities was apparent. The two cyclic systems of primary interest were thiazolidine (XI) and the benzothiazoline derivative XII, recently reported by Kiprianov and Portnyagina;[10] the latter compound is, of course, even more closely related to I because of the attachment of S and N to a benzene ring. It was found



XI



XII

that XI reacted rapidly and smoothly with phenyl isocyanate in anhydrous ether to give in contrast to I the expected phenylurea derivative. The closely

(8) A stepwise process, as discussed in Paper III (ref. 1), is also to be considered, and *vice versa*. The explanations presented are not necessarily intended to be proposals of reaction mechanisms but rather interpretations of product formation based on the possible interaction of logical reactive centers. A convincing case for any specific mechanism would, of course, require more extensive experimentation.

(9) With one exception, these derivatives are new compounds.

(10) A. I. Kiprianov and V. A. Portnyagina, *J. Gen. Chem.* (*U.S.S.R.*), English translation, **25**, 2223 (1955).

related thiazolidine-4-carboxylic acid did not react so smoothly, but gave a hydantoin in low yield. The benzothiazoline XII did not react in ether with phenyl isocyanate, so that it was necessary to remove the ether and heat the mixture to obtain the phenylurea derivative. The same diminished reactivity was observed in the case of the adduct I when the reaction was attempted in ether, and a substantial amount of the starting material I was recovered.

As might have been anticipated, phenyl isothiocyanate proved to be less reactive than phenyl isocyanate. Although it reacted in good yield with both thiazolidine (XI) and thiazolidine-4-carboxylic acid to give the expected products, it failed to react with either I or XII under a variety of conditions. These results raise a question concerning the influence of various factors in diminishing the nucleophilic character of the nitrogen atom in these conpounds. By a comparison of the yields of phenylurea and phenylthiourea derivatives obtained for thiazolidine and pyrrolidine, it was suggested that the α-sulfide group has an effect on the nitrogen atom. Thiazolidine forms a phenylurea derivative in 66% yield and a phenylthiourea derivative in a 73% yield, while pyrrolidine forms the same derivatives in higher yields, 85% and 95%, respectively.[11] An even more dramatic demonstration of the effect, however, was noted by the fact that *o*-methylthioaniline (XIII) reacted readily with phenyl isothiocyanate, while the benzothiazoline XII had not. Phenyl isocyanate also reacted readily with XIII; however, the difference in the reactivity of this reagent with this compound, as compared with I and XII, is not as great as in the case of phenyl isothiocyanate. For structure XIII, of course, the sulfide group is not *alpha* relative to the nitrogen atom and hence cannot exercise the same effect as with I or XII.

EXPERIMENTAL[12]

Reaction of N-[α-(p-tolylthio)benzyl]aniline (I) *with phenyl isocyanate. A. Without catalyst.*[13] A mixture of 3.05 g. (10 mmoles) of I[14] and 0.54 ml. (596 mg., 5 mmoles) of phenyl isocyanate was heated at 90° for 20 min. in an oil bath. Then 20 ml. of ligroin (b.p. 100–110°) was added, and heating was resumed for an additional 10 min. The hot ligroin solution was removed from the solid remaining in the flask by means of a filter stick. The solid was washed with two 3-ml. portions of ligroin, and these were added to the main ligroin solution. The solid which had separated proved to be *carbanilide* (V); yield 655 mg. (72%[15]), m.p. 243–243.5°, lit.[16] m.p. 238–239°, mixed m.p. 242–243.5°.

The ligroin solution which had been separated from the carbanilide was cooled, whereupon a yellow, crystalline solid, which was identified as *p-tolyl phenylthiolcarbamate* (VI), precipitated; yield 272 mg., m.p. 130–131.5°. Recrystallization from ethanol gave 192 mg. of colorless platelets (16%), m.p. 133.5–134.5°, lit.[4] m.p. 127°.

Anal. Calcd. for $C_{14}H_{13}NOS$: C, 69.10; H, 5.38; N, 5.76. Found: C, 69.40; H, 5.51; N, 5.58.

The ligroin filtrate from VI was shaken with two drops of water to convert any unreacted phenyl isocyanate to carbanilide; 13 mg. of material was obtained and discarded. Then 11 ml. of 5% ethanolic potassium hydroxide solution was added to the ligroin solution to convert unreacted adduct to mercaptide and Schiff base. This mixture was extracted with 25 ml. of water; the resulting aqueous extract was acidified with hydrochloric acid and in turn was extracted with one 20-ml. and two 10-ml. portions of ether. The ether extracts, which contained *p*-toluenethiol, were dried over Drierite, and the ether was then removed by evaporation to give a 10-ml. volume of residue. By an iodine–thiosulfate titration, 1.50 mmoles of thiol were shown to be present.

The ligroin solution remaining after the above extraction procedure was subjected to distillation to remove most of the ligroin; the residue then was steam distilled until about 300 ml. of distillate had been collected. The distillate was extracted with one 40-ml. portion and two 20-ml. portions of ether. The solvent was removed from the combined, dried extracts to give 713 mg. of a residual oil. This was crystallized from ligroin to give 476 mg. of *N-benzylideneaniline* (IV), m.p. 49–50.5°, lit.[17] m.p. 53.5°.

The material remaining in the steam distillation flask was extracted with one 20-ml. and two 10-ml. portions of ether. The combined extracts were dried, and the ether was removed by evaporation to yield 1.43 g. of the mercaptal, *α,α-bis(p-tolylthio)toluene* (III). This material was recrystallized from ethanol to yield 786 mg. (55%); m.p. 79–79.5°, lit.[18] m.p. 79°, mixed m.p. 79.5–80°.

B. In ether solution. Phenyl isocyanate (596 mg., 5 mmoles) was added dropwise to 3.05 g. (10 mmoles) of I in 50 ml. of absolute ether. When the ether was evaporated and the residue was recrystallized from 2-propanol, 1.04 g. (34%) of starting material was recovered.

C. With triethylamine as catalyst.[5] Quantities of reactants were identical as in Procedure A; however, 2–3 drops of triethylamine were added. The reaction mixture was heated for 15 min. on a steam bath; then 15 ml. of ligroin (b.p. 100–110°) was added, and heating was resumed for an additional 15 min. The hot ligroin solution was decanted from the insoluble residue, the residue was washed with two 2-ml. portions of ligroin, and the washings were added to the main portion of ligroin. The insoluble residue, 1.26 g., m.p. 119–123°, and the material which precipitated from the ligroin solution, 1.11 g., m.p. 90–110°, were combined and recrystallized twice from ethanol to give fairly pure VI; yield 1.21 g. (50%), m.p. 124–127°, mixed m.p. 128–131°.

The ligroin filtrate was seeded with a crystal of *N*-benzylideneaniline and maintained at −20°. Crude *N*-benzylidene-

(11) A comparison of the acidic and basic dissociation constants of thiazolidine-4-carboxylic acid and proline, as obtained by S. Ratner and H. T. Clarke, *J. Am. Chem. Soc.*, **59**, 200 (1937), also demonstrates the effect of the α-sulfide group in lessening the nucleophilic character of the nitrogen atom.

(12) All melting points are corrected. The microanalytical work was performed by Galbraith Laboratories, Knoxville, Tenn., and by Weiler and Strauss Laboratories, Oxford, England. In most cases, experiments were carried out in duplicate and the agreement between results was good.

(13) Some preliminary aspects of this experiment were carried out by Richard J. Morath, Ph.D. received from the State College of Washington, February 1954.

(14) Prepared in yields of 85–90% by a method previously described, G. W. Stacy, R. I. Day, and R. J. Morath, *J. Am. Chem. Soc.*, **77**, 3869 (1955).

(15) The percentage yield of each product is adjusted for the amount of unreacted adduct as determined by alkaline decomposition and iodine titration (subsequently described).

(16) G. Young and E. Clark, *J. Chem. Soc.*, **73**, 361, 367 (1898).

(17) G. Pyl, *Ber.*, **60**, 287 (1927).

(18) E. Fromm and G. Raiziss, *Ann.*, **374**, 90, 101 (1910).

aniline (IV) crystallized; yield 1.23 g. (68%), m.p. 44–47°, mixed m.p. 48–49°.

p-Tolyl phenylthiolcarbamate (VI) *from p-toluenethiol.* To 1.24 g. (0.01 mole) of *p*-toluenethiol and 1.19 g. (1.09 ml., 0.01 mole) of phenylisocyanate was added 2–3 drops of triethylamine.[5] A crystalline mass formed immediately with a considerable evolution of heat. Recrystallization from ethanol gave colorless crystals; yield 2.10 g. (87%), m.p. 132–132.5°. Admixture of this substance with that isolated in the preceding experiment resulted in no depression in melting point, m.p. 130–131°.

p-Tolyl phenyldithiocarbamate. To a mixture of 1.24 g. (0.01 mole) of *p*-toluenethiol and 1.35 g. (1.20 ml., 0.01 mole) of phenyl isothiocyanate was added 2–3 drops of triethylamine. The crude product, obtained in quantitative yield, was recrystallized from ethanol to give 2.54 g. (98% yield) of colorless needles, m.p. 141–141.5°.

Anal. Calcd. for $C_{14}H_{13}NS_2$: C, 64.82; H, 5.05; S, 24.73. Found: C, 64.77; H, 5.03; S, 24.74.

Attempted reaction of N-[α-(p-tolylthio)benzyl]aniline (I) *with phenyl isothiocyanate.* After preliminary experiments in anhydrous ether showed no perceptible reaction had occurred [by virtue of recovery of starting material (67%)], the following procedure, as employed above with phenyl isocyanate, was attempted. A mixture of 3.05 g. (0.01 mole) of I and 1.35 g. (1.20 ml., 0.01 mole) of phenyl isothiocyanate was heated on a steam bath for 15 min.; 15 ml. of ligroin (b.p. 100–110°) was added, and heating was continued for an additional 15 min. From the ligroin solution, 2.70 g. (89% recovery) of starting material I was obtained, m.p. 63–66°. Recrystallization of this material from 2-propanol gave 2.22 g. (73% recovery) of relatively pure I, m.p. 68–70°.

Phenylurea of thiazolidine (XI). To 890 mg. (0.78 ml., 0.01 mole) of thiazolidine[19] in 25 ml. of absolute ether was added dropwise with stirring 1.19 g. (1.09 ml., 0.01 mole) of phenyl isocyanate dissolved in 25 ml. of absolute ether. As the addition was begun, a crystalline material began to precipitate immediately. When the addition was complete, the product was removed by filtration, yield 1.37 g. (66%), m.p. 129–130.5°. Recrystallization from ethanol gave 550 mg. (26% yield) of colorless plates, m.p. 131.5–132.5°.

Anal. Calcd. for $C_{10}H_{12}N_2OS$: C, 57.66; H, 5.81; N, 13.45. Found: C, 57.88; H, 5.76; N, 13.73.

Phenylthiourea of thiazolidine (XI). To 890 mg. (10 mmoles) of thiazolidine in 25 ml. of absolute ether was added dropwise with stirring 1.35 g. (10 mmoles) of phenyl isothiocyanate dissolved in 25 ml. of absolute ether. The ensuing reaction yielded 1.66 g. (74%) of colorless plates, m.p. 161.5–162.5°. Recrystallization from ethanol gave 1.27 g. (57%), m.p. 166–167°.

Anal. Calcd. for $C_{10}H_{12}N_2S_2$: C, 53.53; H, 5.39; N, 12.49. Found: C, 53.63; H, 5.61; N, 12.56.

Phenylhydantoin derivative of thiazolidine-4-carboxylic acid. To 1.33 g. (0.01 mole) of thiazolidine-4-carboxylic acid[11] dissolved in 9.5 ml. of *N* sodium hydroxide solution was added dropwise with stirring 2.98 g. (0.025 mole) of phenyl isocyanate (sufficient *N* sodium hydroxide solution was added simultaneously to maintain an alkaline reaction mixture). The carbanilide which formed was removed by filtration, and the filtrate was acidified with *N* hydrochloric acid to a *p*H of 3. The hydantoin derivative, which crystallized from solution, was obtained in a yield of 430 mg. (18%), m.p. 152–154°. Recrystallization from 2:1 aqueous ethanol gave 300 mg. (13%), m.p. 153.5–154°.

Anal. Calcd. for $C_{11}H_{10}N_2O_2S$: C, 56.39; H, 4.30; S, 13.69. Found: C, 56.13; H, 4.20; S, 13.10.

Phenylthiohydantoin derivative of thiazolidine-4-carboxylic acid. To 1.33 g. (0.010 mole) of thiazolidine-4-carboxylic acid in 9.5 ml. of *N* sodium hydroxide solution was added slowly 1.43 g. (0.011 mole) of phenyl isothiocyanate. It was necessary to shake the reaction mixture for 60 hr. on a mechanical shaker before the reaction appeared complete. Insoluble material was removed by filtration, and the filtrate was acidified with *N* hydrochloric acid to *p*H 2–3. The resulting product was removed by filtration to give 1.73 g. (69% yield), m.p. 190.5–193.5°. Two recrystallizations from ethanol gave 1.08 g. (43%), m.p. 196–197.5°.

Anal. Calcd. for $C_{11}H_{10}N_2OS_2$: C, 52.77; H, 4.03; N, 11.19; S, 25.62. Found: C, 52.83; H, 4.05; N, 11.18; S, 25.45.

A second method, which has been employed by Edman[20] for the preparation of thiohydantoins, gave a better yield. To 1.33 g. (0.01 mole) of thiazolidine-4-carboxylic acid in a solution of 25 ml. of pyridine and 25 ml. of water was added sufficient *N* sodium hydroxide solution to adjust the *p*H to 9. The mixture was warmed to 40°, and 2.86 g. (0.021 mole) of phenyl isothiocyanate was added with stirring over a period of 1.5 hr. The resulting reaction mixture was extracted with eight 25-ml. portions of benzene to remove pyridine and excess phenyl isothiocyanate. The reaction mixture was acidified to a *p*H of 3, and the precipitated product removed by filtration; yield 2.06 g. (90%), m.p. 192.5–194.5°.

2,2-Pentamethylenebenzothiazoline (XII). This substance was obtained by heating under reflux for 1 hr. on a steam bath a mixture of 2.20 g. (0.0175 mole) of *o*-aminobenzenethiol[21] and 1.76 g. (0.018 mole) of cyclohexanone.[10] Upon cooling, the reaction mixture formed a crystalline mass; this was recrystallized from ethanol to give colorless needles; yield 2.77 g. (77%), m.p. 111–112°, lit.[10] m.p. 111–112°.

Phenylurea of XII. Initially, the reaction of 1.03 g. (5 mmoles) of XII in 25 ml. of absolute ether and 740 mg. (6.22 mmoles) of phenyl isocyanate in an equal volume of ether was attempted. Since no reaction seemed apparent because of the lack of the usual precipitate forming immediately in the solution, the ether was removed, and the reactants heated directly. Under these conditions, a crude, crystalline product formed and was recrystallized from ethanol to give 1.14 g. (70% yield) of long needles, m.p. 155.5–156.5°.

Anal. Calcd. for $C_{19}H_{20}N_2OS$: C, 70.34; H, 6.21; N, 8.64. Found: C, 70.23; H, 6.18; N, 8.90.

Attempted phenylthiourea formation from XII. Several different sets of conditions were employed using equivalent amounts of XII and phenyl isothiocyanate. In all of these attempts, reaction failed to take place, as demonstrated by a good recovery of XII: (1) Reactants stirred in ether solution, recovery 74%. (2) Reactants heated under reflux in benzene solution, recovery 65%. (3) Reactants heated on a steam bath without solvent, recovery 93%. (4) Reactants heated on a steam bath without solvent but with 2–3 drops of triethylamine added as catalyst, recovery 84%.

Phenylurea of pyrrolidine. To 1.00 g. (0.014 mole) of pyrrolidine in 50 ml. of absolute ether was added dropwise with stirring 2.08 g. (0.018 mole) of phenyl isocyanate. A colorless, crystalline precipitate formed immediately and was collected by filtration; yield 2.31 g. (85%), m.p. 134.5–135.5°, lit.[22] m.p. 133–134°.

Phenylthiourea of pyrrolidine. From 1.00 g. (0.014 mole) of pyrrolidine in 50 ml. of absolute ether and 2.38 g. (0.018 mole) of phenyl isothiocyanate was obtained an extremely pure product as fine needles (no recrystallization was required); yield 2.76 g. (95%), m.p. 123–124°. The analytical sample was dried *in vacuo* over phosphorus pentoxide for 2 hr. at room temperature.

Anal. Calcd. for $C_{16}H_{14}N_2S$: C, 64.05; H, 6.84; N, 13.58. Found: C, 64.13; H, 6.81; N, 13.50.

(19) Prepared by the method of Ratner and Clarke (ref. 11); the starting material, mercaptoethylamine hydrochloride (96%), was obtained from Evans Chemetics, Inc., 250 E. 43rd St., New York, N. Y.

(20) P. Edman, *Acta Chem. Scand.*, 4, 277 (1950).

(21) American Cyanamid Co., New York, N. Y.

(22) R. A. Henry and W. M. Dehn, *J. Am. Chem. Soc.*, 71, 2297 (1949).

Drying conditions were critical, for if the sample were dried at 95° for 14 hr., the product was converted to a different substance, m.p. 150–151°. This substance was not investigated further.

Anal. Found: C, 64.36; H, 6.95; N, 14.70.

o-Methylthioaniline (XIII). A mixture of 25.0 g. (0.21 mole) of *o*-aminobenzenethiol,[21] 28.4 g. (0.20 mole) of methyl iodide, and 10 g. of sodium hydroxide in 100 ml. of 50% ethanol was heated under reflux with stirring for 45 min. A major part of the ethanol was removed by distillation, and the resulting solution was extracted with ether. The combined ether extracts were washed with several portions of water to remove sodium iodide and then dried over Drierite. After the ether had been removed by distillation, the residual oil was distilled to give 15.7 g. (57% yield) of a light yellow, foul smelling liquid; b.p. 124° (14 mm.), n_D^{25} 1.6220, d_4^{25} 1.115, lit.[23] b.p. 234°. As the original report[23] of this compound did not include an analysis, this was carried out in respect to the present sample.

Anal. Calcd. for C_7H_9NS: C, 60.39; H, 6.52; S, 23.03. Found: C, 60.52; H, 6.38; S, 23.15.

Phenylurea of XIII. From the reaction of 1.39 g. (0.01 mole) of *o*-methylthioaniline with 1.19 g. (0.01 mole) of phenyl isocyanate, by heating the mixture on a steam bath as previously described, was obtained 2.48 g. (86% yield) of a crystalline product, m.p. 126–127°. Recrystallization from ethanol gave fine needles, yield 2.19 g. (85%), m.p. 129–131°. The analytical sample, prepared by a second recrystallization from ethanol, melted at 132.5–134°.

Anal. Calcd. for $C_{14}H_{14}N_2OS$: C, 65.09; H, 5.46; N, 10.85. Found: C, 65.13; H, 5.39; N, 10.82.

Phenylthiourea of XIII. The same procedure was followed as for the phenylurea except that 1.35 g. (0.01 mole) of phenyl isothiocyanate was used; yield 2.44 g. (89%), m.p. 168–169°. Recrystallization from ethanol gave 1.28 g. (47% yield) of fine needles, m.p. 168–168.5°.

Anal. Calcd. for $C_{14}H_{14}N_2S_2$: C, 61.28; H, 5.14; N, 10.21. Found: C, 61.23; H, 5.16; N, 9.98.

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PULLMAN, WASH.

(23) A. W. Hofman, *Ber.*, **20**, 1788 (1887).

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY OF THE UNIVERSITY OF TENNESSEE]

Benzilic Acid Rearrangement of Carbon-14 Labeled 2-Methylbenzil

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2-Methylbenzil has been synthesized specifically labeled with carbon-14 in the carbonyl group adjacent to the unsubstituted phenyl ring. Rearrangement of the labeled 2-methylbenzil produces 2-methylbenzilic acid with over 97% of the labeling in the carboxyl group, indicating that in the rearrangement the unsubstituted phenyl group migrates almost exclusively. The relationship of this finding to the mechanism of the benzilic acid rearrangement is briefly discussed.

In connection with another problem[1] it was necessary to prepare 2-methylbenzil. Because of recent interest in the rearrangement of benzils,[2] the 2-methylbenzil prepared was labeled with carbon-14 and its benzilic acid rearrangement was examined.

Labeling of 2-methylbenzil with carbon-14 adjacent to the unsubstituted ring was effected by standard reactions shown in Chart I. The 2-methyldesoxybenzoin (I) intermediate in this preparation had not been previously prepared and was characterized by its reduction to a carbinol and also by its conversion to a 2,4-dinitrophenylhydrazone. The specificity of the labeling of the 2-methylbenzil (II) was checked by addition of phenylmagnesium bromide to this compound

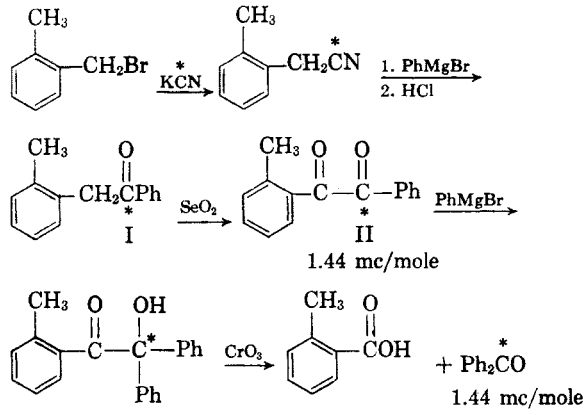

Chart I

followed by oxidation of the resulting α-phenyl-2-methylbenzoin[1] to *o*-toluic acid devoid of radioactivity and benzophenone of the same molar radioactivity as the 2-methylbenzil (II).

Rearrangement of the labeled 2-methylbenzil in the usual manner afforded in good yield 2-methylbenzilic acid (III) of the same molar radioactivity as the benzil (II). The labeled acid (III) was oxidized with chromium trioxide to 2-methyl-

(1) J. F. Eastham, J. E. Huffaker, V. F. Raaen, and C. J. Collins, *J. Am. Chem. Soc.*, **78**, 4823 (1956).

(2) (a) W. von E. Doering and R. S. Urban, *J. Am. Chem. Soc.*, **78**, 5938 (1956); (b) M. T. Clark, E. C. Hendley, and O. K. Neville, *J. Am. Chem. Soc.*, **77**, 3280 (1955); (c) D. B. Ott and G. G. Smith, *J. Am. Chem. Soc.*, **77**, 2325, 2342 (1955); (d) J. D. Roberts, D. R. Smith, and C. C. Lee, *J. Am. Chem. Soc.*, **73**, 619 (1951); (e) W. von E. Doering, T. I. Taylor, and E. F. Schoenwaldt, *J. Am. Chem. Soc.*, **70**, 445 (1948).