tion was filtered off, and the filtrate lyophilized. Approximately 20 g. of an amorphous hygroscopic product was obtained. The product was added to 100 ml. of glacial acetic acid, heated to 95° and kept warm until crystalline. After cooling to room temperature, the product (18 g.) was filtered off and was washed several times with ether. The compound was recrystallized as bundles of microscopic needles from approximately 50 times its weight of hot glacial acetic acid. The compound is assumed to be the acetic acid salt of S-cysteinosuccinic acid.

*Anal.* Calcd. for $C_9H_{15}NO_8S$: C, 36.47; H, 5.05; N, 4.88; S, 10.78. Found: C, 35.90; H, 5.10; N, 4.85; S, 10.77.

After drying over $CaCl_2$ and KOH for two weeks, the total acid equivalency of a sample based on a mol. wt. of 297 was 2.88 (theory 3.0), equivalents volatile acid 0.85 (theory 1.0), and equivalents non-volatile acid (calculated) was 2.03 (theory, 2.00). Upon heating the crystals became moist at 118 to 120°; they contract from 120 to 124°, and then swell until they decompose with bubbling at 132 to 134°. The compound is very soluble in ethanol and water but only slightly soluble in ether. It gives a negative —SH or —S—S— spot test but a positive test for thioether[5] and a positive ninhydrin test for amino acids.

Although the addition of sterile fumaric acid to agar media containing cysteine stimulates growth of small inocula of the yeast phase of *Histoplasma capsulatum* on agar media,[6] the addition of the S-cysteinosuccinic acid salt instead of fumaric acid has no effect. In liquid media the compound does not substitute for the cysteine requirement.

**Acknowledgment.**—Appreciation is expressed for the helpful suggestions given by Dr. Evan C. Horning for the isolation and identification of the fumarate–cysteine addition compound.

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(6) L. Pine, unpublished results.

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## 3,4,5-Triiodobenzoyl Chloride as a Reagent for Identifying Mercaptans

BY DAVID C. O'DONNELL, HENRY A. MARIANI AND DENIS J. DOWNING[1]

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We have reported previously[2,3] the use of 3,4,5-triiodobenzoyl chloride for the identification of cellosolves, carbitols and alcohols. The increasing use of mercaptans has prompted us to extend the use of this acid chloride to the identification of these compounds. The acid chloride was prepared by the method previously described.[4] All of the mercaptans were obtained commercially.

### Experimental

With all but two of the mercaptans, 1 ml. of the mercaptan was added to 1 g. of the acid chloride in a 15-cm. test-tube and gently heated with a micro-burner for 10 minutes. Methyl and isopropyl mercaptans, because of their low boiling points, were treated differently. In these two cases 1 g. of the acid chloride was dissolved in 50 ml. of ether, 1 g. of the mercaptan added and the solution was allowed to stand for 10 minutes. It was then heated for 5 minutes, the ether evaporated and the residue crystallized from a solvent. The lower molecular weight thioesters were crystallized from 40 ml. of either methyl or ethyl alcohol. The higher molecular weight aliphatic and the aromatic thioesters were crystallized from 20 ml. of *n*-butyl alcohol and after filtration the crystals were washed with a small amount of ether. All of the derivatives crystallized in the form of fine white needles with the exception of the two noted in Table I. All melting points are corrected.

TABLE I

THIOESTERS OF 3,4,5-TRIIODOBENZOIC ACID

| Mercaptan used | M.p., °C. | Yield, % | Formula | Iodine, % Calcd. | Found |
|---|---|---|---|---|---|
| Methyl | 153.6–154.6[a] | 43 | $C_8H_5OSI_3$ | 71.85 | 71.56 |
| *n*-Propyl | 97.8–98.8[a] | 37 | $C_{10}H_9OSI_3$ | 68.24 | 68.38 |
| Isopropyl | 153.4–155[a] | 28 | $C_{10}H_9OSI_3$ | 68.24 | 68.40 |
| *n*-Butyl | 90–91.4[a] | 48 | $C_{10}H_{11}OSI_3$ | 66.57 | 66.96 |
| Isobutyl | 89.8–90.8[a] | 37 | $C_{11}H_{11}OSI_3$ | 66.57 | 66.39 |
| *n*-Amyl | 83.2–84.4[b,d] | 34 | $C_{12}H_{13}OSI_3$ | 64.97 | 64.63 |
| *n*-Hexyl | 64.3–65.2[b] | 49 | $C_{13}H_{15}OSI_3$ | 63.63 | 63.63 |
| *n*-Heptyl | 70–70.8[b] | 41 | $C_{14}H_{17}OSI_3$ | 62.00 | 62.13 |
| *n*-Octyl | 67–68.2[b] | 46 | $C_{15}H_{19}OSI_3$ | 60.61 | 60.50 |
| *n*-Nonyl | 70–70.8[c] | 64 | $C_{16}H_{21}OSI_3$ | 59.29 | 59.03 |
| *n*-Decyl | 76–77.2[b] | 55 | $C_{17}H_{23}OSI_3$ | 58.04 | 58.09 |
| *n*-Undecyl | 78.6–79.8[c] | 63 | $C_{18}H_{25}OSI_3$ | 56.81 | 57.08 |
| *n*-Dodecyl | 78.4–78.8[c] | 53 | $C_{19}H_{27}OSI_3$ | 55.65 | 55.59 |
| *n*-Tetradecyl | 86.4–87.4[c,e] | 39 | $C_{21}H_{31}OSI_3$ | 53.46 | 53.76 |
| Hexadecyl | 91.0–91.8[c] | 62 | $C_{23}H_{35}OSI_3$ | 51.48 | 51.65 |
| *o*-Thiocresol | 98.4–99.0[c] | 30 | $C_{14}H_9OSI_3$ | 62.83 | 62.44 |
| Benzyl | 116.2–117.0[c] | 60 | $C_{14}H_9OSI_3$ | 62.83 | 62.88 |
| β-Phenylethyl | 99.8–100.6[c] | 63 | $C_{15}H_{11}OSI_3$ | 61.41 | 61.62 |
| α-Phenylpropyl | 133.4–134.2[c] | 59 | $C_{16}H_{13}OSI_3$ | 60.05 | 59.83 |

[a] Methyl alcohol as solvent. [b] Ethyl alcohol as solvent. [c] *n*-Butyl alcohol as solvent. [d] White plates. [e] White granules.

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(1) Taken from theses submitted in partial fulfillment for the M.S. degree.
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(3) D. O'Donnell, J. Kelley, R. O'Malley and R. Upham, *ibid.*, **70**, 1657 (1948).
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## Preparation of Pure 2-Aminonitropyridines and 2-Aminonitropicolines. Rapid Separations by Sublimation

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Considerable information exists on the nitration of 2-aminopyridine and the 2-aminopicolines. However, there is reported no simple, rapid method of separating the isomeric nitroamines of the pyridine series. This paper gives the results of a study of sublimation as a means of rapid, clean separation.

Separation of aminonitropyridine has been accomplished by steam distillation and fractional crystallization.[2a,b,3] In some instances, no attempt at separation was made until the mixture of isomers had completed a series of additional reactions after which one modified isomer was recovered and the other lost.[2,3]

Separation by sublimation seemed feasible since a vicinal nitroamine is capable of chelation with a resulting increase in molecular symmetry and vapor

(1) From a thesis submitted to the faculty of Allegheny College in partial fulfillment of the requirements for the M.S. degree, June, 1954.
(2) (a) A. E. Chichibabin and B. A. Razorenov, *J. Russ. Phys. Chem. Soc.*, **47**, 1286 (1915); *J. Chem. Soc.*, **108**, I, 992 (1915); (b) W. T. Caldwell and E. C. Kornfeld, THIS JOURNAL, **64**, 1695 (1942).
(3) M. A. Phillips, *J. Chem. Soc.*, 13 (1941).

pressure while any other nitroamine would be capable only of intermolecular hydrogen bonding.

Experiment showed that sublimation was effective in separating the isomers at 120° without decomposition. When a gentle current of air was drawn through the sublimation tube, separation time was reduced to four to six hours. Since temperatures higher than are obtainable in steam distillation are used and the product is obtained nearly pure and dry, sublimation furnishes a more rapid and elegant method for the separation of aminonitropyridines. The apparatus for this work has been described.[4]

Table I summarizes the information obtained on total yield and percentage of each isomer obtained from the nitration of 2-aminopyridine, 2-amino-3-methylpyridine, 2-amino-4-methylpyridine, 2-amino-5-methylpyridine and 2-amino-6-methylpyridine. The nitration and separation of isomers was carried out as described in the Experimental portion of the paper. No claim of originality in the nitration procedure is made, the aim being to combine what proved to be the most useful steps in already published work.[1-3,5-7] In this way, a general method of syntheses for compounds of this type has been devised.

TABLE I

NITROAMINES PREPARED

| Starting pyridine | Isomeric nitro product | M.p., °C. | Yield, % Individual | Total |
|---|---|---|---|---|
| 2-Amino | 3-Nitro | 163–164 | 20.0 | |
| | 5-Nitro | 188 | 63.1 | 83.1 |
| 2-Amino-3-methyl | 5-Nitro | 255 | 90.0 | 90.0 |
| 2-Amino-4-methyl | 3-Nitro | 134–136 | 22.3 | |
| | 5-Nitro | 220 | 47.3 | 69.6 |
| 2-Amino-5-methyl | 3-Nitro | 190 | 33.5 | 33.5 |
| 2-Amino-6-methyl | 3-Nitro | 141 | 24.2 | |
| | 5-Nitro | 187 | 46.4 | 70.6 |

### Experimental

**Nitration Procedure.**—As indicated, this method was used for 2-aminopyridine and all the 2-aminopicolines. 2-Aminopyridine (25.3 g., 0.27 mole) was dissolved cautiously in 50 ml. of concd. sulfuric acid (d. 1.84). Vigorous stirring and cooling were used to keep the temperature below 20°. To this solution, cooled to 5–10°, was added dropwise 40 ml. of a 1:1 mixture of concd. sulfuric acid (d. 1.84) and concd. nitric acid (d. 1.42). During this addition, solution temperature was maintained below 20°.

If the intermediate pyridylnitramine was desired, the solution was poured over ice at this point and the pyridylnitramine (m.p. 185–189° dec.) collected.

If the nitroamines were desired, the solution was warmed cautiously. At 35–40°, the exothermic rearrangement of the nitramine to nitroamines caused a sudden increase in temperature. When this initial rise had subsided, the solution was held at 50° for four hours to complete the rearrangement.

The solution was then poured over ice and neutralized with concd. ammonia (250 ml., d. 0.90). The precipitate of 2-amino-3-nitropyridine and 2-amino-5-nitropyridine was collected by suction filtration and dried in a vacuum oven at 70°.

**Sublimation.**—The apparatus used and its operation has been described.[4] A charge of 20–60 g. can be handled. Six hours is generally sufficient for complete separation.

When the separation is complete, the residual isomer can be recrystallized from dilute alcohol and the sublimed isomer washed out of the condensing tube with acetone and the acetone evaporated to give a pure crystalline product.

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## Hydroxymethylene Ketones. IV. Orientation in the Condensation of Methyl *n*-Hexyl Ketone with Methyl Formate

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In continuation of our investigations concerning the condensation of unsymmetrical ketones with formic esters,[2] it was decided to determine the manner in which methyl *n*-hexyl ketone condenses with methyl formate.

We have shown in the present work that methyl *n*-hexyl ketone condenses with methyl formate in ether solution in the presence of sodium methoxide at *both* the methyl and the methylene units to give the isomeric hydroxymethylene ketones I and II.[3] The presence of both I and II in the condensation product was shown by ultimate conversion of I to α-*n*-amylcrotonaldehyde (IX) and II to α-nonenaldehyde (X) by the reaction sequence of Chart 1. The mixed sodium salts of the hydroxymethylene ketones I and II were treated with methanolic hydrogen chloride according to the procedure of Royals and Brannock[4] to give a reaction product probably consisting of the isomeric β-ketoacetals III and V and the methoxymethylene ketone IV. Reduction of the mixture with lithium aluminum hydride followed by treatment of the resulting mixture (probably containing VI, VII and VIII) with aqueous sulfuric acid gave a mixture of α-*n*-amylcrotonaldehyde (IX) and α-nonenaldehyde (X). The aldehyde mixture was separated by fractional distillation into three fractions constituting 40, 12 and 48% of the distilled aldehydes. The lower boiling fraction was identified as α-*n*-amylcrotonaldehyde by the preparation of the semicarbazone, m.p. 169°, which showed no m.p. depression on admixture with an authentic sample, m.p. 170°. The higher boiling fraction was identified as α-nonenaldehyde by the preparation of a semicarbazone, m.p. 163°, which showed no depression on admixture with an authentic sample, m.p. 164–165°. A mixture of the semicarbazones from the lower and higher boiling fractions showed m.p. 137–150°.

The formation of α-*n*-amylcrotonaldehyde in appreciable amounts from the above reaction sequence was rather unexpected. Despite the above evidence from m.p.'s of semicarbazones, it seemed de-

(1) Abstracted from a thesis presented by E. R. Covington to the Graduate Faculty of Emory University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1954.

(2) See Papers I, II and III, E. E. Royals and K. C. Brannock, THIS JOURNAL, **76**, 3041 (1954), for previous work in this field.

(3) It is known that the results of condensations between esters and ketones are dependent upon the experimental conditions, the nature of the ester, and the type of basic catalyst used. See, for example, R. P. Mariella, *ibid.*, **69**, 2670 (1947); R. Levine, J. A. Conroy, J. T. Adams and C. R. Hauser, *ibid.*, **67**, 1512 (1945).

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