Anal.[7,8] Calcd. for $C_4H_9O_3PSNa_2$: C, 22.43; H, 4.24; S, 14.97. Found: C, 22.17; H, 4.56; S, 14.76.

An average of five iodometric determinations indicated that the disodium salt was 99.1% pure.

Separation of ortho- and pyrophosphate by paper chromatography. The solvent system used was methanol (80 vol.), 90% formic acid (15 vol.), and water (5 vol.).[9] Development by descending chromatography on Whatman No. 1 filter paper in a cylindrical, covered glass jar took approximately 5 hr. at room temperature. The chromatograms were dried and sprayed with a molybdate reagent.[10] Yellow spots corresponding to the orthophosphate appeared immediately; after the chromatograms were dried overnight, faint spots produced by the hydrolyzed pyrophosphate were also visible.

The chromatograms were exposed to ultraviolet light at a distance of about 10 cm. for 30 min. All the blue color except that produced by the phosphomolybdenum complex was removed by treatment with ammonia vapors.[9]

The following R_f values were observed: orthophosphate, 0.70; pyrophosphate, 0.55. The R_f values varied somewhat depending on concentration. Some streaking was observed with pyrophosphate. Washing the filter paper with an alcoholic solution of 8-hydroxyquinoline[10,11] prior to running the chromatogram did not improve the results.

Paper chromatography of S-n-butylphosphorothioate. When acidified (sulfuric acid) aqueous solutions of pure barium or disodium *S-n*-butylphosphorothioate were chromatographed by the method described in the preceding section, considerable streaking was obtained, as well as a spot corresponding to orthophosphate. The streaked portion of the chromatogram was a bright blue as contrasted with the more violet orthophosphate spots. On several chromatograms, but not on all, a spot was obtained corresponding to pyrophosphate.

Treatment of these chromatograms with a mercuric chloride, nitro-prusside and potassium cyanide reagent[4] produced crimson spots, R_f = .85. These may be due to unhydrolyzed ester. On some chromatograms treated with the phosphate-detecting reagents, a faint blue spot appeared at the same R_f value.

Phosphorylation of orthophosphate. Disodium *S-n*-butylphosphorothioate (17.3 mg., 0.0809 mmole) and disodium orthophosphate ($Na_2HPO_4\cdot 7H_2O$, 44.3 mg., 0.163 mmole) were dissolved in 0.21 ml. of 20% sulfuric acid and allowed to stand at room temperature for 24 hr. A paper chromatogram of the resulting solution, diluted to 2 ml., showed spots (R_f = 0.41 and 0.70) corresponding to those (R_f = 0.41 and 0.71) produced by a standard of 30.7 mg. (0.0688 mmole) of sodium pyrophosphate ($Na_4P_2O_7\cdot 10H_2O$) and 42.1 mg. of disodium orthophosphate in 0.21 ml. of 20% sulfuric acid, diluted to 2 ml. The reaction mixture and the standard mixture were chromatographed on the same sheet of filter paper. Inspection of the chromatogram indicated that the amount of pyrophosphate produced in the reaction was roughly one-third to one-half the amount in the standard, and that the amount of orthophosphate was about one-third less than that in the standard. Other runs under similar conditions gave substantially the same results.

"Oxidative" phosphorylation of orthophosphate. Disodium *S-n*-butylphosphorothioate (80.4 mg., 0.375 mmole) was mixed with disodium orthophosphate ($Na_2HPO_4\cdot 7H_2O$, 184.9 mg., 0.690 mmole), 20% sulfuric acid (0.08 ml.), and an aqueous solution of iodine (0.026 ml.). The amount of iodine solution used varied from run to run, but only enough iodine was added until the color of free iodine persisted. The reaction mixture was heated for 15 min. in a bath of boiling water. A paper chromatogram showed spots corresponding to orthophosphate and pyrophosphate. The amount of pyrophosphate produced appeared to be intermediate between standards of 50.9 mg. (0.114 mmole) and 113.1 mg. (0.253 mmole) of tetrasodium pyrophosphate pentahydrate. Therefore, the yield of pyrophosphate was between 30 and 67%.

Disodium *S-n*-butylphosphorothioate (9.7 mg., 0.0453 mmole) was mixed with 85% phosphoric acid (0.005 ml.) in dioxane (0.5 ml.) and heated in a bath of boiling water for 15 min. during which 0.4 ml. of a dioxane solution of iodine was added before the iodine color persisted. The solution was allowed to evaporate overnight and the residue was diluted with 1 ml. of water. Spots for both orthophosphate and pyrophosphate were obtained on a paper chromatogram. There was some streaking. The amount of pyrophosphate produced was nearly as large as that in a pyrophosphate standard (14.2 mg. of $Na_4P_2O_7\cdot 10H_2O$, 0.0318 mmole) which was subjected to the same treatment as the disodium *S-n*-butylthiophosphate. The standard was run on the same chromatogram. The yield would be of the order of 70%.

A sample of orthophosphoric acid (0.005 ml. in 0.5 ml. of dioxane and 0.05 ml. of iodine solution) showed no streaking and its R_f value was unchanged.

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p-Methylthiobenzylamine

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In the course of some other work, *p*-methylthiobenzylamine was needed. The corresponding *ortho* compound had been prepared from thiosalicyclic acid by methylation, conversion to the amide and reduction with lithium aluminum hydride,[1] but a more direct synthesis was desired.

The ease with which a suitably activated fluorine attached to an aromatic nucleus is displaced by nucleophilic agents,[2] the marked nucleophilicity of the RS^- anion,[2] and the commercial availability of *p*-fluorobenzonitrile suggested a simpler method of synthesizing *p*-methylthiobenzonitrile than the use of the Sandmeyer reaction with *p*-methylthioaniline.[3] Reduction of the nitrile with lithium aluminum hydride should yield the benzylamine.

The expectations were realized. The displacement reaction of sodium methylmercaptide with *p*-fluorobenzonitrile afforded 82% yield of crude *p*-methylthiobenzonitrile, which on reduction gave 72% yield of *p*-methylthiobenzylamine.

The *p*-methylthiobenzonitrile was identified by its melting point, analysis, alkaline hydrolysis to

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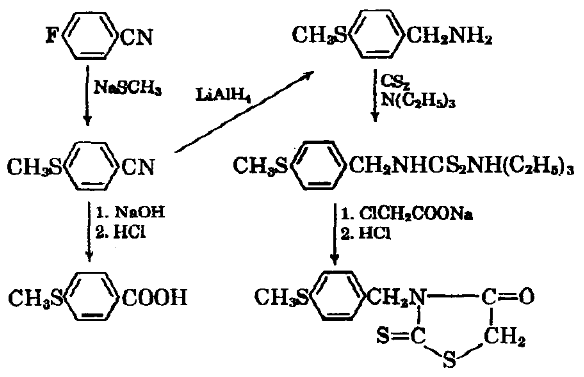

p-methylthiobenzoic acid, and subsequent conversion to p-methylthiobenzamide.

As with other benzylamines, p-methylthiobenzylamine reacts readily with carbon dioxide. It forms a picrate, and a dithiocarbamate with carbon disulfide and a base; the latter forms 3-p-methylthiobenzylrhodanine on reaction with sodium chloroacetate followed by cyclization in acid solution.

When the displacement reaction with sodium methylmercaptide and p-nitrochlorobenzene was tried, reduction of the nitro group took place instead of the desired reaction and a compound which gave an analysis corresponding to p,p'-dichloroazoxybenzene was isolated, thus confirming the similar action of sodium hydrosulfide and methyl sulfate on p-nitrochlorobenzene.[4]

EXPERIMENTAL

p-Methylthiobenzonitrile. A solution of sodium methoxide from 9.2 g. (0.4 g.-atom) of sodium and 200 ml. of methanol was surrounded by an ice bath and treated with chilled methyl mercaptan (23 g.; 0.48 mole). p-Fluorobenzonitrile (24.2 g.; 0.2 mole) was added and the reaction mixture was refluxed gently overnight and cooled. After the filtration of a slight amount of inorganic material, ice water was added, and 24.5 g. (82%) of white precipitate melting at 53–66° formed. Recrystallization from ligroin and a little acetone yielded 17.5 g. melting at 70–71°. From the filtrate an additional amount (4 g. melting at 51.5–57°) was obtained which on recrystallization gave 2.5 g. melting at 69.5–71° (lit.[3] m.p. 64°).

Anal. Calcd. for C_8H_7NS: C, 64.4; H, 4.69. Found: C, 64.51; H, 4.56.

p,p'-Dichloroazoxybenzene. A similar reaction between sodium methyl mercaptide and p-nitrochlorobenzene yielded a yellow solid, which after recrystallization from ethanol melted at 145° (lit.[4] m.p. 150°) and gave an analysis corresponding to p,p'-dichloroazoxybenzene. The infrared spectrum, with peaks at 6.38, 6.88, 7.18, 7.64, 7.70, 7.85, 8.67, 9.22, 9.87, 10.98, and 12.05 μ., is similar to that of azoxybenzene, while the ultraviolet spectrum shows bands at 235 mμ (log ϵ 3.80) and 330 mμ (log ϵ 4.19) [lit.[5] bands at 223 and 236 mμ (log ϵ 3.96) and 330 mμ (log ϵ 4.27)].

Anal. Calcd. for $C_{12}H_8Cl_2N_2O$: C, 53.96; H, 3.02; N, 10.49. Found: C, 54.65; H, 3.18; N, 10.68.

p-Methylthiobenzoic acid. A mixture of 1 g. of p-methylthiobenzonitrile and 20 ml. of 10% sodium hydroxide solution was refluxed for 1 hr. A white solid melting above 210° was removed by filtration and the filtrate acidified with 10% sulfuric acid. The precipitate, when placed on a preheated block, melted at 194° dec. (lit.[3] m.p. 192°). By treatment with thionyl chloride and ammonia, the acid was converted into p-methylthiobenzamide, melting at 186° (lit.[3] m.p. 191°), which is insoluble in cold sodium hydroxide solution and which on admixture with p-methylthiobenzoic acid melts at 160–165°.

p-Methylthiobenzylamine. To a suspension of 11.4 g. (0.3 mole) of lithium aluminum hydride in 500 ml. of sodium-dried ether was added dropwise a solution of 22 g. (0.15 mole) of p-methylthiobenzonitrile in 50 ml. of ether. The flask was cooled as necessary during the addition and subsequently stirred and refluxed overnight. The mixture was decomposed by water followed by 15% sodium hydroxide and water.[6] After filtration of the solid, the ether solution was dried and filtered. After removal of the ether, the product was vacuum distilled, yielding 16 g. (72%) of p-methylthiobenzylamine, b.p. 144–149° (6 mm.). For analysis, the amine was converted into its picrate, which after recrystallization from ethanol, melted at 216–218° with decomposition taking place above 210°.

Anal. Calcd. for $C_{14}H_{14}N_4SO_7$: C, 43.98; H, 3.69. Found: C, 44.12; H, 3.63.

3-(p-Methylthiobenzyl)rhodanine. This compound was prepared by the method described previously.[1] From 16 g. (0.107 mole) of the amine, which was added from a syringe to prevent absorption of carbon dioxide from the air, 5 g. (16.7%) of product melting at 118–121.5° was obtained. Recrystallization from ethanol-acetone gave 3 g. of 3-(p-methylthiobenzyl)rhodanine, melting at 120.5–122°.

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Formation of a 1:1 Adduct from Allylbenzene and Diethyl Methylenemalonate

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When diethyl methylenemalonate is heated at 190° for two days in the presence of an excess of allylbenzene (4.5:1 molar ratio) a 32% yield of the 1:1 adduct 5,5-dicarbethoxy-1-phenylpentene-1 is obtained. This is obviously another example of a reaction taking place between a dienophile and an unconjugated olefinic bond.[5–10] The formation of

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