ration of the crystalline product was prompt, and, after cooling, the crude yield was 33.8 g. (70.4%). It was recrystallized from a large volume of aqueous methanol; m.p. 142–143°, $[\alpha]^{16}\text{D}$ −41° (*c* 0.5, pyridine, 24 hr.).

Anal. Calcd. for $C_{19}H_{30}N_2O_{10}\cdot 3H_2O$: C, 45.59; H, 7.25; N, 5.60. Found: C, 45.04; H, 7.16; N, 5.68.

2-D-*arabino*-Tetrahydroxybutyl-6-methylquinoxaline.—An amount of 4.5 g. of *N,N'*-di-D-glucosyl-3,4-diaminotoluene was heated to boiling in 50 ml. of 10% acetic acid for 30 min. Under an ordinary atmosphere no separable amount of the crystalline product was obtained, but, under vigorous passing of oxygen through the solution, this quinoxaline derivative was obtained in the yield of 0.35 g. (7.8%) after cooling. When the equimolecular amount of hydrazine was added to the reaction system under an ordinary atmosphere, the yield was 0.82 g. (18.2%). This compound had m.p. 177–178° and $[\alpha]^{16}\text{D}$ −200° (*c* 0.8, pyridine).

Anal. Calcd. for $C_{13}H_{16}N_2O_4$: C, 59.08; H, 6.10; N, 10.60. Found: C, 58.87; H, 6.33; N, 10.61.

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Dimethylamides from Alkali Carboxylates and Dimethylcarbamoyl Chloride

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Dimethylamides of carboxylic acids have become increasingly interesting in recent years because certain ones are good solvents for polymers composed mainly of acrylonitrile[1,2] and because they are excellent reaction solvents, particularly for nucleophilic displacements.[3] Ordinarily they may be prepared by almost any of the conventional means for synthesis of amides in general, including thermal reaction between the appropriate acid and dimethylamine, or reaction between dimethylamine and an acid chloride, anhydride, or ester.

Recently in our laboratories it became necessary to convert a small amount of the sodium salt of an acid into the corresponding dimethylamide as quantitatively as possible, yet with a high degree of product purity. While one of the preparative methods mentioned above might have been used, it appeared that each one offered some points of inconvenience and possible loss. A study of the literature did not suggest any more promising approaches until attention was drawn to the reaction between carboxylic acids and isocyanates to form monoalkylamides.[4] This reaction has been demonstrated[4b] to proceed through the intermediate formation of a relatively unstable mixed carboxylic–carbamic anhydride, RCOOCONHR'. Because a similar mixed anhydride should result from the action of a dialkylcarbamoyl chloride on a salt of a carboxylic acid, it seemed likely that such a reaction would be useful in preparing dialkylamides.

The mixed anhydrides from isocyanates and carboxylic acids are capable of decomposing by either of the routes shown below.[4c,d,e]

$$\text{RCOOCONHR'} \longrightarrow \text{RCONHR'} + CO_2 \qquad (1)$$

$$2\text{RCOOCONHR'} \longrightarrow (\text{RCO})_2\text{O} + (\text{R'NH})_2\text{CO} + CO_2) \qquad (2)$$

Fry[4c] demonstrated that all of the carbon dioxide formed in these reactions arose from the isocyanate used, and indicated further that the acid anhydride and dialkylurea formed in reaction 2 would interact at somewhat higher temperatures to form additional quantities of monoalkylamide as indicated in equation 3.

$$(\text{RCO})_2\text{O} + (\text{R'NH})_2\text{CO} \longrightarrow 2\text{RCONHR'} + CO_2 \qquad (3)$$

These facts suggested that this reaction was potentially capable of giving high yields of monoalkylamides from carboxylic acids, and that dialkylamides might by synthesized equally well by the action of dialkylcarbamoyl chlorides on salts of carboxylic acids (equation 4).

$$\begin{aligned} &\text{RCOONa} + \text{R}_2'\text{NCOCl} \longrightarrow \text{NaCl} + \text{RCOOCONR}_2' \\ &\text{RCOOCONR}_2' \longrightarrow CO_2 + \text{RCONR}_2' \qquad (4) \end{aligned}$$

Support for this conclusion was obtained from the work of von Braun,[5] who obtained dimethylbenzamide almost quantitatively from the spontaneous decomposition of benzoyl dimethyldithiocarbamate. Somewhat

$$(CH_3)_2NCSSCOC_6H_5 \longrightarrow CS_2 + C_6H_5CON(CH_3)_2 \qquad (5)$$

similarly, Herzog and Hancu[6] prepared the diphenylamides of benzoic and cinnamic acids by the action of diphenylcarbamoyl chloride on the appropriate acid in excess pyridine at 100°. Presumably this procedure involves a mixed anhydride as an intermediate.

$$\begin{aligned} &C_6H_5COOH + (C_6H_5)_2NCOCl + C_5H_5N \longrightarrow \\ &\qquad C_6H_5COOCON(C_6H_5)_2 + C_5H_5N\cdot HCl \\ &C_6H_5COOCON(C_6H_5)_2 \longrightarrow CO_2 + C_6H_5CON(C_6H_5)_2 \qquad (6) \end{aligned}$$

At the conclusion of the work described here, further search of the literature revealed that the reaction between salts of carboxylic acids and dialkylcarbamoyl chlorides is the subject of a patent.[7] Because the results reported here give some additional insight as to the general utility of the reaction, it is felt that they may be of value.

A synthesis of dimethylacetamide from potassium acetate and dimethylcarbamoyl chloride gave a 96.5% yield of product having the correct refractive index and containing less than 0.01% residual chlorine. Similarly, repetition of this experiment with labeled sodium acetate on two occasions gave yields of 94.2 and 95.8%, with isotopic conversions of 95.88 and 97.1%, respectively.

Other experiments were then performed to determine the generality of this reaction. Dimethylpropionamide with the correct refractive index was obtained in 97% yield. Sodium palmitate gave an 87% yield of dimethylpalmitamide. Sodium carbonate was converted to tetramethylurea in 96.5% yield; while the refractive index has not been previously reported, the product had the proper density and boiling point. The technique is not suitable for the preparation of dimethylformamide;

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(1) G. H. Latham (to E. I. du Pont de Nemours & Co., Inc.), U.S. Patent 2,404,714 (July 23, 1946).

(2) G. F. D'Alelio (to Industrial Rayon Corp.), U.S. Patent 2,531,407 (November 28, 1950).

(3) H. E. Zaugg, B. W. Horrom, and S. Borgwardt, *J. Am. Chem. Soc.*, **82**, 2895 (1960).

(4) (a) C. Naegeli and A. Tyabji, *Helv. Chem. Acta*, **17**, 931 (1934); (b) W. Dieckmann and F. Breest, *Ber.*, **39**, 3052 (1906); (c) A. Fry, *J. Am. Chem. Soc.*, **75**, 2686 (1953); (d) J. H. Saunders and R. J. Slocombe, *Chem. Rev.*, **43**, 210 (1948); (e) R. G. Arnold, J. A. Nelson, and J. J. Verbanc, *ibid.*, **57**, 52 (1957).

(5) J. von Braun, *Ber.*, **36**, 3525 (1903).

(6) J. Herzog and V. Hancu, *ibid.*, **41**, 636 (1908).

(7) E. Stein and O. Bayer (to Farbenfabriken Bayer A.-G.), West German Patent 875,807 (May 7, 1953).

the intermediate mixed anhydride from sodium formate and dimethylcarbamoyl chloride decomposes in accordance with equation 2 to an appreciable extent. This mode of decomposition causes carbon monoxide to appear in the off-gases and tetramethylurea to be present in the liquid product. Fractional distillation of the liquid from two runs indicated that the ratio of dimethyl formamide to tetramethylurea was about 3.5 or 4 to 1. Application of the same reaction to a synthesis of N,N-dibutyldodecanamide from sodium laurate and N,N-dibutylcarbamoyl chloride gave a 78% yield of product.[8]

Extension of this reaction to the dibasic acid series was less successful. In spite of repeated efforts, no tetramethyloxamide could be obtained from sodium or potassium oxalate and dimethylcarbamoyl chloride. These salts appeared to be distinctly less reactive than those of the monobasic acids, and higher temperatures were required to cause reaction to occur. The only organic product isolated was tetramethylurea. A low yield (7.6%) of tetramethyloxamide was obtained by the technique of Herzog and Hancu,[6] but even in this case tetramethylurea was the major product isolated (44.4%). An authentic specimen of tetramethyloxamide was prepared by the action of dimethylamine on ethyl oxalate at 100°, and it was ascertained that this product would have been isolated if formed.

Very similar results were obtained from sodium malonate and dimethylcarbamoyl chloride; only small yields (*ca.* 10%) of tetramethylmalonamide were obtained. Again tetramethylurea was one of the products, but unexpectedly dimethylacetamide was also found present in large amounts. Sodium succinate gave tetramethylsuccinamide in yields of 53.5 and 49% in two experiments. Glutaric acid was not investigated, but it was found that sodium adipate gave an 86.5% crude yield of tetramethyladipamide (77% of recrystallized product suitable for analysis).

These results suggest that the reaction between sodium (or potassium) carboxylates and dialkylcarbamoyl chlorides is a fairly general means of preparing dialkylamides, provided that complications are not introduced by instability of an anhydride which may be formed through reaction 2 above.

Experimental[9,10]

Dimethylcarbamoyl chloride was Matheson, Coleman and Bell practical grade. It was fractionally distilled and a center cut (b.p. 61–64°/19 mm.) was taken for use in this work. Potassium acetate was Baker and Adamson reagent grade which had been recently fused. Sodium carbonate, sodium formate, and sodium oxalate were Baker and Adamson reagent grade. The other sodium salts were prepared by neutralization of the appropriate acid (Matheson, Coleman and Bell or Baker and Adamson, reagent grade) with sodium hydroxide to a phenolphthalein end point. They were isolated by evaporation of their solutions on a steam bath, and were dried in a vacuum oven at 100° for at least 24 hr.

Dimethylacetamide.—To a large heavy-wall test tube (4 cm. × 15 cm.) was charged 49 g. (0.5 mole) of fused potassium acetate. The salt was covered with 53.8 g. (0.5 mole) of dimethylcarbamoyl chloride and the vessel was attached to a condenser. This mixture was heated in a boiling water bath until no more gas was evolved (2–3 hr.) and was then heated briefly up to 150° in a glycerol bath. After cooling the tube was attached to a high vacuum assembly and all volatile matter was distilled into a similar vessel which was used as a vacuum trap. The contents of the trap were then warmed at 100° for 3 hr. with 15 g. of fresh potassium acetate, heated briefly at 150°, and distilled once more under high vacuum. The weight of dimethylacetamide so obtained was 42.0 g. (96.5%). A small sample was warmed with methanol to destroy any dimethylcarbamoyl chloride present, and the solution analyzed by high frequency titration. Found: Cl, approximately 0.001%. The refractive index was n^{24}D 1.4366 (reported,[11,12] n^{20}D 1.4384, n^{25}D 1.4351).

Dimethylpropionamide.—Prepared on a 0.5-molar scale by the procedure described above, this compound was obtained in a yield of 49.0 g. (97.3%). The product contained 0.002% chlorine and had a refractive index of 1.4372 at 23.5° (reported,[12] n^{25}D 1.4371).

Dimethylpalmitamide.—This dimethylamide was prepared in a generally similar fashion. Dimethylcarbamoyl chloride (0.18 mole) was heated to 105° with a slight excess of sodium palmitate until apparent reaction ceased, and the mixture was then heated briefly to 185°. Dimethylpalmitamide was extracted from the cooled reaction mixture by boiling with chloroform. After filtration and removal of the solvent, the residue was distilled under a pressure of 0.2–0.5 mm. in a modified Hickman still (bath temperature 150–160°). The yield of colorless distillate, crystallizing to a white solid, was 44.5 g. (86.8%). A sample twice recrystallized from ethanol for analysis had m.p. 43–45°. This compound apparently has not been previously reported.

Anal. Calcd. for $C_{18}H_{37}ON$: C, 76.32; H, 13.07. Found: C, 76.02, 76.42; H, 13.09, 13.22.

Tetramethylurea.—Dimethylcarbamoyl chloride (58.5 g., 0.5 mole) was heated with anhydrous sodium carbonate (25.5 g., 0.25 mole) under the same conditions used in making dimethylacetamide. Reaction occurred relatively slowly, and it was necessary to redistil the original product twice more from small amounts of sodium carbonate before the density agreed with the reported value and no further change occurred in the refractive index. Nevertheless, a high yield was obtained (28 g., 96.5%). The product had the following properties: d^{15} 0.9726 (reported,[13] d^{15} 0.972); b.p. 175° (reported,[13] 177.5°); n^{25}D 1.4495 (not previously reported).

A sample prepared from dimethylamine and phosgene had b.p. 176° and n^{25}D 1.4492.

Reaction between Sodium Formate and Dimethylcarbamoyl Chloride.—When half-molar quantities of sodium formate and dimethylcarbamoyl chloride were heated together at 100° a vigorous reaction ensued. After a reflux period of 1 hr. in a bath at 170° the reaction mixture was distilled under high vacuum as in the other runs. The yield of slightly yellow distillate was only 21.5 g. (theory, 36.5 g.). This material had n^{25}D 1.4348 (reported,[12] n^{25}D 1.4269).

This product was redistilled from 5 g. of sodium formate at atmospheric pressure and only the portion boiling between 150 and 160° was collected. The distillate was colorless, but had not changed appreciably in refractive index (n^{24}D 1.4330). A second run was conducted at 80° (the lowest temperature at which gas evolution occurred) until reaction was essentially complete. A small portion of the evolved gas was passed through 50% potassium hydroxide solution in a crude pneumatic trough and it was found that not all of this gas was carbon dioxide, since a substantial portion was not absorbed. The unabsorbed gas was found to burn and was assumed to be carbon monoxide. The distilled product from this reaction had $n^{23.5}$D 1.4318, and the yield was 28.7 g. of a theoretical 36.5 g. of dimethylformamide.

Two more similar batches of crude product were prepared by this second procedure. These were combined and fractionally distilled through a Nester and Faust spinning band column at atmospheric pressure. Results obtained are given in Table I.

The dimethylformamide obtained in this distillation still had the odor of an amine. It was warmed with a small amount of phosphorus pentoxide and was redistilled under reduced pressure. By this procedure 31.0 g. of dimethylformamide was recovered; $n^{22.5}$D 1.4300. Bruhl[14] observed a refractive index of 1.4294 at this temperature.

Comparison of infrared spectra showed that the tetramethylurea isolated in this distillation was identical with the sample previously prepared. It was not entirely pure, since its refractive index was low, n^{25}D 1.4438.

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[8] This experiment performed by Dr. T. L. Tolbert.

[9] Melting points uncorrected.

[10] Analyses and infrared spectra by personnel of the Analytical Section, Chemstrand Research Center, Inc.

[11] B. V. Ioffe, *Zh. Obsch. Khim.*, **25**, 902 (1955).

[12] J. R. Ruhoff and E. E. Reid, *J. Am. Chem. Soc.*, **59**, 4012 (1937).

[13] A. P. N. Franchimont, *Rec. trav. chim.*, **3**, 226 (1884).

[14] J. W. Bruhl, *Z. physik. chem.*, **22**, 389 (1897).

TABLE I

DISTILLATION OF REACTION PRODUCT FROM SODIUM FORMATE AND DIMETHYLCARBAMOYL CHLORIDE[a]

Cut no.	B.p. (atm.), °C.	Wt., g.	Identity	Per cent of charge	Per cent yield[d]
1	Up to 150	10.5	Forerun[b]	15.8	..
2	152–153	35.5	Dimethylformamide	53.4	73.1
3	153–172	2.5	Mixed, intermediate	3.8	..
4	173–175	10.0	Tetramethylurea	15.0	13.7
4	...	3.0	Residue[c]	4.5	..

[a] Original charge, 66.6 g. [b] The forerun had a strong amine-like odor and probably consisted of dimethylformamide heavily contaminated with dimethylamine. [c] The residue did not consist of nonvolatile matter, since it had already been distilled once in the high vacuum system. Presumably it was largely tetramethylurea. [d] Based on dimethylcarbamoyl chloride.

N,N-Dibutyldodecanamide.—A sample of dibutylcarbamoyl chloride was prepared by the action of excess phosgene on dibutylamine. Obtained in 80% yield, it had b.p. 100.5°/4 mm. Interaction of this product (76 g., 0.385 mole, 10% excess) with sodium laurate (77.5 g., 0.35 mole) under the conditions used in making dimethylpalmitamide gave 92.1 g. (78%) of the desired dibutylamide, b.p. 182°/1.8 mm., n^{25}_{D} 1.4543.

Anal. Calcd. for $C_{20}H_{41}NO$: C, 77.17; H, 13.18; N, 4.50. Found: C, 77.45, 77.54; H, 12.97, 13.27; N, 4.88, 4.70.

Reaction of Potassium Oxalate with Dimethylcarbamoyl Chloride.—Potassium oxalate monohydrate was converted to the anhydrous salt by heating in a vacuum oven to 100–120° for 24 hr., and was then ground to pass a 100-mesh sieve. The salt (51.5 g., 0.31 mole) was treated with 134 g. (1.24 moles, 100% excess) of dimethylcarbamoyl chloride and the mixture was heated at 100° for 40 hr. and at 150° for 4 hr. Gas evolution was slow; a part of the evolved gas was alkali-insoluble and was flammable. It was assumed to be carbon monoxide.

Distillation of the reaction mixture in the vacuum system gave 96 g. of distillate, which was dissolved in 500 ml. of methanol and allowed to stand several days, to destroy excess dimethylcarbamoyl chloride. At the end of this time, the solution was neutralized to phenolphthalein with methanolic potassium hydroxide, and the precipitated potassium chloride was filtered off. Methanol and water were removed from the filtrate by distillation through a 1-ft. Vigreux column. Distillation of the residue through a spinning band column gave methyl N,N-dimethylcarbamate (b.p. 131°), followed by tetramethylurea (b.p. 172–175°, 22 g., 61% based on potassium oxalate, n^{25}_{D} 1.4490). The residue in the distilling flask (4 g., n^{25}_{D} 1.4518) was liquid and could not be induced to crystallize. The melting point of tetramethyloxamide has been reported as 80° by Franchimont and Rouffaer,[15] who prepared it by the action of sodium on dimethylcarbamoyl chloride in dry ether.

An authentic sample of tetramethyloxamide was prepared by heating ethyl oxalate (292 g., 2.0 moles) with dimethylamine (295 g., approximately 6.5 moles) in a low pressure oxygen cylinder on a steam bath overnight. Distillation of the reaction mixture gave 261 g. (90.6%) of tetramethyloxamide, b.p. 158–160°/20 mm. The distillate crystallized very easily. Upon recrystallization from warm ether, in which it was difficultly soluble, it melted at 78–80°. The characteristics of the product gave assurance that it would not have been overlooked in the preceding experiment.

In contrast to the slow reaction above, oxalic acid reacted rapidly with dimethylcarbamoyl chloride in pyridine.[6] Anhydrous oxalic acid (90 g., 1.0 mole) was mixed with 325 ml. of dry pyridine, and dimethylcarbamoyl chloride (215 g., 2.0 moles) was added slowly from a dropping funnel. Reaction took place almost at once, with effervescence. When addition had been completed, the mixture was allowed to stand overnight, and was then treated with an excess of concentrated potassium carbonate solution to destroy pyridine hydrochloride. Fractional distillation of the separated and filtered pyridine layer gave 51.5 g. (44%) of tetramethylurea (impure, redistilled to give 36.5 g. of product boiling constantly at 175°, $n^{24.5}_{\mathrm{D}}$ 1.4490.) Distillation of the residue gave 11 g. (7.6%) of material which solidified on cooling and which yielded 9 g. of recrystallized tetramethyloxamide melting at 78–80°.

Reaction of Sodium Malonate with Dimethylcarbamoyl Chloride.—Anhydrous sodium malonate (148 g., 1.0 mole) was stirred with dimethylcarbamoyl chloride (215 g., 2.0 moles) in a 1-l., three-neck flask for 8.5 hr. at an internal temperature of 110–120°. A slow stream of dry nitrogen was passed through the flask continuously during this period. Loss of any volatile liquid was prevented by passing exit gases through an efficient condenser, followed by a trap immersed in an ice–hydrochloric acid mixture. At the end of the heating period, when evolution of carbon dioxide had essentially ceased, the mixture was cooled, diluted with methylene chloride, and filtered. The weight of sodium chloride obtained was 115.5 g. (theory, 117 g.).

Methylene chloride was stripped from the filtrate by distillation from a steam bath, finally at slightly reduced pressure. The residue was distilled from a steam bath at 10 mm., and the distillate so obtained (113 g.) was dissolved in 500 ml. of methanol and allowed to stand at room temperature for several days to convert any unchanged dimethylcarbamoyl chloride to methyl N,N-dimethylcarbamate. The higher boiling residue was distilled at 1 to 2 mm. from an oil bath at 150–160° to give 20.5 g. of distillate and 23.0 g. of tar. This distillate was redistilled through a short Vigreux column to give 15 g. (9.5%) of tetramethylmalonamide, b.p. 138–140°/4 mm., $n^{24.5}_{\mathrm{D}}$ 1.4875. Corresponding values for an authentic sample (prepared by heating ethyl malonate (2.0 moles) with dimethylamine (10.0 moles) and a few milliliters of a strong aqueous solution of dimethylamine hydrochloride in a bomb at 150° for 8 hr.) were b.p. 135–138°/3.8–4.0 mm., n^{24}_{D} 1.4915. The yield of authentic sample was 251 g. (79.5%).

Anal. Calcd. for $C_7H_{14}N_2O_2$: C, 53.16; H, 8.86; N, 17.72. Found: C, 53.15, 52.93; H, 9.07, 9.17; N, 17.89, 17.94.

After standing 3 days, the methanolic solution was neutralized to phenolphthalein with a standard solution of sodium methoxide in methanol. Titration indicated that 0.0613 mole of dimethylcarbamoyl chloride had been present in the original distillate. After filtration, the neutralized solution was stripped of methanol at the steam bath and the residue was distilled through a 15″ column packed with glass helices. A forerun consisting mostly of methyl N,N-dimethylcarbamate and weighing 10 g. was collected at 130–132°. This was followed by 6 g. of an intermediate cut, boiling from 132–165°. Finally, 83 g. of a cut boiling at 165–177° was collected. Careful fractionation indicated that this liquid was composed of dimethylacetamide and tetramethylurea. Its percentage composition was determined by comparison of its refractive index with a plot of refractive index *vs.* composition for the system dimethylacetamide–tetramethylurea. The observed value (n^{25}_{D} 1.4444) corresponded to that of a mixture of 60% tetramethylurea and 40% dimethylacetamide. Thus the yield of dimethylacetamide based on dimethylcarbamoyl chloride was 19.1%, and the yield of tetramethylurea on the same basis was 43.0%.

Tetramethylsuccinamide.—Sodium succinate (81 g., 0.5 mole) was heated on a steam bath with dimethylcarbamoyl chloride (107.5 g., 1.0 mole) with magnetic stirring. Evolution of carbon dioxide was moderately vigorous. Heating was continued for about 12 hr. At the end of this period the mixture was cooled and filtered, the solid being washed with a little dimethylacetamide. Concentration of the filtrate was effected by distillation from a steam bath at 15–20 mm. The residue, containing possibly succinic anhydride and dimethylcarbamoyl chloride in addition to the desired product, was mixed with 200 ml. of concentrated ammonium hydroxide and stirred for 30 min. to ensure destruction of these substances. Product was then extracted from the dark solution by shaking three times with equal volumes of chloroform. After removal of chloroform from the combined extracts, the residue was distilled at a pressure of about 1 mm. Following a very small forerun, tetramethylsuccinamide was collected at 112–113° as a colorless liquid which rapidly set to a white solid. The yield of this product, m.p. 84.5–85.5°, was 42 g. (49%). Franchimont[16] reported a melting point of 81°.

Tetramethyladipamide.—Sodium adipate (100 g., 0.53 mole) was heated with dimethylcarbamoyl chloride (150 g., 1.4 moles, 40% excess) at 130° with stirring until evolution of carbon dioxide ceased. While the mixture darkened appreciably, it was noted that it never became so dark as the reaction mixtures from the lower dicarboxylic acids. Without cooling, the mixture was slowly diluted with chloroform and the solution was filtered through a mat of filter aid. The filtrate was stripped of chloro-

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(15) A. P. N. Franchimont and H. A. Rouffaer, *Rec. trav. chim.*, **13**, 341 (1894).

(16) A. P. N. Franchimont, *ibid.*, **4**, 202 (1885).

form at the steam bath and the residue distilled under reduced pressure (approx. 1 mm.). Crude product (91 g., 86.5%) was collected at 160–165°. On redistillation at 0.7 mm., this product was still yellowish in color and had a b.p. of 137–145°. This distillate was crystallized from 2.5 l. of isopropyl ether to give 80 g. (77%) of white needles, m.p. 82–83°.

Anal. Calcd. for $C_{10}H_{20}O_2N_2$: C, 60.00; H, 10.00; N, 14.00. Found: C, 60.11, 60.34; H, 10.16, 10.06; N, 14.02, 14.06.

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A Direct Synthesis of Sulfonium Perchlorates

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A few examples of the synthesis of trialkylsulfonium salts by direct alkylation of organic sulfides with perchloric acid–alcohol mixtures have appeared in the literature.[1,2] Recently the utility of this reaction has been demonstrated in the synthesis of 5-dimethylsulfonium-2-pentanone perchlorate from 5-methylmercapto-2-pentanone and perchloric acid in methanol.[3] The renewed interest in such reactions reported by Overberger, *et al.*,[4] prompt us to report our findings.

When equimolar quantities of dibenzyl sulfide and 70% aqueous perchloric acid were heated in benzyl alcohol solution for 2.5 hours at 65–70°, dilution with ether afforded an excellent yield of tribenzylsulfonium perchlorate. This reaction was extended to a number of aliphatic alcohol-sulfide systems, and gave surprisingly good yields of pure sulfonium salts if the time, temperature, and most important, the water content of the system were properly adjusted. The products were obtained as colorless crystals of high purity, and were dried for elemental analysis without recrystallization. The properties of the salts are recorded in Table I.

TABLE I

SULFONIUM PERCHLORATES—$R_3S^{(+)}ClO_4^{(-)}$

R	M.p.	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found
Benzyl	171.5–174°[a]	62.29	62.58	5.23	5.27
n-Butyl	94–95°[b]	47.25	47.37	8.99	8.99
n-Propyl	155–157°	41.35	42.00	8.12	8.14
Ethyl	111.5–112.5°	32.95	32.74	6.91	6.73

[a] Reported 178°; J. de Pascual Teresa, *Anales real soc. españ. fis. quim.*, **45B**, 235 (1949). [b] reported 94°; ref. 5.

Discussion and Results

The initial attempts to prepare *n*-alkylsulfonium salts under the conditions used for the benzyl compound afforded only low yields. Even after heating the mixtures under reflux for 24 hours, the yields ranged from less than 1% (ethyl) through 24% (*n*-propyl) to 46% (*n*-butyl). A remarkable improvement was achieved when water was removed from the mixture by azeotropic distillation. Under these conditions tri-*n*-butylsulfonium perchlorate was obtained in a yield of 84%. The limited yield in the presence of water was in fact due to an equilibrium phenomenon. This was confirmed when the yields after 24 hours (46%) and 48 hours (45%) were shown to be the same. The equilibrium involved was not, however, reaction 1, since 92% of tri-*n*-butylsulfonium perchlorate was recovered unchanged after 24 hours of heating in butanol containing the same amount of water as was present under the conditions of synthesis.

$$Bu_3S^{(+)}ClO_4^{(-)} + H_2O \rightleftharpoons Bu_2S + BuOH_2^{(+)} + ClO_4^{(-)} \quad (1)$$

It was determined that one source of the variation in yields from the three aliphatic sulfides was the difference in boiling points of the alcohols used as solvents. A reaction carried out in a sealed vessel at 120° afforded 16% triethylsulfonium perchlorate without removal of water.

It is of interest to note the apparent total absence of carbon-skeleton rearrangement in the sulfonium salts. The tri-*n*-butylsulfonium perchlorate had a melting point identical with the previously reported value,[5] and the infrared spectra of all the compounds indicated them to be free of chain branching.

Several experiments were carried out without success in attempts to detect perchlorate ester formation by chemical means. A mixture of butanol and perchloric acid refluxed for 24 hours in the absence of dibutyl sulfide and titrated with potassium butoxide retained all of the original acid concentration. When water was azeotropically removed from such a mixture, only dark polymer was obtained. Another possible alkylating species is of course the alkyloxonium on $ROH_2^{(+)}$.[4]

If our conception of the reaction path is correct, it should be possible to accomplish direct synthesis of unsymmetrical sulfonium salts without the troublesome "alkyl scrambling" which frequently occurs in the synthesis of sulfonium salts from sulfides and alkyl halides.[6] Only the alkyl group corresponding to the alcohol should be introduced, and the non-nucleophilic nature of perchlorate ion as compared to halide ion should make the process irreversible. This possibility has been demonstrated in one case, the benzylation of dibutyl sulfide, which affords benzyldi-(*n*-butyl)-sulfonium perchlorate as a single product in 83.5% yield.

Experimental

Dialkyl sulfides were Eastman Kodak White Label materials. Perchloric acid was Baker Analyzed reagent grade. Melting points are uncorrected and were obtained on a Mel-Temp capillary melting point apparatus. Elemental analyses were by Dr. S. M. Nagy of the Microchemical Laboratory, Massachusetts Institute of Technology. Infrared spectra were obtained in potassium bromide pellets on a Perkin–Elmer Model 21 spectrophotometer by Mr. Walter Legsdin and his associates of these laboratories.

Tribenzylsulfonium Perchlorate.—A solution of dibenzyl sulfide (0.77 g., 3.59 mmoles) in 5 ml. of benzyl alcohol was mixed with 0.512 g. (3.59 mmoles) of 70% perchloric acid. The resulting

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(1) (a) O. Hinsberg, *Ber.*, **62**, 2167 (1929); (b) O. Hinsberg, *ibid.*, **69**, 492 (1936).

(2) J. de Pascual Teresa and H. Sanchez Bellido, *Anales real soc. españ. fis. quim.*, **50B**, 71 (1954).

(3) N. J. Leonard, T. W. Milligan, and T. L. Brown, *J. Am. Chem. Soc.*, **82**, 4075 (1960).

(4) C. G. Overberger, P. Barkan, A. Lusi, and H. Ringsdorf, *ibid.*, **84**, 2814 (1962).

(5) E. R. Kline and C. A. Kraus, *ibid.*, **69**, 814 (1947). We did not find our sample of this compound to be unstable.

(6) W. Steinkopf, "Die Methoden der Organischen Chemie," 3rd ed., J. Houben, ed., Vol. 3, Verlag George Thieme, Leipzig, 1930, p. 1261.