

CHROM. 13,097

Note

Gas-liquid chromatography of straight chain homologues of alkylbenzyl-dimethylammonium compounds*

S. L. ABIDI

U.S. Fish and Wildlife Service, National Fishery Research Laboratory, La Crosse, WI 54601 (U.S.A.)

(Received May 27th, 1980)

Surfactant quaternary ammonium compounds are basically high-molecular-weight tetra-substituted organic quaternary ammonium salts in which the nitrogen atoms are attached to at least one of the homologous long-chain aliphatic alkyl groups with the carbon number extending from 8 to 18. They are widely used as algicides, bactericides and fungicides for domestic, industrial and veterinary disinfection and water treatments, and as antistatic agents in textile-softener formulations. In studying residue levels of quaternaries in tissues of animals exposed to low concentrations of commercial products formulated with mixtures of the title compounds, we needed a sensitive method for their separation, characterization and quantitative evaluation.

A number of analytical methods has been reported on the determination of a variety of quaternary ammonium compounds, including colorimetry¹, chemical titration², nuclear magnetic resonance spectroscopy³ and various chromatographic techniques⁴⁻⁸. Of all these existing methods, gas chromatography (GC) appears to be the method of choice, since it tends to be more sensitive and specific, especially in the separation and trace measurement of closely related quaternary ammonium compounds. This paper describes new methods of chemical derivatization that convert the non-volatile alkylbenzyl-dimethylammonium chloride homologues into more volatile substances amenable to GC with enhanced detectability. Results of an investigation on the GC characteristics of two types of derivatives using electron-capture as well as nitrogen-specific thermionic detecting systems are summarized for comparison.

EXPERIMENTAL

Chemicals and reagents

All chemicals employed in this work were of reagent grade. Solvents for gas chromatography were acquired from Burdick & Jackson Labs. (Muskegon, MI, U.S.A.). Tetrahydrofuran was dried over and distilled from lithium aluminium hydride before use. Anhydrous potassium carbonate, benzyl chloride, cyanogen

* Presented, in part, before the Division of Analytical Chemistry at the 179th National Meeting of the American Chemical Society, 1980, Houston, TX, U.S.A.

bromide, lithium triethylborohydride (1 *M* solution in tetrahydrofuran), potassium hydroxide, and trichloroethyl chloroformate were purchased from Aldrich Chemical Co. (Milwaukee, WI, U.S.A.). Quaternary ammonium standards[alkylbenzyl-dimethylammonium chlorides (C_{12} - C_{18})] were synthesized from the corresponding tertiary amines, which were obtained from Armak Chemical Co. (Chicago, IL, U.S.A.), with benzyl chloride and purified by fractional recrystallization from benzene.

Derivatization

Trichloroethyl carbamate derivatives. Approximately 1 mg of each of the quaternary ammonium samples, weighed to 0.1 mg accuracy in a small reaction vial, was dissolved in 1 ml of dry tetrahydrofuran under nitrogen. To this, 30 μ l of 1 *M* lithium triethylborohydride in tetrahydrofuran was added. The PTFE-faced screw-cap septum was replaced, and the sample was stirred in a metal-block heater at 65°C for 10 min. About 1 ml of water was then added at room temperature, and the mixture was evaporated under reduced pressure to leave an aqueous solution, which was shaken with three 2-ml portions of hexane; the combined organic phases were dried over anhydrous potassium carbonate. After removal of hexane, the residue in a reaction vial was treated with 0.2 ml of trichloroethyl chloroformate along with 1 ml of toluene. The vial was sealed as before and heated at 120°C for 30 min. Upon cooling, the contents of the vial were quantitatively transferred to a test tube by means of 10 ml of benzene. Approximately 5 ml of 2 *M* methanolic potassium hydroxide solution was then added, and the mixture was thoroughly mixed on a Vortex mixer for 10 min. An aliquot of the organic layer was withdrawn, and, after serial dilutions, was analyzed with use of an electron-capture detector.

Cyanamide derivatives. The residue obtained from the preceding reduction step was dissolved in 2 ml of chloroform. The resulting solution was added dropwise to a refluxing solution of 1 mg of cyanogen bromide in 2 ml of chloroform. After completion of addition, the reaction was continued at 55°C for 30 min. An aliquot of the cooled solution was diluted to a desired concentration before GC injections and detection with a thermionic nitrogen detector (AFID).

Gas chromatography and mass spectrometry (MS)

Gas chromatograms were obtained using a Varian 3711 gas chromatograph equipped with an electron-capture detector and a thermionic nitrogen detector. Nitrogen was used as the carrier gas at a flow-rate of 30 ml per min. The column temperatures were maintained at 250°C for the analysis of chlorinated derivatives and at 220°C for the analysis of nitrogenized derivatives. The detector and injection-port temperatures were 350°C and 250°C, respectively. Coiled glass columns (200 cm \times 6.35 mm O.D. \times 2 mm I.D.) packed with 3% OV-17 or 3% SE-30 on Gas-Chrom Q (80-100 mesh) were used. For GC-MS work, a Perkin-Elmer 900 gas chromatograph interfaced with a differentially pumped magnetic mass spectrometer (Hitachi Model RMU6) operating at 70 eV and a scanning speed of 3 sec was used.

RESULTS AND DISCUSSION

The structures of dodecyl-, tetradecyl-, hexadecyl- and octadecylbenzyl-dimethylammonium chlorides are shown in Fig. 1. All the investigated quaternary

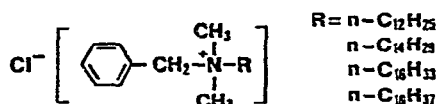


Fig. 1. General formula for alkylbenzyltrimethylammonium chlorides.

ammonium salts were found to undergo smooth reductive debenylation with lithium triethylborohydride⁹ under the conditions described in the procedure to give non-ionic alkyltrimethylamines (95–100% yield), which, in turn, upon treatment with trichloroethyl chloroformate, gave trichloroethyl carbamates (93–98% yield). In the alternative method of derivatization, the alkyltrimethylamines were noted to react readily with cyanogen bromide to give cyanamides as homogeneous products (89–96% yield)¹⁰. The over-all scheme of conversions is illustrated in Fig. 2. The structural identities of derivatives were confirmed by GC-MS. Each of the mass spectra exhibited an invariably weak, but discernible, mass ion due to the molecular ion involved and was superimposable with that obtained with a direct probe from an authentic sample.

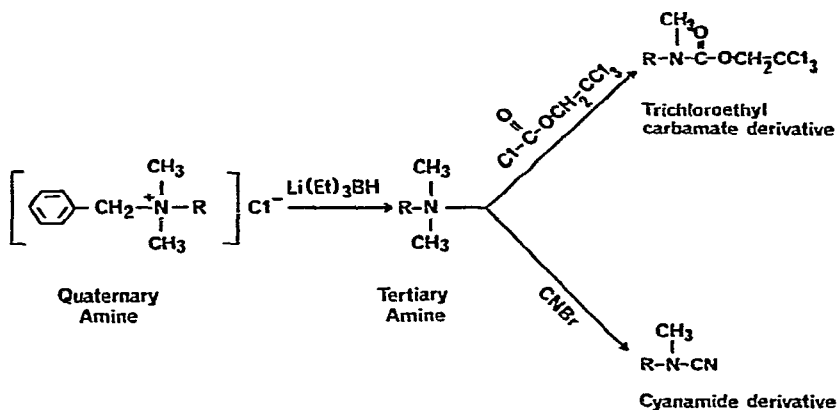


Fig. 2. Methods for derivatizing title compounds prior to GC.

The latter observation showed that the derivatized compounds are thermally compatible with the ordinary operating conditions of GC. The base peaks appeared in all the spectra of relevant carbamates (*m/e* 219) and cyanamides (*m/e* 69), and were probably attributable to the fragments generated by the β -cleavage of the long-chain alkyl groups as commonly observed for compounds containing trivalent nitrogen. Figs. 3 and 4 show typical chromatograms of samples containing mixtures of the respective carbamate and cyanamide derivatives. In each case, excellent separation of the homologues in the series is demonstrated. As mentioned briefly earlier, many of the commercially formulated quaternary ammonium compounds consist of mixtures of homologous components. Adequate resolution of mixtures of this nature by an appropriate chromatographic technique prior to quantitative measurement would be of practical importance. Table I gives the values of relative retention times and minimum detection limits for the derivatives studied. The minimum detectable amounts of the chlorinated compounds lie in the low picogram region using electron-

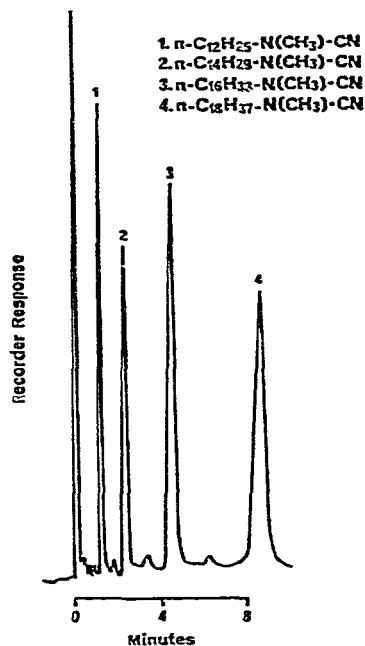
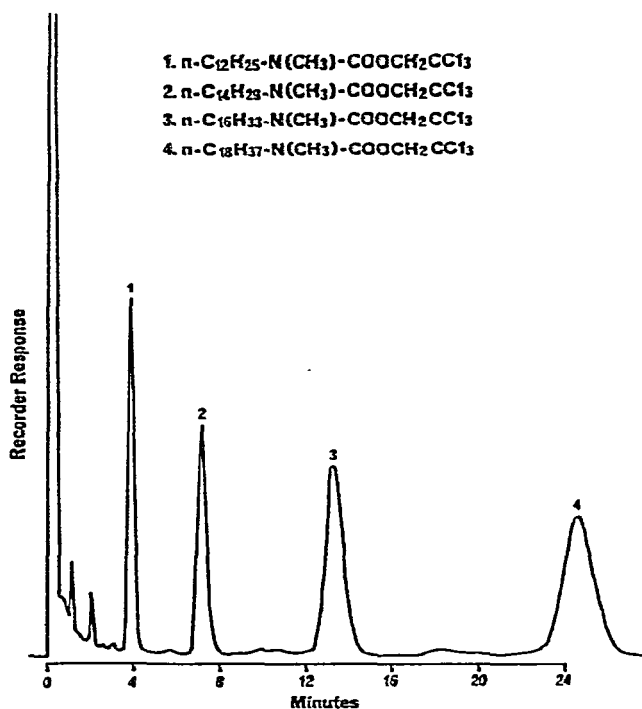


Fig. 3. Gas chromatogram of a sample containing trichloroethyl carbamate derivatives.

Fig. 4. Gas chromatogram of a sample containing cyanamide derivatives.

TABLE I

VALUES OF RELATIVE RETENTION TIME AND MINIMUM DETECTION LIMIT

Compound	RT* (min)	RRT**	Minimum detection limit (g)		
			ECD	AFID	FID
<i>Trichloroethylcarbamate derivatives</i>					
$n\text{-C}_{12}\text{H}_{25}\text{-N}(\text{CH}_3)\text{-COOCH}_2\text{CCl}_3$	4.05	0.16	$2 \cdot 10^{-12}$	—	$2 \cdot 10^{-7}$
$n\text{-C}_{14}\text{H}_{29}\text{-N}(\text{CH}_3)\text{-COOCH}_2\text{CCl}_3$	7.31	0.29	$2 \cdot 10^{-12}$	—	$2 \cdot 10^{-7}$
$n\text{-C}_{16}\text{H}_{33}\text{-N}(\text{CH}_3)\text{-COOCH}_2\text{CCl}_3$	13.22	0.54	$5 \cdot 10^{-12}$	—	$4 \cdot 10^{-7}$
$n\text{-C}_{18}\text{H}_{37}\text{-N}(\text{CH}_3)\text{-COOCH}_2\text{CCl}_3$	24.50	1.00	$5 \cdot 10^{-12}$	—	$6 \cdot 10^{-7}$
<i>Cyanamide derivatives</i>					
$n\text{-C}_{12}\text{H}_{25}\text{-N}(\text{CH}_3)\text{-CN}$	1.35	0.15	$1.5 \cdot 10^{-8}$	$1 \cdot 10^{-10}$	$3 \cdot 10^{-7}$
$n\text{-C}_{14}\text{H}_{29}\text{-N}(\text{CH}_3)\text{-CN}$	2.25	0.25	$1.5 \cdot 10^{-8}$	$5 \cdot 10^{-10}$	$3 \cdot 10^{-7}$
$n\text{-C}_{16}\text{H}_{33}\text{-N}(\text{CH}_3)\text{-CN}$	4.48	0.50	$1.5 \cdot 10^{-8}$	$6 \cdot 10^{-10}$	$6 \cdot 10^{-7}$
$n\text{-C}_{18}\text{H}_{37}\text{-N}(\text{CH}_3)\text{-CN}$	9.00	1.00	$2.0 \cdot 10^{-8}$	$8 \cdot 10^{-10}$	$11 \cdot 10^{-7}$

* RT = retention time.

** RRT = relative retention time.

capture detection. With a nitrogen detector (AFID), the nitrogenous compounds can be detected to the lowest limit of 0.1 ng, which is significantly more sensitive than that attainable with a flame ionization detector. The chromatograms obtained from various concentrations (0.01–10 $\mu\text{g}/\text{ml}$) of compounds demonstrated that peak areas

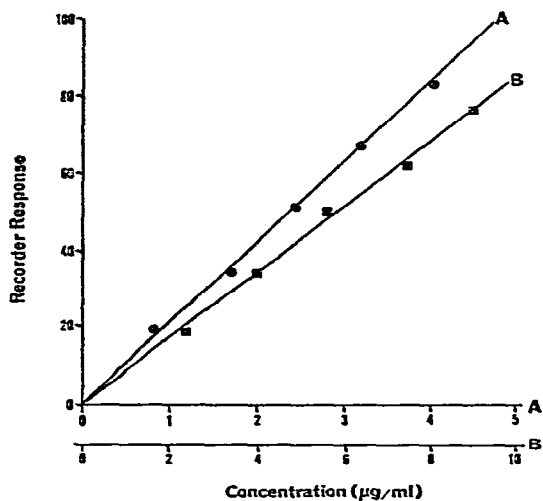


Fig. 5. Plots showing linear relationship between peak area (gas-chromatographic response) and concentration for (A) trichloroethyl N-methyl-N-tetradecylcarbamate, and (B) N-methyl-N-tetradecylcyanamide.

(gas chromatographic responses) were a function of concentration (Fig. 5). The coefficients of variation for repetitive injections of the same sample averaged 3.6%.

In conclusion, the two-step derivatization procedures developed in this study not only provide versatile methods of detection and separation, but also facilitate detection of quaternary ammonium compounds at the picogram level by GC methodology. The method is expedient, sensitive and reliable, and may be applicable to other classes of quaternary ammonium compounds.

ACKNOWLEDGEMENT

The author wishes to thank Dr. Irwin Schmeltz (Hoffmann LaRoche, Nutley, NJ, U.S.A.) for valuable discussion.

REFERENCES

- 1 M. E. Auerbach, *Ind. Eng. Chem., Anal. Ed.*, 15 (1943) 492.
- 2 St. J. H. Blakeley and V. J. Zatka, *Anal. Chim. Acta*, 74 (1975) 139.
- 3 F. Chastellian and P. Hirsbrunner, *Z. Anal. Chem.*, 278 (1976) 207.
- 4 C. Radecka, K. Genest and D. W. Hughes, *Arzneim.-Forsch.*, 21 (1971) 548.
- 5 S. E. Brooker and K. J. Harkiss, *J. Chromatogr.*, 89 (1974) 96.
- 6 D. J. Jenden, R. A. Booth and M. Roch, *Anal. Chem.*, 44 (1972) 1879.
- 7 W. F. H. McLean and K. Jewers, *J. Chromatogr.*, 74 (1972) 297.
- 8 H. J. Vidic, H. Dross and H. Hewitz, *Z. Klin. Chem. Klin. Biochem.*, 10 (1972) 156.
- 9 M. Fieser and L. F. Fieser, *Reagents for Organic Synthesis*, Vol. 6, Wiley-Interscience, New York, 1977, p. 348.
- 10 S. L. Abidi, T. C. Carpenter and G. Fodor, *J. Org. Chem.*, 39 (1974) 1507.