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Analysis of Methyl Bromide at Ultra Low Concentration Levels

Theodore Dumas* and Edwin J. Bond

The conditions for measuring methyl bromide concentrations in air along with calibration data using gas chromatographs with photoionization and flame-ionization detectors are given. Sensitivity for detection at very low concentrations was found to be greatest with the photoionization detector; the flame-ionization detectors were suitable for the higher concentrations used for pest control. With the photoionization detector quantities of methyl bromide down to 10 pg could be measured with an accuracy of 3.9%.

Concern about the potential chronic effects on human health of toxic gases in the atmosphere has created the need for sensitive and precise methods for analyzing these gases. For toxic compounds like fumigants, where residual quantities of the gases occasionally may be released into the atmosphere, the need for effective monitoring capability is apparent. Some methods for rapid measurement of fumigants at low levels in the atmosphere with gas chromatography have already been described (see summarized account Bond and Dumas, 1984).

The purpose of this communication is to provide further details of a procedure for increasing sensitivity and precision in the analysis of one fumigant, methyl bromide. Comparative data for two different detector systems, flame ionization, and photoionization are also given.

MATERIALS AND METHODS

The gas chromatographs used in this study were the Photovac 10 A 10 with a photoionization detector (PID), a Bendix 2300, and a Gow Mac with flame-ionization detectors (FID).

Very low concentrations of methyl bromide have been analyzed in the Photovac 10 A 10 with a PID previously described Bond and Dumas (1982). A Teflon column 2 m long, 3 mm ID, and filled with Carbopak 40/60 mesh was used with a column temperature of 32 °C and high purity air (with less than 0.1 ppm hydrocarbons) at a flow rate of 10 mL/min. Under these conditions retention time for methyl bromide was 5.7 min. Calibration standards were prepared for the high sensitivity PID, by injecting 3 μL or 300 μL of undiluted methyl bromide gas into a 12.6-L flask with sampling ports. When this gas was uniformly dispersed in the flask, aliquots of 10–30 μL were drawn by gas syringe and injected into the Photovac GC. For analysis of samples of the higher concentration the signal

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Table I. Calibration Data for Methyl Bromide on the Bendix GC with a Flame-Ionization Detector

sample vol, μL	MeBr applied, ng	detector response,[a] counts	SD, counts	CV, %	MeBr calcd,[b] ng
300	30	1658	114	6.9	19.7
400	40	2365	185	7.8	30.3
600	60	3646	285	7.8	49.4
1000	100	6350	300	4.7	89.8

[a] Mean of 5 determinations. [b] Calculated using regression parameters. Calibration parameters for MeBr using least-squares regression analysis: intercept counts −341.08[c] ± 184.36; slope counts × ng^{-1} 66.90[c] ± 4.02; correlation coefficient (r) 0.9932. [c] 95% confidence interval.

was attenuated 100 times. A Hewlett Packard integrator 3390A was used with the Photovac GC for computing of the data.

Higher concentration levels of methyl bromide were analyzed by the less sensitive FID in the Bendix and Gow Mac instruments. In the Bendix a nickel column 2 m long, 3 mm ID, with Chromosorb 102, 120/140 mesh, a column temperature of 110 °C, and a nitrogen carrier gas flow rate of 20 mL/min gave a retention time of 5.3 min. A Hewlett Packard 3380A integrater computed the data.

In the Gow Mac GC a stainless steel column 2 m long, 3 mm ID, and filled with Apiezon L 30% on Chromosorb W 60/80 mesh was used with a column temperature of 25 °C and a nitrogen flow rate of 10 mL/min. When the high concentration standard (300 μL methyl bromide per 12.6 L) was used, 300–1000-μL samples of standard were drawn by a syringe and injected into the GC. A Hewlett Packard 3390A integrator was used with this instrument.

RESULTS AND DISCUSSION

Tables I–IV show calibration data obtained for the FID and PID. Five replicate determinations were performed for each quantity of MeBr analyzed. For the Bendix GC with FID a 5.3-min retention time was required to give good separation of MeBr from other components of the

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Table II. Calibration Data for Methyl Bromide on the Gow Mac GC with a Flame-Ionization Detector

sample vol, μL	MeBr applied, ng	detector response,[a] counts	SD, counts	CV, %	MeBr calcd,[b] ng
20	2	1889	491	26	2.2
50	5	4698	698	15	5.2
100	10	9815	950	9.7	10.7
200	20	18310	577	3.2	19.9
300	30	28175	881	3.1	30.6

[a] Mean for 5 determinations. [b] Calculated using regression parameters. Calibration parameters for MeBr using least-squares regression analysis: intercept counts $116.57^c \pm 439.88$; slope counts $\times$ ng^{-1} $924.77^c \pm 29.47$; correlation coefficient (r) 0.9972. [c] 95% confidence interval.

Table III. Calibration Data for Methyl Bromide on the Photovac 10 A 10 GC with a Photoionization Detector[a]

sample vol, μL	MeBr applied, ng	detector response,[a] counts	SD, counts	CV, %	MeBr calcd,[b] pg
10	10	52109	2040	3.9	8.6
15	15	81126	1830	2.2	13.8
20	20	107284	2305	2.1	18.4
30	30	166522	5652	3.4	29.0

[a] Mean of 5 determinations and attenuation at 1. [b] Calculated using regression parameters. Calibration parameters for MeBr using least-squares regression analysis: intercept counts $-3850.43^c \pm 3787.3$; slope counts $\times$ pg^{-1} $5616.68^c \pm 236.38$; correlation coefficient (r) 0.9972. [c] 95% confidence interval.

Table IV. Calibration Data for Methyl Bromide in the Photovac 10 A 10 GC with a Photoionization Detector[a]

| sample vol, μL	MeBr applied, ng	detector response,[a] counts	SD, counts	CV, %	MeBr calcd,[b] ng
10	1	51004	1944	3.8	0.73
15	1.5	81886	1258	1.5	1.25
20	2	112822	3936	3.5	1.77
30	3	170516	1031	0.6	2.74

[a] Mean of 5 determinations and attenuation at 100. [b] Calculated from detector response using regression analysis: intercept counts $-7565.29^c \pm 2012.51$; slope counts $\times$ ng^{-1} $59398.39^c \pm 859.92$; correlation coefficient (r) 0.9989. [c] 95% confidence interval.

sample at high levels of over 30 ng. The coefficient of variability (CV) for 30 ng was 6.9% and for 100 ng was 4.7% (Table I).

When no interferring components were present in the sample a shorter retention time of 1.3 min was selected and the Gow Mac GC was used for this analysis. The sensitivity under these conditions was higher, allowing measurement of 2–30 ng, but the variability was also much higher. The CV at 30 ng was 3.1% and at 2 ng 26% (Table II).

Table III shows calibration data for the Photovac GC with a PID where the retention time (5.7 min) was similar to that used in the Bendix GC (5.3 min), but the sensitivity was 3000 times higher and the variability was lower. For 10–30 pg the CV was less than 3.9%. When the signal was attenuated 100 times on the Photovac the sensitivity was still better than the GC with an FID and the variability was lower (at 1 ng 3.8% and at 3 ng 0.6%, Table IV). Since the PID was more sensitive and precise compared to the FID, this detector was most useful for the low concentrations of methyl bromide.

Some of the applications of these procedures will include monitoring of atmospheres containing both the high concentration levels of methyl bromide used for pest control operations and the low concentrations that may contaminate atmospheres to which human beings are exposed. In
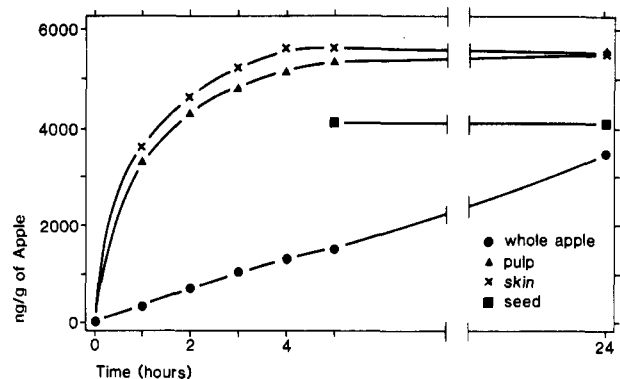
Figure 1. Desorption of methyl bromide from Granny Smith apples treated with 32 mg/L of methyl bromide for 2.5 h at 25 °C.

addition the capability of measuring at ultra low concentration levels has been found useful for experimental work on desorption of methyl bromide from treated commodities. In experiments designed to determine quantities of fumigant desorbing from treated fresh fruit, very low levels of the gas were found after many days of aeration. Granny Smith apples treated with 32 mg/L of methyl bromide for 2.5 h at 25 °C were placed in a 6-L desiccator and desorption of the whole apples, skin, and pulp was determined at intervals after the treatment. Desorption from seeds was determined by placing them in a 40-mL flask and sampling the gas at 5 and 24 h after treatment. Figure 1 shows the concentration levels of methyl bromide that desorbed from whole and parts of apples after such a treatment. The desorption rates at 5 h after treatment were found to be similar from the pulp and skin and about 3-fold that which desorbed from the whole apples. Desorption from the seeds was a little less than from pulp and skin. In apples that were aerated for 7 days at 25 °C the amount of methyl bromide that desorbed in a 5-h period from whole apple, skin, pulp, and seeds was measured and found to be 4, 49, 407, and 0.28 ng/g, respectively.

This procedure also may be used for detection of previous treatments of commercial commodities with the fumigant methyl bromide. In one instance, encountered in a related study, samples from a shipment of supposedly untreated apples were tested and found to emit methyl bromide. The room where 20 boxes of these apples were stored (at 4 °C) was found to contain a concentration of 5 ng/L of methyl bromide and analysis of individual apples showed that methyl bromide was being given off at a rate of 1 ng/g of apple in 24 h. Back checking on the history of this shipment revealed that fumigation with methyl bromide had been done about 3 weeks prior to the time the shipment was received at this laboratory. While the apples had been aerated at room temperature after the treatment and then retained and transported in cold storage around 4 °C the method of analysis was sufficiently sensitive to easily detect desorbing fumigant and to indicate that the apples had been previously subjected to a fumigation treatment.

Although the sensitivity of the methods described here are likely to be adequate for most types of analysis of methyl bromide in air the sensitivity for measurement of even lower concentration can still be increased. By use of the trapping method in which very dilute quantities of methyl bromide in air can be concentrated to easily measured levels (Dumas, 1982), the capability of the analysis can be appreciably extended.

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A Convenient Preparation of Pure Menthol and Menthone Isomers

Stephen A. Haut

Menthol isomers can be easily prepared in gram quantities and in a high state of purity by utilizing simple and inexpensive chemical procedures and preparative-scale high-performance liquid chromatography (prep-HPLC). Chemically pure (–)-menthol (1) was oxidized with Jones reagent in ether. The resulting (–)-menthone (5), freed of (+)-isomenthone (6) by prep-HPLC, was reduced with $LiAl(OCH_3)_3H$ to give predominantly (+)-neomenthol (2), which was freed from 1 by prep-HPLC. Epimerization of 5 with acid or base produces an equilibrium mixture of 69% 5 and 31% 6. Isolation of 6 by prep-HPLC, subsequent reduction with $Li/NH_3/t$-BuOH or $LiAlH_4$, and purification by prep-HPLC give (+)-isomenthol (3) and (+)-neoisomenthol (4), respectively. Physical properties, GC, HPLC, and optical rotation indicated that these materials are free of related compounds.

There are four geometric isomers of (–)-menthol (1) that occur in nature. They are, in addition to 1, (+)-neo-

1	2	3
(–)-menthol	(+)-neomenthol	(+)-isomenthol
4	5	6
(+)-neoisomenthol	(–)-menthone	(+)-isomenthone
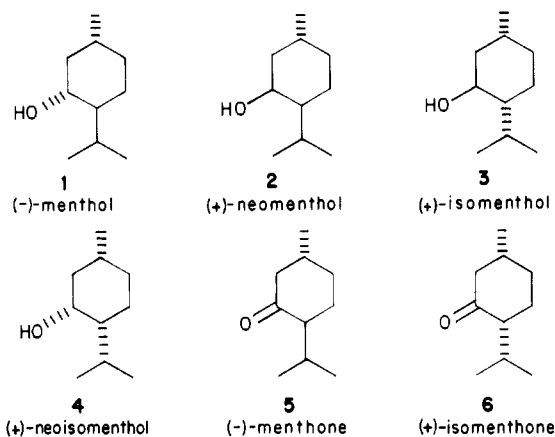
menthol (2), (+)-isomenthol (3), and (+)-neoisomenthol (4). Closely related to these are the ketones (+)-menthone (5) and (+)-isomenthone (6). Compounds 1–6 are components of peppermint and other essential oils (Guenther, 1949; Lawrence, 1980).

Pure 1 is readily available, and considerable research effort by many groups has been expended toward optimizing its production from natural (Guenther, 1949) and synthetic sources (Solodar, 1976).

Many synthetic methods have been devised over the years to obtain the other isomers, but all are complicated by the simultaneous formation of one or more of the other isomers. This requires time-consuming and tedious separation techniques (e.g., derivatization, fractional crystallization, preparative gas chromatography, and spinning-band distillation).

Commerical samples of these compounds, particularly 2, are often contaminated by the other isomers. Since physical, chemical, and sensory properties can differ widely with minor differences in molecular structure, it was

necessary to have isomerically pure samples of 1–4 and 5–6 in order to fully differentiate their characteristics.

The intent of this paper is to present for the first time a simple procedure to obtain these pure menthol and menthone isomers by combining their chemical interconvertability with separation techniques developed in our previous work with analytical (Haut and Core, 1981) and preparative high-performance liquid chromatography (prep-HPLC) (Haut and Core, 1982).

METHODOLOGY

Readily available 1 was used as the starting point in the scheme
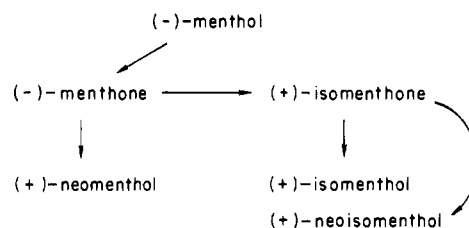
(–)-Menthol (1), purified by HPLC, was oxidized to (–)-menthone (5). The ketone 5 was then epimerized by acid or base to produce the equilibrium mixture containing 31% (+)-isomenthone (6). Pure samples of 5 or 6 tend to reequilibrate slowly on standing at room temperature. Storage in the cold is recommended to retard this process.

The complete separation of these ketones is a crucial step. Prior to HPLC (Bergman and Hall, 1979; Bergman, 1979), this separation was not a simple or efficient task and, as a result, may have led to some isomeric cross contamination in later synthetic manipulations. Reduction of either purified ketone with a suitable reagent followed by HPLC purification leads to the various isomers.

The synthesis of pure 1 or 3 by the dissolving metal reduction of 5 or 6 has already been described in the literature (Solodar, 1976).

Neoisomenthol (4) was produced by $LiAlH_4$ reduction of 6. The byproduct, compound 3 (2%), was easily removed by HPLC.

Isomerically pure neomenthol (2) was the most difficult of these compounds to obtain because (a) reduction of 5

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