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THE TRACE DETECTION OF SOME NON-VOLATILE NITROSAMINES BY COMBINED GAS CHROMATOGRAPHY AND MASS SPECTROMETRY

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SUMMARY

A gas chromatographic–mass spectrometric procedure based on characteristic-ion monitoring is described for the separation and detection of trace amounts of some non-volatile nitrosamines. A silver-frit interface and a modified spectrometer-inlet system used to transfer material from the gas chromatograph to the mass spectrometer are described.

INTRODUCTION

Several papers describing the gas chromatographic separation of volatile dialkyl and heterocyclic nitrosamines have been published[1–6]. In view of the carcinogenic nature of some nitrosamines, the detection of trace amounts of such material is desirable. Techniques for detecting steam-volatile nitrosamines by combined gas chromatography and mass spectrometry (GC–MS) down to the μg/ml level are now well established[7–9]. The GC of some less volatile dialkyl and aromatic nitrosamines on both packed and capillary columns has been reported[6,10], but no procedure for the GC–MS high-resolution confirmation of trace amounts of these materials has been evolved. This paper describes such a method, based on a technique used in this laboratory for detection of traces of volatile nitrosamines[8].

DISCUSSION AND EXPERIMENTAL

The GC–MS equipment used has been described[8]. Transfer of sample from the chromatograph to the mass spectrometer is normally by means of a silicone-membrane separator, which has been operating satisfactorily up to 160° for about 3 years. The life of the membrane is substantially reduced by continuous operation at higher temperature, and at over 230° is reduced to a matter of hours. High-temperature operation also results in an increase in the pressure in the mass spectrometer. For the analysis of less volatile nitrosamines (which requires sustained high-temperature operation), a different separator is required. To facilitate interchange between a membrane separator and a high-temperature separator, a device of similar geometry would be

convenient. Separators described in the literature which may be used at high temperatures include that of Watson and Biemann[11], that of Ryhage[12] and the silver frit[13]. Apart from the incompatibility of a glass Watson–Biemann separator with the existing interface geometry, it was found that the transfer of a number of nitrosamines was less effective than with the membrane separator. In view of the limited availability of the Ryhage separator, it was decided to study the suitability of a silver-frit separator, which can be constructed at negligible cost. In one such device[13], the frit was mounted in the stem of a metal tee piece; more recently, details of a separator of much lower internal volume and suitable for high-resolution GC have been published[14].

A diagram of the silver-frit separator used in the present work is shown in Fig. 1. The frit is contained in the same housing as the silicone membrane described previously (*cf.* Fig. 1 of R3f. 8). The silve frit (Flotronics, Spring House, Pa., U.S.A.,

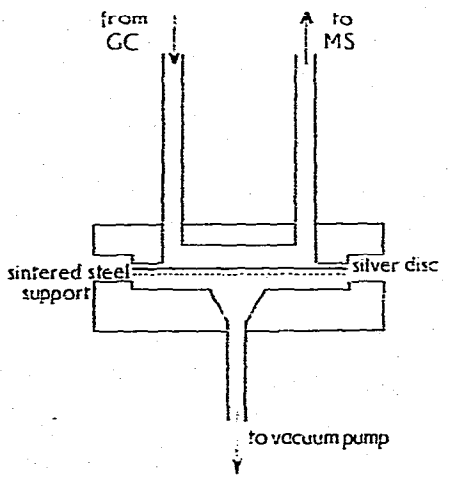

Fig. 1. Silver-frit separator.

and Systems and Components Ltd., Devizes, Great Britain) consists of a disc 21 mm in diameter by 50 μm, with a pore size of 0.2 μm. It is supported against a coarse sintered stainless-steel disc on the low-pressure side of the housing. The steel disc is compressed against a gold O-ring, and the two faces of the housing are sealed against the atmosphere by means of a second gold ring. The internal volume of the separator, excluding the transfer lines, is 4 μl. Since the separator housing is identical to that used for the silicone-membrane separator, interchange between the two devices is straightforward. The silver separator is not suitable for the transfer of trace amounts of low-molecular-weight compounds and does not therefore supersede the membrane separator for the transfer of volatile nitrosamines. The separator is connected to the chromatograph and mass spectrometer by stainless-steel tubing (0.5 mm I.D.). Isolation from the mass spectrometer is by a stainless-steel bellows valve, and the silver-frit face is evacuated by means of a rotary pump. Constrictions in the transfer and pumping lines are adjusted to give a pressure of 0.1 torr with a helium carrier-gas flow-rate of 10 ml/min at the GC column exit. The useful flow-rate range over which the separator may be used is limited by the resulting pressure in the mass spectrometer.

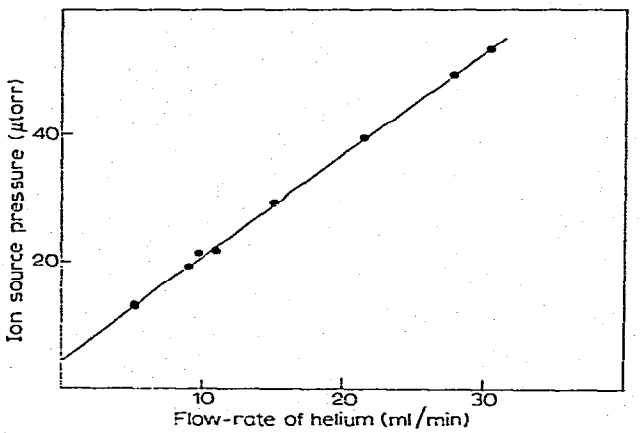

Fig. 2. Variation of ion-source pressure with carrier-gas flow-rate.

Changes in source pressure with carrier-gas flow-rate (at the column exit) are shown in Fig. 2. As examples, three high-boiling dialkyl nitrosamines were studied, *viz.*, di-*n*-pentyl, di-*n*-hexyl and di-*n*-octyl nitrosamines; di-cyclohexyl nitrosamine (m.p. 100°) was also included. Aromatic nitrosamines tend to decompose at elevated temperature, particularly on polar stationary phases[10]; diphenyl and dibenzyl nitrosamines (m.p. 59° and 67°, respectively) were selected. The nitrosamines were partitioned by 5% SE-52 on 80–100 BS mesh Chromosorb W AW DMCS contained in a 15 m × 1.8 mm I.D. stainless-steel column. The chromatograph oven and transfer-line temperature was 210°, and the carrier-gas flow-rate was 3.4 ml/min. Comparison of the spectra obtained by introducing each nitrosamine into the mass spectrometer both via the chromatograph and directly showed that negligible decomposition occurred under these conditions. Retention data are presented in Table I, together with Kováts retention indices (I) at 210° and change in index per 10° ($\Delta I/10°$) covering the range 210–240°.

A comparison of the GC flame ionisation detector and MS total-ion-monitor response profiles for the nitrosamines listed in Table I showed that significant peak distortion was occurring after elution from the GC column; under the same experimental conditions, distortion was not observed with some of the lower dialkyl nitrosamines. The transfer line to the mass spectrometer passes into the ion source via a metal-to-glass seal and terminates as a jet above, and in line with, the ion block.

TABLE I

RETENTION DATA

Nitrosamine	*Retention time (min)*	$I_{210°}$	$\Delta I/10°$
Di-*n*-pentyl	3.7	1510	5.0
Di-*n*-hexyl	6.8	1705	3.3
Di-*n*-octyl	22.1	2080	11.6
Dicyclohexyl	6.2	1675	6.6
Diphenyl	11.2	1865	11.6
Dibenzyl	15.7	1970	10.0

Compounds emerging from the transfer line are thus directed at the ion block, and some loss can occur before ionisation. Distortion and sample losses can be minimised by terminating the transfer line within the ion block[15], and a transfer line with a retractable silica jet was built for the purpose. The transfer line outside the ion source is attached to a steel bellows operated by a micrometer head. The bellows are attached by means of a gold compression fitting to a silica jet within the ion source. For normal operation, the jet is moved into the ion block by rotating the micrometer head; for source removal, the jet is retracted. A study was made of the effect of jet position on the peak symmetry and sensitivity for a wide range of compounds. In general, for compounds of decreasing volatility, the position of the jet relative to the ion block became more critical. For the nitrosamines listed in Table I, concentrations of 100 μg/ml injected on to the column could readily be detected by total ion monitoring when the jet terminated within the ion block. The elution profiles were compatible with those observed on the flame ionisation detector. With the jet 3 mm away from the ion block, peak distortion and a diminished response were observed. At 8 mm away from the block, none of the nitrosamines was detected. For the specific detection of smaller amounts of nitrosamines, in which the jet was within the ion block, characteristic ion monitoring under high resolution was used. The dialkyl nitrosamines give progressively less intense parent ions as the series is ascended, and for di-*n*-pentyl nitrosamine the relative intensity of the parent ion is only 4%. For some dialkyl nitrosamines, loss of OH is characteristic[16], and the fragment resulting from this loss was used as a basis for detection. For dicyclohexyl and dibenzyl nitrosamines, the parent ions are sufficiently intense to be analytically useful. For diphenyl nitrosamine[17], major ions occur at *m/e* 167 ($C_{12}H_9N$), 168 ($C_{12}H_{10}N$) and 169 ($C_{12}H_{11}N$). The ion at *m/e* 169 is produced by an ion–molecule reaction, and its intensity is therefore pressure dependent. For quantitative analysis, it is preferable to use *m/e* 168 formed by loss of NO from the parent. Table II lists the accurate masses used for specific detection, together with the corresponding masses of perfluorotri-n-butylamine fragments used for peak monitoring. Relative intensities with respect to the appropriate base peak are also shown. With a resolution of 7000, the detection limit was about 10 μg/ml (based on the amount of material injected on to the column) for all the compounds.

TABLE II

MASS SPECTRAL DATA

Nitrosamine	*Molecular formula*	*Mass monitored*	*Relative intensity*	*Reference mass*
Di-*n*-pentyl	$C_{10}H_{22}N_2O$	169.1705	15	168.9888
Di-*n*-hexyl	$C_{12}H_{26}N_2O$	197.2018	22	196.9848
Di-*n*-octyl	$C_{16}H_{34}N_2O$	253.2643	40	256.9887
Dicyclohexyl	$C_{12}H_{22}N_2O$	210.1732	56	211.9871
Diphenyl	$C_{12}H_{10}N_2O$	168.0813	100	168.9888
Dibenzyl	$C_{14}H_{14}N_2O$	226.1106	68	225.9903

CONCLUSIONS

Non-volatile nitrosamines can be specifically detected by characteristic ion monitoring in a high-resolution mass spectrometer after gas chromatographic separation. The detection limit using the system described herein is 10 μg/ml.

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