

GAS CHROMATOGRAPHIC SEPARATION
OF BROMO- AND CHLOROPYRIDINES

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In the course of investigations, carried out in this laboratory on the bromination and mercuration of pyridine and pyridine-N-oxide¹⁻⁴, rather complicated reaction products were obtained, which for analysis were converted into mixtures of the corresponding bromopyridines. An attempt was made to separate these substances quantitatively by gas-liquid chromatography (GLC). In this paper a description is given of a suitable method for the chromatographic determination of the compounds mentioned.

At first, only a column (A) was used at 165° with a filling of Chromosorb W coated with tritoyl phosphate (weight ratio 100:20), the carrier gas being hydrogen. With this column it was possible to separate all mono- and dibromopyridines, except 3-bromopyridine and 4-bromopyridine, which have the same retention volumes.

Therefore we changed to a procedure based on the fact that 4-bromopyridine polymerizes to non-volatile pyridyl pyridinium bromide when heated. Mixtures containing both bromopyridines were chromatographed before and after keeping them for 3 h at 100-110°. Since in the first analysis both 3- and 4-bromopyridine were evolved from the column and during the second one only 3-bromopyridine emerged the amounts of both isomers could be estimated. Results were not completely satisfactory, however, because 4-bromopyridine partly reacted with 3-bromopyridine when heated, yielding 4-pyridyl 3-bromopyridinium bromide. Therefore, we investigated whether other stationary phases would realize a direct separation of 3-bromo- and 4-bromopyridine. Experiments were carried out with Apiezon L, polyethylene-glycol, diglycerol, phenanthrene, polyglycol glutarate and Tide. Whereas Apiezon, diglycerol and phenanthrene effected no separation of 4-bromo and 3-bromopyridine at all, polyethylene glycol and polyglycol glutarate showed separation factors of 1.04 and 1.08 respectively, indicating a possible separation on high efficiency columns. The best result, however, was obtained with the commercial detergent Tide.

Tide is the trademark for a special all-purpose detergent made by Procter and Gamble (U.S.A.). Its composition according to DECORA AND DINNEEN⁵ is: lauryl sulphate (sodium salt, 12 %), alkyl arylsulphonate (sodium salt, 5 %), sodium sulphate (15 %), higher molecular phosphates (45 %), silicates (9 %), lauryl alcohol (1.5 %), water (11 %), carboxymethyl-cellulose (sodium salt, 1 %), optical dyes.

The use of Tide in GLC was introduced by GOHLKE AND MCLAFFERTY⁶. In 1959, DESTY AND HARBOURN⁷ gave details for its use as a packing in general purpose columns. DECORA AND DINNEEN^{5,8} extracted Tide with petroleum ether and used the porous

residue as a stationary phase support. They studied the behaviour of 10 stationary phases in combination with this support for the separation of a mixture of 14 pyridine homologues. Tide as such was used by PORCARO AND JOHNSTON⁹ for the separation of the isomeric amyl alcohols and by MATTHEWS *et al.*¹⁰ in large scale columns for the separation of C₈-aldehydes. SANDLER AND STORM¹¹ extracted the surface active agent of Tide with petroleum ether and impregnated kieselguhr with the Tide extracts for the determination of formaldehyde.

We found that a column filled with Chromosorb impregnated with a petroleum ether extract of Tide, achieved complete separation of 3- and 4-bromopyridine at 100°, 3-bromopyridine again being eluted first. The peak of 4-bromopyridine was very asymmetric with a sharp front and tailed. Usually this is an indication of adsorption of the compound in question by the column material. It was confirmed that adsorption occurs in this case, by the fact that the retention time of 4-bromopyridine decreases with increasing amounts of sample. The separation factor of 4- and 3-bromopyridine varied from 1.1 to 1.2.

The tailing of the 4-bromopyridine peak also interferes with the separation of this compound from 2-bromopyridine, which elutes after the 4-isomer. We succeeded in suppressing the undesirable tailing of the 4-bromopyridine by coating the Chromosorb with soda before impregnating it with Tide extract according to the procedure of GOLDING AND TOWNSEND¹² for the separation of mono-, di- and trimethylpyridines. Table I shows the separation factors obtained when using the column filled with this stationary phase (B).

TABLE I

SEPARATION FACTORS FOR BROMOPYRIDINES

Column B: length 200 cm, diameter 0.4 cm; filling 9.2 g of a mixture of Chromosorb W, soda and Tide extract (weight ratio = 100:6.3:21.3).

<i>Separation factors</i>	100°	80°
R_v 4-bromopyridine/ R_v 3-bromopyridine	1.15	1.17
R_v 2-bromopyridine/ R_v 4-bromopyridine	1.11	1.05-1.10
R_v (= retention volume) of 3-bromopyridine	1010 ml	2090 ml

The separation of 2-bromo and 4-bromopyridine was still incomplete, however, due to some residual tailing of the 4-bromopyridine peak. An attempt was made to increase the separation factor of 2-bromo- and 4-bromopyridine by using a short pre-column (length 30 cm, diameter 0.4 cm; filling: 1.6 g of Chromosorb coated with soda and Polywachs 2000 (weight ratio = 100:6:20)). Now the separation of these isomers was good (factor = 1.52), but that of 4- and 3-bromopyridine was incomplete again (separation factor 1.07 at 100°; R_v 3-bromopyridine = 1380 ml). A better result was obtained when the pre-column (C) was filled with 1.5 g of a mixture of Chromosorb, soda, Tide extract and Polywachs 2000 (weight ratio = 78.3:5.0; 15.2:1.5). Table II shows the separation factors obtained with columns B + C and their dependence on the column temperature.

With increasing temperature the 4-bromopyridine peak tends to shift towards the 3-bromopyridine peak. This temperature effect is another indication that 4-bromopyridine is much more strongly adsorbed by the column filling than 3-bromo-

TABLE II
SEPARATION FACTORS FOR BROMOPYRIDINES
Columns B + C

<i>Separation factors</i>	100°	90°	80°
R_v 4-bromopyridine/ R_v 3-bromopyridine	1.12	1.15	1.17 ⁵
R_v 2-bromopyridine/ R_v 4-bromopyridine	1.18	1.18	1.17
R_v of 3-bromopyridine	1250 ml	1710 ml	2500 ml

pyridine, adsorption occurring to a lesser degree at higher temperatures. As well as the temperature effect, the asymmetric form of the 4-bromopyridine peak on column (A) and the large shift of the peak top to smaller retention volumes with increasing sample amounts, there is the effect of the soda which is known to suppress adsorption, on the peak form of 4-bromopyridine. Thus it may be concluded that some kind of selective adsorption must be responsible for the separation of 3-bromo- and 4-bromopyridine when Tide extract is used as stationary phase.

According to DECORA AND DINNEEN⁵, the sodium salts of lauryl sulphate and of a dodecyl phenylsulphonate are the chief organic components of Tide. In order to establish a stationary phase more precisely which allows the separation of 3- and 4-bromopyridine, four columns containing the following fillings were tried:

1. Chromosorb W (83 %), lauryl sulphate (sodium salt, 17 %).
2. Chromosorb W (83 %), dodecyl phenylsulphonate (sodium salt, 17 %).
3. Chromosorb W (83 %), lauryl sulphate (sodium salt 12 %).
4. Inorganic residue of the Tide extraction (85 %), lauryl sulphate (sodium salt, 15 %) and dodecyl phenylsulphonate (sodium salt, 5 %).

None of these columns gave a separation of 3- and 4-bromopyridine as effected by the Tide extract, possibly due to the fact that the structures of the surface active agents used in our experiment differ from those of the Tide components. Thus, for the quantitative analysis of mixtures of bromopyridines, application of the Tide-column B + column C must be recommended, together with a second analysis using the tritoyl phosphate column (A), which enables a better separation of the dibromopyridines.

The chromatographic analysis of mixtures of monochloropyridines has also been studied. Analogous phenomena were encountered here. The columns with the Tide extract filling again gave the best separation of the three isomers, 4-chloropyridine showing a less symmetric peak and eluting between the 3- and 2-isomers. Also the temperature effects, though somewhat smaller, corresponded with those observed in the experiments with the monobromopyridines.

EXPERIMENTAL

A Becker gas chromatograph (Delft, the Netherlands) with a katharometer as detector was used.

Preparation of Tide extract

The detergent was extracted in a Soxhlet apparatus (after drying at 120°) with

petroleum ether (boiling range: 60–80°). The petroleum ether solution was evaporated to dryness on a steam bath, whereupon the residue was heated for some hours at 120°, yielding a semi solid.

Impregnation of Chromosorb with soda

30 g of Chromosorb was allowed to stand in 150 ml of a 13.5 % aqueous solution of soda crystals ($\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$) for some hours. Then the liquid was sucked off and the solid matter dried at 120° to constant weight (31.9 g), 6 % soda being left on the Chromosorb.

Impregnation of Chromosorb with the stationary phase

Amounts of the stationary phases, usually dissolved in chloroform, were added to the Chromosorb in the desired ratios. The slurries were evaporated to dryness on a steam bath with gentle stirring with a feather, whereupon the powders obtained were dried at 120° and screened to 60–100 mesh.

Columns

These are copper tubes, internal diameter 0.4 cm.

Column A. Length: 200 cm; filling: 8.0 g of Chromosorb + tritoyl phosphate (weight ratio 100:20).

Column B. Length: 200 cm; filling: 9.2 g of a mixture of Chromosorb W, soda and "Tide" extract (weight ratio 100:6.3:21.3).

Column C. Length: 30 cm; filling: 1.5 g of a mixture of Chromosorb W, soda, "Tide" extract and Polywachs 2000 (weight ratio 100:6.3:19.3:1.93).

Carrier gas

Hydrogen was used, the flow rate varying from 60 to 120 ml/min.

The retention volumes given in the text are all uncorrected.

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SUMMARY

A method is described for quantitative analysis of mixtures of mono- and dibromopyridines or mono- and dichloropyridines by gas chromatography.

The procedure consists of two subsequent chromatographic separations. In the first one a column containing tritoyl phosphate on Chromosorb is used; it enables the separation of all components except the 3- and 4-halogenopyridines which have the same retention volume. A second separation is carried out with a column containing a filling developed on the basis of an extract of the commercial detergent Tide, which gives an excellent analysis of the monohalogeno pyridines.

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