

# GAS CHROMATOGRAPHIC ANALYSIS OF 1,3,5-BENZENETRICARBOXYLIC AND 1,3,5-CYCLOHEXANETRICARBOXYLIC ACID AND THEIR DERIVATIVES

M. ŠAFÁŘ, Z. KAFKA, V. GALÍK and S. LANDA

*Laboratory of Synthetic Fuels,*

*Institute of Chemical Technology, 166 28 Prague 6*

Received November 28th, 1972

Methyl and ethyl 1,3,5-benzenetricarboxylate, methyl and ethyl *cis*- and *trans*-1,3,5-cyclohexanetricarboxylate, 1,3,5-tris(hydroxymethyl)benzene, and 1,3,5-tris(hydroxymethyl)cyclohexane have been prepared as well as the acetates and trimethylsilyl derivatives of the last two compounds. On bromination of these two compounds 1,3,5-tris(bromomethyl)benzene and 1,3,5-tris(bromomethyl)cyclohexane, resp. were obtained, the latter together with the partially brominated compounds, 1,3-bromomethyl-5-hydroxymethylcyclohexane acetate and 1-bromomethyl-3,5-hydroxymethylcyclohexane diacetate. In gas chromatography, the relative elution volumes were measured on the stationary phases SE-30 (at 200°C) and butanediol succinate (at 210°C).

1,3,5-Benzenetricarboxylic and 1,3,5-cyclohexanetricarboxylic acid have been gas chromatographically analysed in form of their methyl esters, and frequently also besides other benzene carboxylic acids, by employing temperature programming<sup>1-3</sup>. With the isothermal analysis are dealing other papers<sup>4-9</sup>. Less customary is the determination of aromatic acids in form of the trimethylsilyl esters<sup>10</sup>. With the elution properties of the possible stereoisomeric methyl cyclohexanetricarboxylates were dealing Bendel, Meltzow, and Vogt<sup>11</sup>. By means of a capillary column they separated a mixture of the isomeric 1,3,5-cyclohexanetricarboxylic acid esters, however without accurately assigning the structure to the individual peaks.

The present work deals with the separation of 1,3,5-benzenetricarboxylic and 1,3,5-cyclohexanetricarboxylic acid and their derivatives as intermediates in the synthesis of 1,3,5-tris(bromomethyl)cyclohexane. A survey of the chromatographic data for the compounds studied on the stationary phases SE-30 and butanediol succinate resp. gives Table I. The values of the relative elution volumes for methyl and ethyl 1,3,5-benzenetricarboxylate on the polar stationary phase differ only very little (1.00 and 1.08, resp.), since the interaction of the polar ester groups comes into play to a decisive extent. Also by larger interaction of the aromatic nucleus with the stationary phase may be explained the marked difference in the elution volumes of 1,3,5-tris(hydroxymethyl)benzene triacetate (2.75) and 1,3,5-tris(hydroxymethyl)cyclohexane triacetate (1.55) in contrast to those on the stationary phase SE-30 (1.58 and 1.53, resp.). The smaller elution volume of methyl and ethyl *trans*-1,3,5-cyclohexanetricarboxylate in comparison with that of the isomers is in accord with the supposed

structure, as it is known that for compounds having axially disposed substituents the interaction with the stationary phase is impeded<sup>1,2</sup>. Similar relations have been observed with the dimethyl esters of *cis*- and *trans*-1,3-cyclohexanedicarboxylic acid<sup>1,3</sup>. From the presented results it follows that the comparison of the chromatographic data obtained and the stationary phases SE-30 and butanediol succinate makes possible to distinguish between the individual derivatives of 1,3,5-benzenetricarboxylic acid and those of 1,3,5-cyclohexanetricarboxylic acid.

## EXPERIMENTAL

The melting points are uncorrected.

**Apparatus.** Gas chromatography was effected on a Chrom 31 apparatus (Laboratorní přístroje, Prague) fitted with a flame-ionisation detector. Nitrogen was the carrier gas. The feeding chamber was partly filled with glass spheres and heated to 290°C.

**Columns and packing.** The columns made of stainless steel had an i.d. of 6 mm. Column A was 3.6 m long and contained 3% SE-30 on silanised Chromosorb G, 60/80 mesh (Carlo Erba, Milano). The weight of the packing was 48.3 g and the nitrogen flow rate 45 ml/min. Column B

TABLE I  
Survey of Chromatographic Data for 1,3,5-Benzenetricarboxylic and 1,3,5-Cyclohexanetricarboxylic Acid and their Derivatives

Compound	I	Column A : 200°C $V_g^{rel}$	Column B : 210°C $V_g^{rel}$
Methyl 1,3,5-benzenetricarboxylate	1 879	1.00	1.00
Ethyl 1,3,5-benzenetricarboxylate	2 066	1.95	1.08
Methyl <i>cis</i> -1,3,5-cyclohexanetricarboxylate	1 791	0.73	0.86
Methyl <i>trans</i> -1,3,5-cyclohexanetricarboxylate	1 740	0.62	0.56
Ethyl <i>cis</i> -1,3,5-cyclohexanetricarboxylate	1 972	1.39	0.90
Ethyl <i>trans</i> -1,3,5-cyclohexanetricarboxylate	1 910	1.13	0.56
1,3,5-Tris(hydroxymethyl)benzene triacetate	2 010	1.58	2.75
1,3,5-Tris(hydroxymethyl)cyclohexane triacetate	1 998	1.53	1.55
1-Bromomethyl-3,5-hydroxymethylcyclohexane diacetate	1 974	1.41	1.42
1,3-Bromomethyl-5-hydroxymethylcyclohexane acetate	1 955	1.32	1.29
1,3,5-Tris(bromomethyl)cyclohexane	1 937	1.22	1.18
1,3,5-Tris(bromomethyl)benzene <sup>a</sup>	1 968	1.35	2.24
1,3,5-Tris(hydroxymethyl)benzene TMS	1 911	1.12	1.79
1,3,5-Tris(hydroxymethyl)cyclohexane TMS	1 827	0.83	1.79
$V_g^0$ of methyl 1,3,5-benzenetricarboxylate, ml	—	290	1 343

<sup>a</sup> Under partial decomposition.

was 1.2 m long and contained 2% butanediol succinate (Lachema, Brno) on ChromatonN-AW-HMDS of grain size 0.16–0.20 mm (Lachema, Brno). The weight of the packing was 9.7 g and the nitrogen flow rate 35 ml/min.

*The preparation of 1,3,5-benzenetricarboxylic acid*, its methyl<sup>14</sup> and ethyl ester, of methyl and ethyl 1,3,5-cyclohexanetricarboxylate, 1,3,5-tris(hydroxymethyl)cyclohexane, and 1,3,5-tris(bromomethyl)cyclohexane has been described in an earlier communication<sup>15</sup>. The steric arrangement of methyl 1,3,5-cyclohexanetricarboxylate was studied by analysis. From the measuring results it follows that the carboxyl groups are situated in triequatorial position. Our observation is in accord with citation<sup>16</sup>.

*Methyl trans-1,3,5-cyclohexanetricarboxylate*. The isomerisation of methyl *cis*-1,3,5-cyclohexanetricarboxylate was performed by a similar procedure as that described in ref.<sup>17</sup>. The *cis*-isomer (0.3 g) was put in an ampoule containing methanol (5 ml) and sodium methylate prepared from 0.1 g of sodium. The sealed ampoule was set aside at room temperature for 39 days, whereupon its content was transferred to a flask, evaporated to dryness and the residue extracted with benzene. On evaporation a thick non-crystallising residue was obtained containing approximately 45% of the new substance. Mass spectroscopy (LKB 9000) showed that its mass was identical with that of the starting ester. The spectra of both substances show only minute differences indicating that they belong to two isomers.

*Ethyl trans-1,3,5-cyclohexanetricarboxylate*. This isomeric ester present in small quantity in the crude ethyl 1,3,5-cyclohexanetricarboxylate was determined on the basis of the analogy of the retention time ratio of the methyl *cis*- and methyl *trans*-1,3,5-cyclohexanetricarboxylate.

*1,3,5-Tris(hydroxymethyl)benzene*. Into a three-necked flask containing 250 ml of dry ether and fitted with a stirrer, Soxhlet extraction apparatus, and dropping funnel, lithium aluminium hydride (3.8 g) was weighed in. In the thimble of the extractor ethyl benzenetricarboxylate (9.8 g) was placed. The flask was heated on a water bath for about 3 h under continuous stirring. For decomposition 2 ml of water and 30 ml of 10% sulphuric acid were added. The ether was decanted and the solid material was treated with ethanol (200 ml) followed by refluxing the mixture on a water bath for 2 h, whereupon it was filtered and the ethanol removed by distillation. The residue consisting of a syrupy liquid solidified after short time. It was washed with ether and dried affording the title compound in 86% yield, m.p. 75°C (lit.<sup>18</sup> gives m.p. 77°C).

*1,3,5-Tris(hydroxymethyl)benzene triacetate*. 1,3,5-Tris(hydroxymethyl)benzene (1.7 g) was mixed with 30 g of a 3 : 1 mixture of pyridine and acetic anhydride and heated for 4 h on a water bath. The volatile substances were removed from the reaction mixture by distillation *in vacuo*. The residue was dissolved in chloroform and after removing the solvent, the residue was taken up in ether. Upon strong cooling the ethereal solution the product crystallised in form of needles; yield 90%, m.p. 41°C (lit.<sup>18</sup> gives m.p. 35–36°C).

*1,3,5-Tris(hydroxymethyl)cyclohexane triacetate*. 1,3,5-Tris(hydroxymethyl)cyclohexane (0.2 g) was treated with acetic anhydride (5 ml) and the mixture allowed to stand overnight. Then it was heated on a water bath for 1 h. After removing the acetic anhydride *in vacuo* a chromatographically uniform residue was obtained.

*Bromo derivatives of 1,3,5-tris(hydroxymethyl)cyclohexane*. 1 g of 1,3,5-tris(hydroxymethyl)cyclohexane was treated with 15 ml of 25.5% hydrogen bromide in acetic acid. This mixture was heated in a sealed ampoule at 50°C for 10 h. The content of the ampoule was then diluted with water and extracted several times with chloroform. The combined chloroform extracts were neutralised with aqueous sodium hydrogen carbonate, washed with water and dried over anhydrous sodium sulphate. Removing the chloroform by evaporation yielded a yellow syrupy

material (1.8 g) consisting according to gas chromatography of four substances, two of which correspond with 1,3,5-tris(bromomethyl)cyclohexane and 1,3,5-tris(hydroxymethyl)cyclohexane triacetate, resp. The retention times of the remaining two substances lie between those of known compounds. The unknown substances were identified by means of mass spectrometry as 1,3,5-tris(hydroxymethyl)cyclohexane monobromodiacetate and dibromoacetate, resp.

*1,3,5-Tris(bromomethyl)benzene.* 1,3,5-Tris(hydroxymethyl)benzene was treated with 8 ml of 29.5% hydrogen bromide in acetic acid. This mixture was heated in a sealed ampoule at 50°C for 10 h. Working up in the usual way afforded the chromatographically uniform substance.

*Trimethylsilyl ethers* of 1,3,5-tris(hydroxymethyl)benzene and 1,3,5-tris(hydroxymethyl)cyclohexane. The silylation was performed by a modified method according to Sweeley<sup>19</sup>.

#### REFERENCES

1. Jüttner B.: *Brennstoff-Chem.* 44, 206 (1963).
2. Schnitzer M., Desjardins J. G.: *J. Gas Chromatog.* 2, 270 (1964); *Chem. Abstr.* 61, 11306 (1964).
3. Funasaka W., Kojima T., Hirono H.: *Bunseki Kagaku* 13, 1116 (1964); *Chem. Abstr.* 62, 7113 (1965).
4. Ratuský J., Baštář L.: *Chem. Ind. (London)* 1962, 650.
5. Funasaka W., Kojima T., Kimoto J.: *Bunseki Kagaku* 12, 242 (1963).
6. Ratuský J., Baštář L.: *This Journal* 29, 3066 (1964).
7. Jiráček J., Dvořáček J.: *Chem. listy* 64, 75 (1970).
8. Kucharenko T. A., Grigorjeva E. A.: *Neftechim.* 10, 303 (1970).
9. Maximov O. B., Šapovalov V. E.: *J. Chromatog.* 66, 29 (1972).
10. Kaufman M. L., Friedman S., Wender I.: *Anal. Chem.* 39, 1011 (1967).
11. Bendel E., Meltzow W., Vogt V.: *J. Chromatog.* 38, 133 (1968).
12. Eliel E. L.: *Stereochemie uhlikatých sloučenin*, p. 250. Academia, Prague 1970.
13. Allinger N. L., Curby R. J. jr: *J. Org. Chem.* 26, 933 (1961).
14. Galík V., Kafka Z., Šafář M., Landa S.: *This Journal* 39, 895 (1974).
15. Lukeš R., Galík V.: *Chem. listy* 48, 858 (1954).
16. Yoshimo T., Kikuchi V., Komiyama J.: *J. Phys. Chem.* 70, 1059 (1966).
17. Tichý M., Šipoš F., Sicher J.: *This Journal* 31, 2889 (1966).
18. Hesse G., Rämisch F.: *Chem. Ber.* 87, 764 (1954).
19. Sweeley C. C., Walker B.: *Anal. Chem.* 36, 1461 (1964).

Translated by R. Wichs.