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A SPLIT SYSTEM APPLICABLE AS A GAS CHROMATOGRAPHIC–MASS SPECTROMETRIC INTERFACE AND AS EFFLUENT SPLITTER FOR SPECIFIC GAS CHROMATOGRAPHIC DETECTORS

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SUMMARY

An interface is described which allows the open split mode and direct coupling operation to be used. The transfer line consists of a fused silica tube which leads from the end of the column to the mass spectrometer. This device is suitable for various applications in gas chromatography alone and in gas chromatography–mass spectrometry work. The advantages are (1) the possibility of suppressing unwanted peaks, such as those due to solvents and bulk impurities; (2) dead volume-free connections through a transfer line which does not show any active sites; (3) cheap and easy to replace; (4) atmospheric pressure at the column end, so that chromatograms are exactly comparable with previous runs; and (5) easy change of columns without affecting the ion source conditions or flushing and activating the transfer line with air. Examples of applications are given for pterins and steroids.

INTRODUCTION

Since the introduction of capillary columns into gas chromatography–mass spectrometry (GC–MS), various types of coupling devices have been constructed in order to retain the excellent separation characteristics of these columns. Nowadays, the most widely used interfaces are classified into two types: (i) direct connection of the GC column to the MS system, and (ii) open split coupling.

Direct coupling, first described by Ten Noever de Brauw and Brunnée[1] and Henneberg and Schomburg[2], has the advantage of a 100% yield, lack of dead volumes and, therefore, no reduction of the resolving power; on the other hand, the vacuum at the end of the column may affect retention times. The main disadvantage arises from the fact that all of the eluate reaches the ion source. In trace analysis, especially with on-column injection, amounts of up to 5 μl are applied to the column and the solvent and bulk impurities such as derivatizing reagents contaminate the ion source and can diminish the sensitivity severely.

These difficulties can be circumvented by the use of an open split connection, introduced by Henneberg *et al.*[3]. The features of such a device are as follows. As the end of the column is at atmospheric pressure, the separation characteristics (resolving

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power, retention times, flow through the column) are not affected and the chromatograms are easily comparable with chromatograms obtained with flame-ionization detection (FID). The possibility of using the split device allows the cut-off of unwanted peaks, conditioning of the column without contaminating the ion source with column bleed and rapid changing of columns without flushing the system with air so that oxygen cannot activate the transfer line.

Concerning the material of the transfer line, four types can be used: platinum[3-6], glass-lined steel tubes[7,8], glass[9-13] and flexible quartz capillaries[14].

Platinum capillaries exhibit good mechanical stability, but there is no conformity of the catalytic effects of this material. Grob[15] showed this metal to be responsible for various problems arising in the analysis of some critical classes of substances, whereas Etzweiler[6] could not detect such phenomena. We ourselves would agree with Grob[15], as we had severe problems when measuring hawkinsin[16] and we were not able to determine pterins in amounts below 20 ng*.

Glass-lined tubes are mechanically unproblematical; their drawback arises from the fact that the amount of metal ions in the glass is high, and they cannot be deactivated efficiently. Also, it is not possible to check their condition optically.

Of increasing importance are glass transfer lines. If they consist of the same type of glass as the capillary column and are deactivated in the same way[18], they give excellent results[11]. One must, however, have some expertise when handling them.

The introduction of fused silica capillaries offers some attractive features for connecting a GC to an MS system: flexibility, good mechanical properties, inactivity and cheapness[14].

Our demands for a GC–MS interface which led to a do-it-yourself type of system may be summarized as follows:

(1) The separation characteristics of the capillary column must be fully retained (dead volume-free connection and homogeneous heating).

(2) Substance losses due to catalytic decomposition of labile compounds and adsorption should be minimal (chemically inert material, no contact sites with metal parts).

(3) Possibility of cutting off of solvent and parts of the chromatogram by a multi-timer system.

(4) Ease of handling and replacing the transfer line.

(5) Rapid column changing without affecting the ion source conditions.

(6) The device should also be applicable to GC work alone.

EXPERIMENTAL

Instrumentation

Gas chromatographs. A Carlo Erba Fractovap 2101, equipped with an FID, and a Carlo Erba Fractovap 2900, reconstructed for GC–MS, were used. The carrier gas was helium.

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* It seems that these problems arise only when analysing special and critical substances and are not observed when testing the material with alkanes. For a detailed study concerning the adsorption of pterins, see Grob *et al.*[17].

Transfer line. A 300 × 0.12 (I.D.) × 0.24 mm (O.D.) fused silica tube was used.

Coupling capillary. 20 × 0.12 (I.D.) × 0.24 mm (O.D.) fused silica capillaries were obtained from ICT-Handelsgesellschaft (Frankfurt, G.F.R.). Graphpack high-temperature connections for glass and fused silica capillaries were supplied by: Fa. Gerstel (Mülheim/Ruhr, G.F.R.).

Pressure controllers. A precision micro pressure controller, type ND, was obtained from Siemens (Karlsruhe, G.F.R.).

Mass spectrometer. A micromass 16-F instrument with an electron energy of 40 eV (nominal) and an ion source temperature of 220°C was used.

Interface

Construction. The principle of the interface is shown in Fig. 1. The GC-column (14) is connected to the transfer line (1) via the coupling capillary (7), both consisting of fused silica. As there was no coupling capillary available with dimensions suitable for positioning it in the transfer line (1), we used a "guiding tube" (6) to bring both capillaries as near as possible together. For splitting purposes, we adapted the principle introduced by Deans[19]. Further constructional details are given elsewhere[20].

Direct coupling mode. The outlet C in Fig. 1 is closed. Two streams of helium, through A and B (flow-rate 0.1–0.2 ml/min each), guide the eluate from the GC column directly into the transfer line (1). This mode corresponds to a fixed connection, as for instance with a platinum capillary. Therefore, the pressure at the end of the GC column is a function of the flow through the column. The flow of scavenger gas through A and B allows the system to be dead volume-free.

Open split coupling mode. The outlet C is now open and at atmospheric pres-

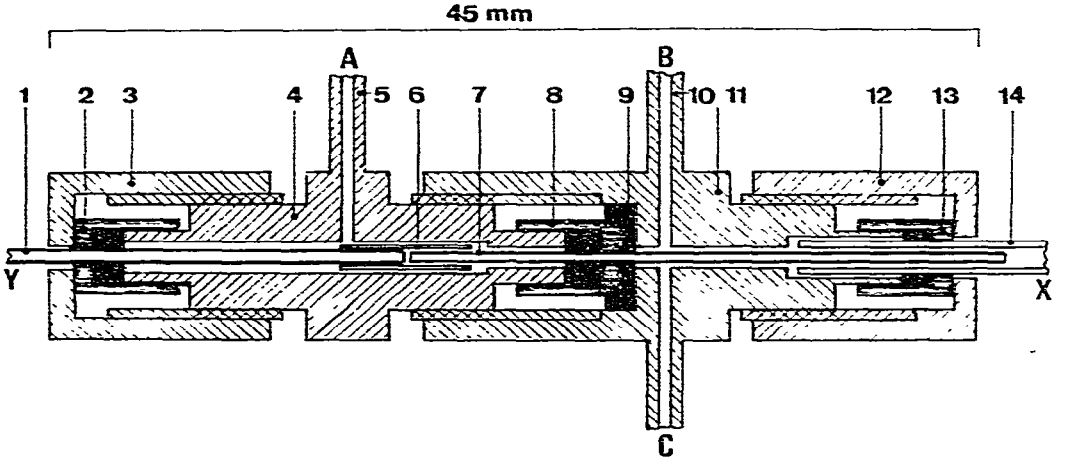

Fig. 1. Schematic diagram of the interface system. 1 = Transfer line (fused silica), I.D. 0.12 mm, O.D. 0.24 mm; 2, 8, 13 = metal sleeves and graphite packings; 3, 12 = nuts; 4, 11 = stainless-steel blocks; 6 = guiding tube (fused silica), I.D. 0.32 mm, O.D. 0.5 mm; 7 = coupling capillary (fused silica), I.D. 0.12 mm, O.D. 0.24 mm; 9 = graphite vespel seal; 5, 10 = stainless-steel tubes, I.D. 0.5 mm, O.D. 1.6 mm; 14 = gas chromatographic column; A = scavenger gas (helium) inlet; B = scavenger gas (helium) inlet; C = scavenger gas (helium) outlet; C = scavenger gas (helium) outlet; Y = to mass spectrometer or detector; X = GC column.

sure. At A, there is a flow-rate of 0.1–0.2 ml/min. In order to prevent air entering through C, the pressure at B is higher (0.5 ml/min). The result is atmospheric pressure at the column end, independent of the flow through the column, which varies when working with a temperature programme. Hence retention times obtained are identical with those obtained with a GC detector.

Cut mode. In instances where unwanted peaks have to be suppressed, C is open and the flow at A is increased to 3–4 ml/min. There is now a stream of helium opposite to the flow from the GC column (flow from Y to X *versus* flow from X to Y). Therefore, the whole eluate is split off through outlet C and does not reach the transfer line and the mass spectrometer.

RESULTS

To test the performance of the interface, we used the Grob test mixture[21]. A comparison of chromatograms obtained with an FID and total ion current (TIC) is shown in Figs. 2 and 3. The separation characteristics of the capillary column are fully retained and no peak broadening or tailing can be seen. The differences in the relative intensities of the peaks should not be overestimated, because the various substances show different responses with an FID and an electron impact detector. The good

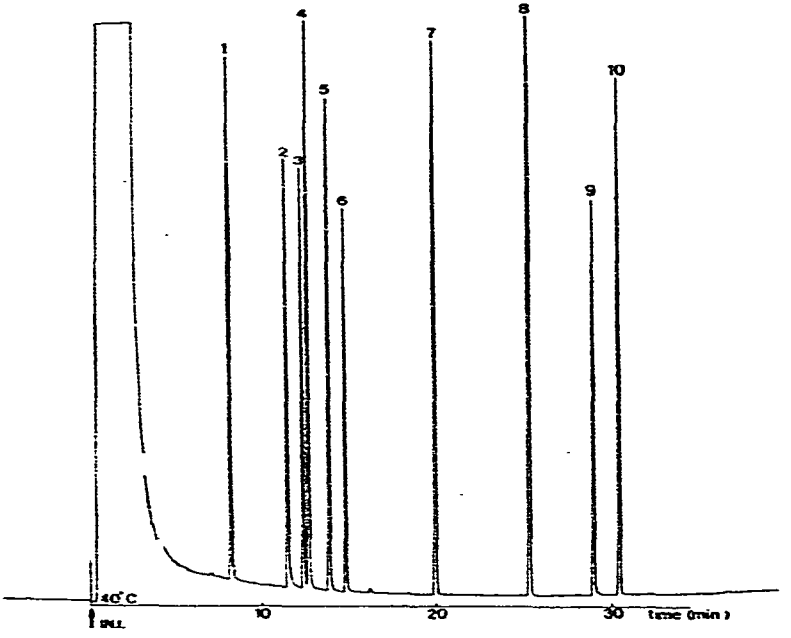

Fig. 2. Gas chromatogram (flame-ionization detection) of the Grob test mixture[21] consisting of (1) decane (5.7 ng), (2) 1-octanol (7.1 ng), (3) 2,6-dimethylphenol (6.4 ng), (4) nonanal (8.0 ng), (5) undecane (5.7 ng), (6) 2,6-dimethylaniline (6.4 ng), (7) C_{10}-acid methyl ester (8.5 ng), (8) C_{11}-acid methyl ester (8.3 ng), (9) dicyclohexylamine (6.3 ng) and (10) C_{12}-acid methyl ester (8.0 ng) in hexane. (the peak for 2,3-butanediol elutes with the solvent and is therefore not visible; 2-ethylhexanoic acid was not added to the mixture). Column, 20 m × 0.3 mm, OV-1; carrier gas, helium, 1.2 bar; Temperature programme, from 40°C (2 min isothermal) to 140°C at 2°C/min.

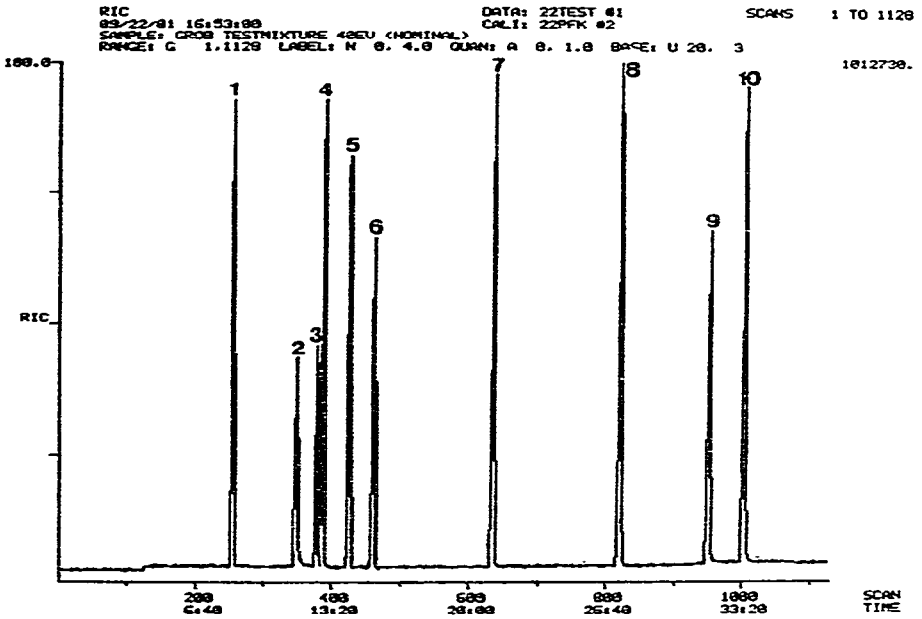

Fig. 3. Total ion current chromatogram of the Grob test mixture[21]. For peak identification and conditions, see Fig. 2.

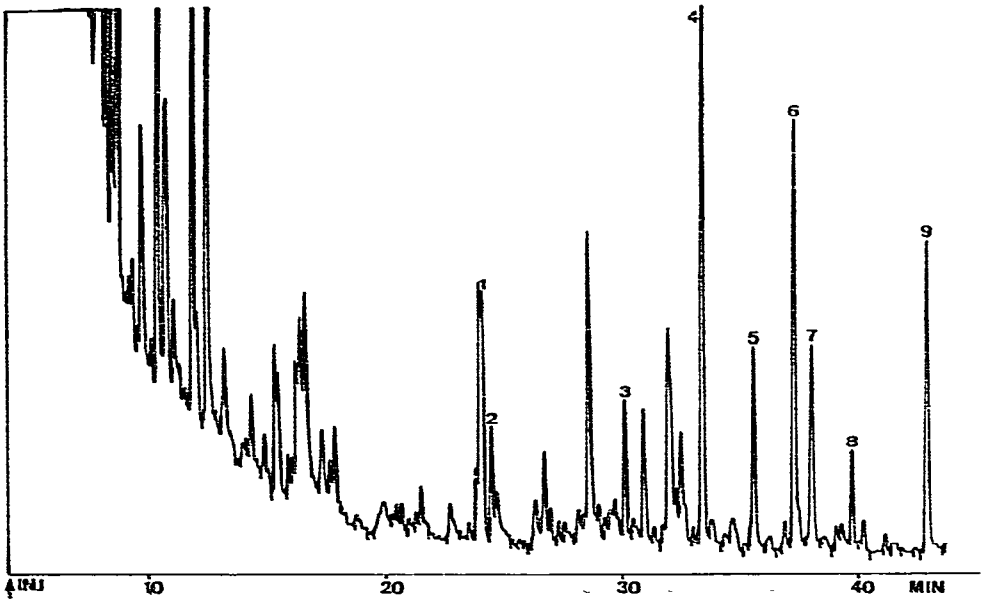

Fig. 4. Chromatogram (FID) of a urine steroid fraction. Peaks: 1 = androsterone (3α-hydroxy-5α-androstane-17-one); 2 = etiocholanolone (3α-hydroxy-5β-androstane-17-one); 3 = pregnanediol (3α,20α-dihydroxy-5β-pregnane); 4 = pregnanetriol (3α,17α,20α-trihydroxy-5β-pregnane); 5 = pregnanetriolone (3α,17α,20α-trihydroxy-5β-pregnane-11-one); 6 = cholesterin; 7 = tetrahydrocortisone (3α,17α,21-trihydroxy-5β-pregnane-11,20-dione); 8 = cortolone (3α,17α,20α,21-tetrahydroxy-5β-pregnane-11-one); 9 = internal standard (cholesteryl butyrate). Derivatives: Methoxime trimethylsilyl ethers; for details, see ref. 23. Column, 20 m × 0.3 mm, OV-1; carrier gas, helium, 0.8 bar; temperature programme, 10 min at 160°C, then increased to 260°C at 3°C/min.

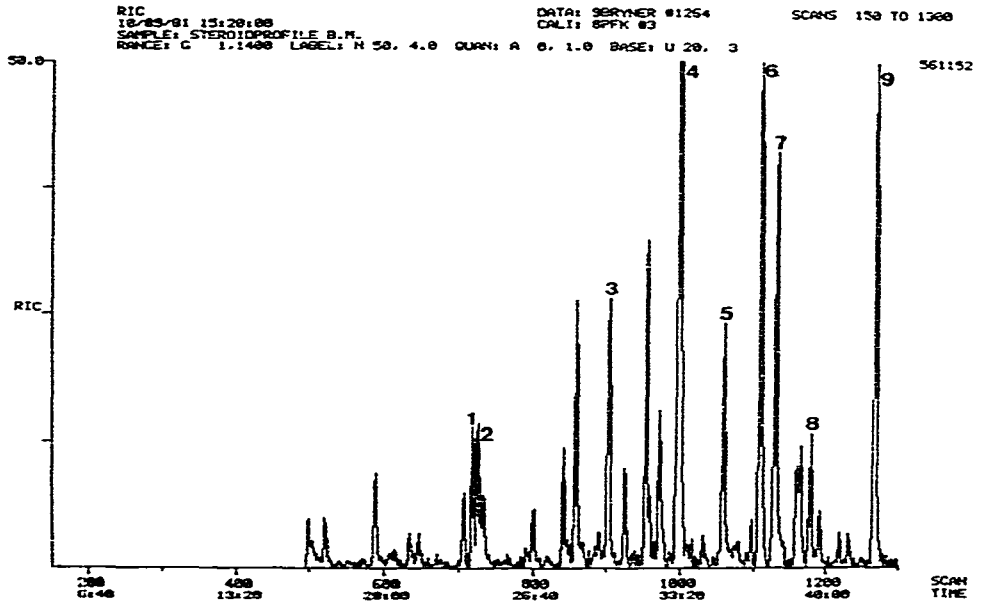

Fig. 5. Total ion current chromatogram of the same urine fraction as in Fig. 4. During the first 17 min the interface splitter was open, in order to cut off the unwanted part of the chromatogram. For peak identification and conditions, see Fig. 4.

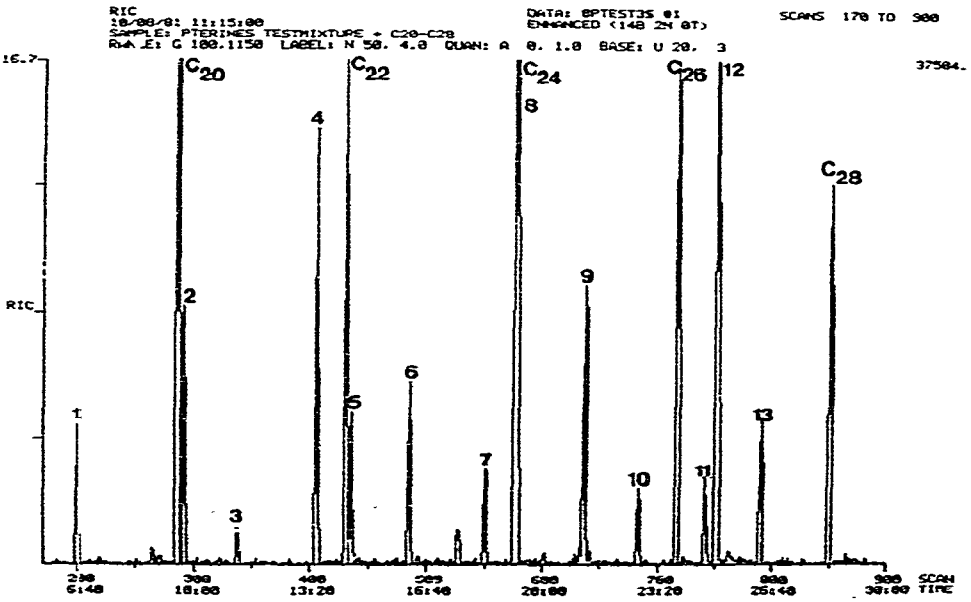

Fig. 6. Total ion current chromatogram of a pterin test mixture. Peaks: 1 = lumazine; 2 = pterin; 3 = 6-methylpterin; 4 = isoxanthopterin; 5 = xanthopterin; 6 = leukopterin; 7 = 6-hydroxymethylpterin; 8 = deoxysepiapterin; 9 = biopterin; 10 = sepiapterin; 11 = monapterin; 12 = neopterin; 13 = 3-hydroxysepiapterin. C_{20}–C_{28} alkanes. Derivatives: Trimethylsilyl ethers; for details see ref. 22. Column: 20 m × 0.3 mm, SE52; carrier gas, helium, 1.4 bar; temperature programme, from 150 to 270°C at 3°C/min.

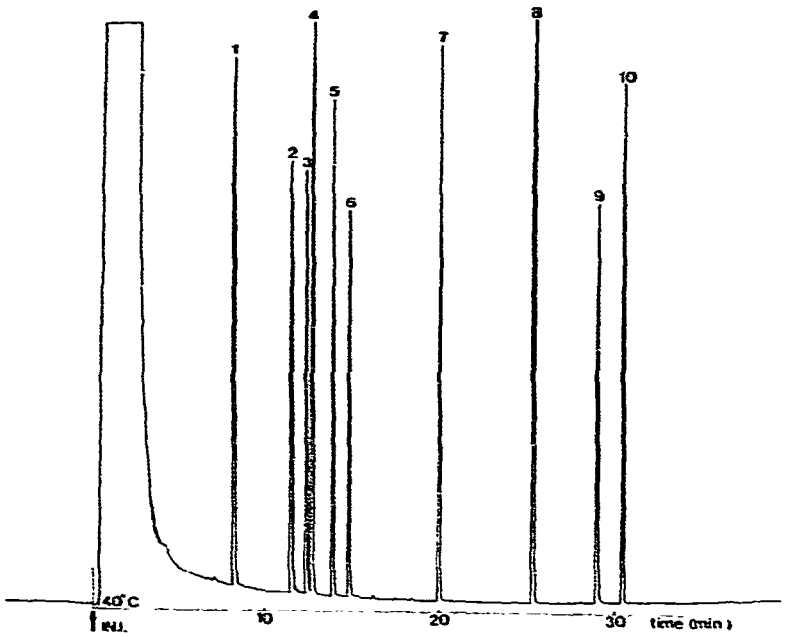

Fig. 7. Chromatogram (FID) of the Grob text mixture. Interface mode (A).

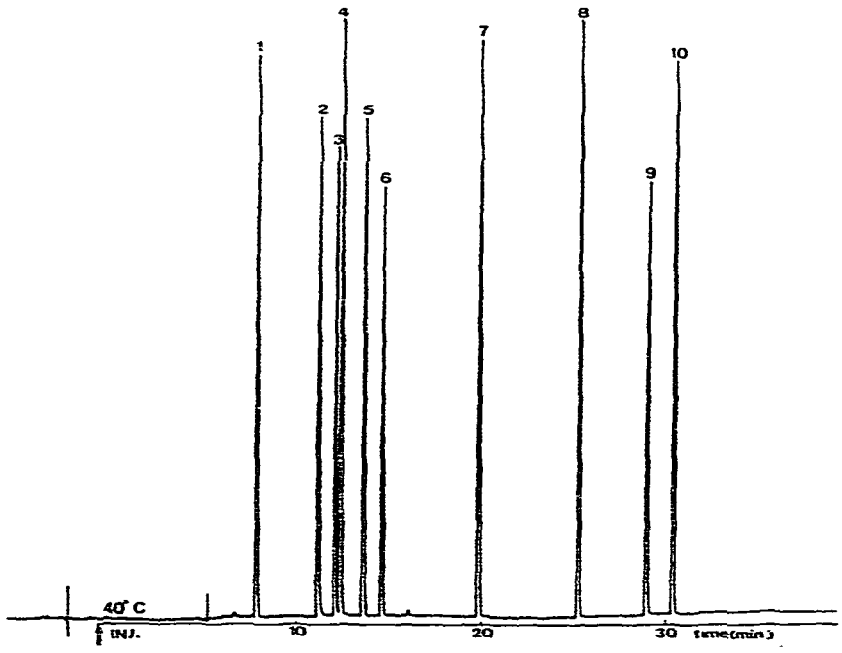

Fig. 8. Chromatogram (FID) of the Grob test mixture. Interface mode (C) to cut off the solvent peak. Conditions as in Fig. 2.

stability of the baseline arises from the constant carrier gas flow-rate into the ion source, independent of the flow through the column. The comparison of the two chromatograms also confirms the absence of dead volumes in the system, as we found equal separation numbers under GC and GC–MS conditions.

Fig. 4 shows a steroid profile obtained during a routine run in our laboratory. The first part of the chromatogram up to 20 min is not relevant to the analysis, as it consists mainly of derivatizing agents, fatty acids and other impurities. When confirming anomalous metabolic patterns with GC–MS, we cut off this part with the splitting facilities (mode C) of the interface and the result is shown in Fig. 5, where only the interesting steroid peaks are visible.

Fig. 6 shows the chromatogram of a pterin test mixture[22]. The amount of each of the substances lies in the range 5–10 ng, levels which we were not able to analyse with the platinum or glass-lined tube transfer line. Fig. 6 confirms the results obtained with the test mixture, as there is no loss of sensitivity or resolving power due to adsorption or catalytic decomposition.

Figs. 7 and 8 show how this interface can be applied to GC work alone. When performing analyses at trace levels, the detector is very sensitive towards contamination (this holds especially for an electron-capture detector). In such instances, it is highly desirable to split off the solvent and/or impurities originating from the derivatizing agent. This is possible when operating the system in the cut-off mode (C). Fig. 8 shows how the solvent peak in the Grob test mixture is suppressed totally. In a similar way, parts of the chromatogram can be split off when the desired time intervals are set by a multi-timer system.

REFERENCES

1 M. C. ten Noever de Brauw and C. Brunnée, *Z. Anal. Chem.*, 229 (1967) 321.
2 D. Henneberg and G. Schomburg, *Z. Anal. Chem.*, 221 (1964) 55.
3 D. Henneberg, U. Henrichs and G. Schomburg, *Chromatographia*, 8 (1975) 449.
4 K. Grob and H. Jaeggi, *Anal. Chem.*, 45 (1973) 1788.
5 N. Neuner-Jehle, F. Etzweiler and G. Zarske, *Chromatographia*, 6 (1973) 211.
6 F. Etzweiler, *J. Chromatogr.*, 167 (1978) 133.
7 G. A. Thome and G. W. Young, *Anal. Chem.*, 48 (1976) 1423.
8 U. Rapp, U. Schröder, S. Meier and H. Elmenhorst, *Chromatographia*, 8 (1975) 474.
9 H. W. Dürbeck, I. Büker and W. Leymann, *Chromatographia*, 11 (1978) 295.
10 H.-J. Stan and B. Abraham, *Anal. Chem.*, 50 (1978) 2161.
11 P. P. Schmid, M. D. Müller and W. Simon, *J. High Resolut. Chromatogr. Chromatogr. Commun.*, 2 (1979) 31.
12 W. Blum and W. J. Richter, *J. Chromatogr.*, 132 (1977) 249.
13 D. Henneberg, U. Henrichs, H. Husmann and G. Schomburg, *J. Chromatogr.*, 167 (1978) 139.
14 W. D. Koller and G. Tressl, *J. High Resolut. Chromatogr. Chromatogr. Commun.*, 3 (1980) 359.
15 K. Grob, *Chromatographia*, 9 (1976) 509.
16 A. Niederwieser, A. Matasović, F. Neuheiser and E. Wetzel, *J. Chromatogr.*, 146 (1978) 207.
17 K. Grob, G. Grob, B. Brechbühler and P. Pichler, *J. Chromatogr.*, 205 (1981) 1.
18 K. Grob, G. Grob and K. Grob, Jr., *J. High Resolut. Chromatogr. Chromatogr. Commun.*, 2 (1979) 31.
19 D. R. Deans, *Chromatographia*, 1 (1968) 18.
20 E. Wetzel and Th. Kuster, *J. High Resolut. Chromatogr. Chromatogr. Commun.*, submitted for publication.
21 K. Grob Jr., G. Grob and K. Grob, *J. Chromatogr.*, 156 (1978) 1.
22 A. Niederwieser and Th. Kuster, in preparation.
23 Th. Kuster, M. Zachmann and B. Zagalak, in press.