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REPORT

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REPORT TITLE:

ORGANIC GEOCHEMICAL CHARACTERISATION OF OIL AND GAS SAMPLES FROM WELL 34/7-8.

REPORT NO.: 22.1830.00/01/86

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CLIENT:

Saga Petroleum a.s., v/ E.S. Mo

SUMMARY:

Oil and gas samples from drill stem tests (DST) 1a, 2 and 3 of well 34/7-8 were characterised using organic geochemistry.

The DST samples are of similar composition, and are described as light paraffinic/-naphthenic oils of moderate thermal maturity. The gas samples contain a high percentage of C2+ hydrocarbons (50-70%) as might be expected in gases associated with oils. It is noted that the abundance of gaseous components decreases from DST 1a to DST 3, although this may be due to sampling effects.

The DST oils are compositionally similar to other DST oils from the 34/7 block, and an upper Jurassic source rock is suggested for the 34/7-8 oils/gases.

KEY WORDS:	
Organic Geochemistry	Snorre Field
DST Oil and Gas	Well 34/7-8

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1.INTRODUCTION

Three oil and three gas samples from drill stem tests (DST) 1a, 2 and 3 in well 34/7-8 (Figure 1) were sent to IKU for organic geochemical characterisation by Saga Petroleum A/S. The three samples were received from Core Lab Norsk and the following single stage flash analytical results were provided with the samples:

	GAS/OIL RATIO (SM3/M3)	GAS GRAVITY (AIR=1.000)	OIL DENSITY (KG/M3)	OIL MOLE WT. (GM/MOLE)
DST 1a Bottom Hole Samples	54.9	1.009	851.9	223
DST 2 Well Head Sample	84.2	0.991	843.0	202
DST 3 Well Head Sample	81.3	0.995	842.1	200

The DST samples were analysed according to the analytical programme outlined in the Saga letter of 8.10.85. These analyses are as follows:

Gas samples

- GC of C_1-C_8 hydrocarbons for recombination.
- 13C/12C ratio of the C_1, C_2, C_3 and C_4 hydrocarbons.
- D/H ratio of methane.

Oil samples

- API Gravity.
- S, Ni and V content.
- GC of C_2-C_8 hydrocarbons for recombination.
- GC of whole oil.
- Evaporation of light oil compounds (<210^{o}C).
- Chromatographic separation by MPLC, including asphaltene precipitation.
- GC of Saturated and Aromatic hydrocarbons.

- Urea Adduction of saturated hydrocarbons and GC of branched/cyclic hydrocarbons.
- Combined GC-MS of Saturated and Aromatic fractions.
- 13C/12C ratio of Saturate, Aromatic, NSO and Asphaltene fractions.

The samples were analysed under IKU project number 22.1830 and were assigned the following IKU identification numbers:

DST 1a:- C-4630 = Gas
C-4629 = Oil

DST 2 :- C-4603 = Gas
C-4604 = Oil

DST 3 :- C-4602 = Gas
C-4605 = Oil

A preliminary report will be sent to Saga Petroleum for approval, followed by ten copies of the final report on approval of the preliminary report. Ten copies of the report are retained at IKU.

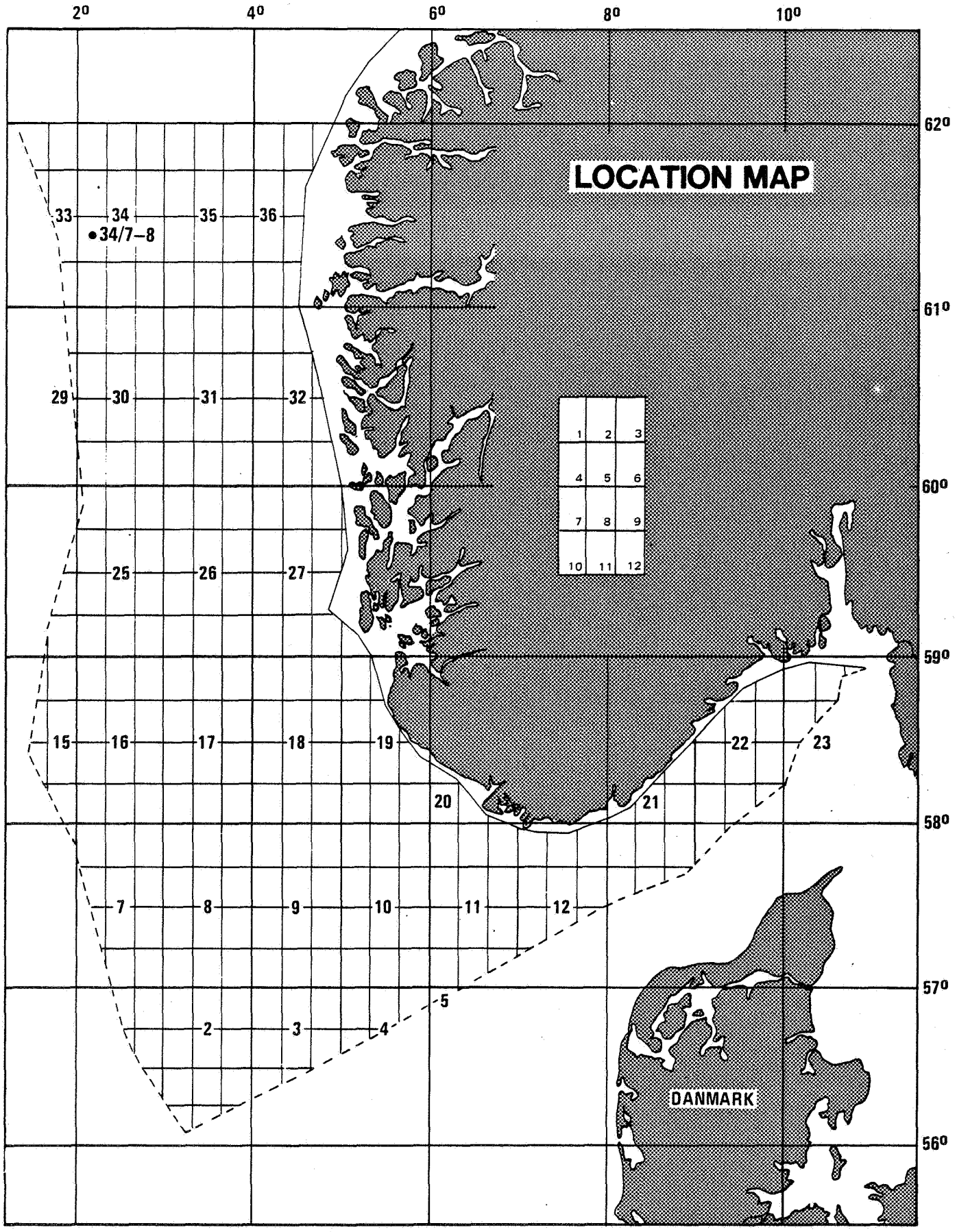

Figure 1: Location of well 34/7–8

2. RESULTS AND DISCUSSION

2.1 Recombination of DST oil and gas samples (C_1-C_8 hydrocarbons)

2.1.1 Composition of DST gases

The gases from DST samples 1a and 2 are similar (Figure 2), with methane contents of 26.5%-29.4% and gas wetness values of 64.5%-67.8% (Table 1a). The DST 3 gas sample differs from the other two in its higher methane content of 46.3% and lower gas wetness value of 51.3%. However, this apparent difference may reflect the very poor hydrocarbon abundance in the DST 3 gas (Table 1b). The DST 1a and 2 gases have identical iC_4/nC_4 ratio values of 0.37, and the DST 3 gas has a slightly higher value of 0.50. These ratios all suggest that the gases are thermally mature.

2.1.2 Composition of DST oils (C_2-C_8 Hydrocarbons)

The composition of the DST oil samples is summarised in Table 2. The C_2-C_8 gas chromatograms of the three oil samples (Figure 3) indicate that n-alkanes are the most prominent compounds, although a number of branched/cyclic compounds are also well developed. High paraffinicity indices of between 1.15 and 1.28 suggest that the oils are probably thermally mature (Thompson, 1978).

2.1.3 Recombination of the DST oil and gas samples

As requested by Saga Petroleum, the C_1-C_8 gas composition and the C_2-C_8 oil composition data for the three DST samples were combined to provide some indication of the light hydrocarbon composition of the reservoir fluids sampled by the three DST samples. The data were combined using the gas/oil ratio data provided by Core Lab Norsk. The recombined fluid compositions are shown in table 1b.

2.1.4 Stable Isotope Composition of the DST gases

Stable isotope data were obtained for the C_1 to C_4 components of the DST gases (Table 3). The δC_{13} ratios obtained for the C_1 component range from -49.2o/oo to -50.8o/oo and are similar to values obtained from most of the other 34/7 DST gases analysed at IKU. The δC_{13} isotope ratios for the C_2-C_4 components are slightly lower than those obtained from

other 34/7 DST gases, with the exception of the 34/7-3 and 34/7-5 gases. The ratios for the iC_4 component in all these DST gases are significantly lower than the values observed in other 34/7 DST gases, with values of -22.2o/oo, -21.8o/oo and -23.8o/oo. The three DST gases have similar δD isotope ratios of between -170o/oo and -178o/oo (Table 3).

In figures 4a and 4b, the three DST gases plot close to each other and to the 34/7-7 gases. This suggests that the gases share a similar source, although, unexpectedly, the three gases plot in the field for mixed biogenic/catagenic gases adjacent to the field for oil-associated gases. This may suggest a slightly lower thermal maturity or minor microbial activity in the gases.

2.2 Crude oil characterisation

2.2.1 API Gravity

The three DST oil samples have similar API gravity values of between 33.9^{o} and 35.8^{o}. The API gravities tend to increase from DST 1a to DST 3 (Table 4). These API gravities are similar to those recorded from the other 34/7 oils analysed at IKU and suggest moderately light oils.

2.2.2 Sulphur, Nickel and Vanadium Content

The sulphur content of the three DST oils varies from 0.4-0.5% and is slightly higher than values obtained from the other 34/7 oils which typically to have values of 0.2-0.3% S (Table 5). However, the DST oils are still classified as low sulphur oils.

Nickel contents vary from 2.22 mg/kg to 3.49 mg/kg, the highest values occurring in the DST 2 oil. Vanadium contents are slightly higher than the nickel contents and vary from 2.87 mg/kg to 3.81 mg/kg. The highest values are again found in the DST 2 oil, although the DST 1a oil also has a relatively high vanadium content. These values lie close to the average values for the the other 34/7 oils analysed to date (Av. Ni=2.5mg/kg; Av. V=3.0mg/kg).

2.2.3 Gross composition of the DST oil samples

Low molecular weight compounds ($<210^{o}C$) account for 36.0%-42.7% of the

DST oil samples (Table 6). This is a similar percentage to that seen in the 34/7-7 DST oils, but is higher than is seen in any of the 34/7 oils analysed prior to 34/7-7.

The asphaltene content of the oils varies from 1.4% to 3.3% and lies within the range of values obtained for the other 34/7 oils (Table 7). NSO compounds account for 20.1% to 22.6% of the DST oils (Table 7). These levels are 2-3 times higher than has been observed in any of the previously analysed 34/7 oils.

Hydrocarbon compounds account for between 60% and 70% of the $>210^{o}C$ oil fraction (Tables 8a and 8b). With the exception of DST 1a, this is more or less equially divided between saturated and aromatic hydrocarbon compounds. In the DST 1a oil, saturated compounds represent around 40% of the $>210^{o}C$ oil fraction.

2.2.4 Gas chromatography of the DST oils

a) Whole oil gas chromatography

The whole oil gas chromatograms of the three DST oils show fairly similar n-alkane profiles (Figure 5) smooth n-alkane peak envelopes which decrease from a maximum at about $nC_{5/6}$ to a minimum at around nC_{30}. These chromatograms are similar to those obtained from the 34/7-5 and 34/7-7 DST oils. The whole oil gas chromatograms of the 34/7-8 oils suggest thermally mature oils.

b) Saturated hydrocarbons

The saturated hydrocarbon gas chromatograms of the three DST oils are shown in figure 6. The three oils have similar gas chromatograms with a unimodal n-alkane distribution reaching a maximum at around nC_{16}-nC_{20}. The rapid decrease in peak intensity below this may reflect the sample preparation procedure. The n-alkane peak envelopes for the DST 1a and 2 oils shows slight shoulders in the nC_{21}-nC_{25} and nC_{27}-nC_{30} ranges, respectively. The causes of this are uncertain.

The three oil samples have similar pristane/phytane ratios of 1.3-1.4 and similar pristane/nC_{17} ratios of 0.8-0.9 (Table 9). These data suggest that the oils share a common source rock and are of similar ther-

mal maturity. This is supported by the appearance of the whole oil and saturated hydrocarbon gas chromatograms, and by similar CPI values of 0.9-1.0 (Table 9).

The pristane/phytane ratios of the 34/7-8 oils are similar to those of the other 34/7 oils, especially those from 34/7-7. It is difficult to compare the saturated gas chromatograms of the 34/7-8 oils to those of the other 34/7 oils due to the loss of the lighter hydrocarbon peaks, although some similarities may be observed with other 34/7 oils, e.g. 34/7-1, 34/7-4, 34/7-6 and 34/7-7.

c) Branched and cyclic hydrocarbon gas chromatograms

The gas chromatograms of the branched and cyclic hydrocarbons are shown in figure 7, and all show prominent isoprenoid peaks. The gas chromatograms of the DST 2 and 3 oils show significant humps of higher molecular weight, largely unresolved compounds.

The distribution of branched and cyclic compounds in these three samples is similar to that observed in the 34/7-7 samples.

d) Aromatic hydrocarbon gas chromatograms

The aromatic hydrocarbon gas chromatograms of the three DST oils are shown in figure 8. The gas chromatograms are similar in appearance, all showing prominent 'humps' of higher molecular weight unresolved compounds. The alkyl naphthalene and phenanthrene peaks are relatively prominent, especially the former. This distribution is fairly typical of mature, undegraded oils and condensates.

MPI-1 ratio values of between 0.99 and 1.07 suggest that the oil samples are thermally mature. The MPI-2 values are lower than the MPI-1 values, but also suggest thermal maturity (Table 10). The MPI values of these three oils are higher than those obtained from previously analysed 34/7 oils, with the exception of the two 34/7-7 oil samples which have similar MPI values.

2.2.5 Combined gas chromatography-mass spectrometry (GC-MS)

The mass chromatograms representing the terpane and sterane compounds are shown in figures 9 and 10, and the calculated peak ratios are given in tables 10 and 11.

Of the three DST samples from 34/7-8, DST 1a appears to contain lower concentrations of the lower molecular weight steranes and terpanes than the other two samples. This may indicate a slightly lower maturity for the DST 1a oil relative to the other two samples. The terpane chromatogram of the DST 2 oil contains a hump of apparently unresolved compounds, although this may be a result of the generally low peak intensity observed from this sample. Except for these relatively minor differences, the saturated hydrocarbon mass chromatograms of the three samples are similar.

The saturated hydrocarbon mass chromatograms of these samples show a mature distribution of compounds. This is reflected in hopane ratios with thermally stable values and in sterane ratios with near-thermally stable values. Abundant regular steranes in the m/z 217 mass chromatograms suggest moderate thermal maturity. More highly mature samples might be expected to contain a greater abundance of rearranged steranes (Ratio a/a+j in table 9).

An upper jurassic source rock may be suggested, based on a high relative abundance of 28,30 bisnorhopane (Peak z in m/z 191). This compound is often encountered in samples from the Draupne and Heather formations. A slightly higher abundance of C_{29} regular steranes in the DST 1a sample may reflect the slightly lower maturity of this sample.

The total ion chromatograms (TIC) for the aromatic hydrocarbons in these samples are shown in figure 11. These show a similar distribution of compounds to those observed in the gas chromatograms. The methyl-phenanthrene and dibenzothiophene mass chromatograms show compound distributions indicative of early oil-window to main oil-window maturity. The mass chromatograms of the mono- and tri-aromatic compounds were of good quality, and the distribution of these compounds suggests early oil window thermal maturity. Previously discussed data would suggest a maturity more typical of the main oil window (Sections 2.2.1 and 2.2.4). The molecular ratios calculated from the m/z 253 and m/z 231 mass chromatograms

(Table 13) support a slightly lower thermal maturity for the DST 1a sample.

2.2.6 Stable carbon isotope data for the oil fractions

Stable carbon isotope ratio values were obtained for the saturate, aromatic, asphaltene and NSO fractions of the three DST oil samples from 34/7-8. These data are shown in figure 12 and table 14. The isotopic values for the fractions of the three oils are largely similar, with the exception of a relatively high value of -35.1 for the NSO fraction of DST 1a. the general similarity of the values suggests that the oils share a common source and are of similar thermal maturity.

The isotope profiles for the DST samples in figure 12 suggest that the three DST samples are isotopically similar except for the anomalous NSO isotope value for DST 1a.

With the exception of the DST 1a NSO isotope ratio, the isotope ratios of the samples are comparable to those of the other 34/7 oils analysed at IKU.

3. ANALYTICAL PROCEDURES

Gas analyses

Natural gas (full analysis of hydrocarbons and inert gases):

Natural gas samples were analysed on an HP 5880 gas chromatograph equipped with a capillary column and an FID for hydrocarbon analysis and two packed columns and a TCD for analysis of the inert gases (N_2, O_2, CO_2):

- 50 m x 0.2 mm i.d. fused silical column, coated with 0.5 µm OV-101.
- 3 ft steel column packed with molecular sieve 13x, 80/100 mesh.
- 6 ft steel column packed with Porapack T x 4 ft steel column packed with Porapack Q, 80/100 mesh.

Temperature program: $30^{o}C$ (12 min.) - $8^{o}C$/min. - $150^{o}C$ (5 min.).

A standard gas sample containing methane, ethane, propane, n-butane, n-pentane and n-hexane was used for quantification.

Evaporation of the light components in fluid samples

Prior to chromatographic separation, the oil/condensate samples were heated to $210^{o}C$ at atmospheric pressure until constant weight (at $210^{o}C$) was obtained.

The fraction of light components was determined as the weight difference between the original sample and the residuum left after heating.

Medium-pressure liquid chromatography (MPLC)

The oil (>$210^{o}C$) sample was diluted in DCM (1:3 mg/µl) and the asphaltenes were precipitated using excess n-pentane (40:1 pentane:(DCM+oil)). The asphaltene fraction was weighed after drying at $50^{o}C$ for 12 hours.

The remaining maltenes were separated into saturated, aromatic and non-hydrocarbon fractions using an MPLC system with n-hexane as eluant (Radke et al., 1980). The various fractions were concentrated using a Büchi Rotavapor, transferred to glass vials and the remaining solvent removed.

Urea adduction

An aliquot of the saturated hydrocarbon fraction (5 mg) was diluted with n-hexane (2 ml), followed by the addition of acetone (1 ml). A saturated solution of urea in methanol (1 ml) was then added dropwise. The solvent was removed in a nitrogen stream and the adduction procedure repeated twice more. The white crystals were rinsed with hexane (3x5 ml) and the combined extract was filtered through a cotton plug covered with Al_2O_3 to produce a non-adduct containing the branched and cyclic hydrocarbons. GC analyses were performed on the non-adduct using the conditions outlined in the next section.

Gas chromatographic analysis

A whole oil sample was analysed using an HP 5730A gas chromatograph fitted with a 15 m DB-5 fused silica column. 0.02 µm of sample solution was injected in split mode (split ratio = 1:10). Hydrogen was used as a carrier gas with a flow rate of 2.5 ml/min, and the temperature programme used was -50°C (2 min) - 4°C/min - 280°C.

The C_2-C_8 hydrocarbon compounds were investigated by hydrogen stripping on a Carlo Erba Fractovap gas chromatograph fitted with a 60 m x 0.32 mm (i.d.) fused silica column coated with DB-1, 1.0 µm. The temperature programme used was 50°C (2 min) - 4°C/min - 210°C. An internal standard was used for quantification.

The saturated and the branched/cyclic hydrocarbon fractions were each diluted with n-hexane and analysed on an HP 5730A or an HP 5710 GC. Both GCs are equipped with 15 m DB-1 fused silica columns, and hydrogen is used as carrier gas with a flow rate of about 1.5 ml/min. Injections were performed in split mode (split ratio 1:10). The temperature programme used was 80°C (2 min) - 4°C/min - 280°C.

The total aromatic fractions were diluted with n-hexane and analysed on an HP 5730A gas chromatograph, fitted with a DB-5 fused silica column (15 x 0.25 mm i.d.), using a hydrogen carrier gas with a flow rate of 2.5 ml/min. The injection split ratio was 1:10.

The temperature programme used was 80°C (2 min.) - 4°C/min - 280°C.

Data processing for all the GC analyses was performed on a VG Multichrom lab data system.

Gas chromatography - mass spectrometry (GC-MS)

GC-MS analysis were performed on a VG Micromass 70-70H GC-MS-DS system. The Varian Series 3700 GC was fitted with a fused silica OV-1 capillary column (30m x 0.3 mm i.d.). Helium (1.5 ml/min) was used as carrier gas and the injections were performed in split mode (1.5 µl, split ratio 1:15).

The GC oven was programmed from 120°C (2 min.) to 280°C at 4°C/min. for analysis of the saturated hydrocarbons, and from 70°C/min. to 280°C at 4°C/min. for analysis of the aromatic hydrocarbons.

The saturated hydrocarbons were analysed in multiple ion mode (MID) at a scan cycle time of approximately 2 secs. Full data collection was applied for the aromatic hydrocarbons at a scan time of 1 sec./decade.

The mass spectrometers operated at 70eV electron energy with an ion source temperature of 200°C. Data acquisition was performed using VG data systems.

Peaks were identified by comparison with elution patterns in certain mass chromatograms. Peak ratios were calculated from peak heights in the appropriate mass chromatograms.

$\delta^{13}C$ isotope analysis

The $\delta^{13}C$ isotope analyses were performed by mass spectrometry at the Institute for Energy Technology (IFE) in Oslo according to their method. Their reference value for the standard NBS-22 is -29.8 °/oo (PDB).

The samples were filled in a glass capillary and transferred into a combustion system filled with copper dioxide, heated to 900°C. A stream of ultrapure helium and oxygen flushed the reaction products through silver wool (450°C) to remove traces of halogens and sulphur.

H_2O and CO_2 were trapped in separate cooltraps. After removal of the carrier gas by high vacuum, CO_2 and H_2O were sealed off separately in

6 mm glass tubes. H_2O was reduced to H_2 by zinc at 460°C.

The $^{13}C/^{12}C$ - isotope ratio (and D/H- isotope ratio) was measured with a high precision mass spectrometer Finnigan MAT 251.

Precision of the preparation lines and the mass spectrometer was daily controlled by measurements of standard substances and by double analyses.

The isotope ratios are given as delta-values (del):

$$\text{del } (\%) = ((R \text{ sample} - R \text{ stand.}) / (R \text{ stand.})) * 1000$$

13C/12C- isotope ratios are calculated versus PDB.
D/H-isotope ratios are calculated versus SMOW.

The CV value is calculated after SOFER (1984) to differentiate between marine and terrestrial-sourced oils:

$$CV = (-2.53 * \text{del}^{13}C_{sat}) + (2.22 * \text{del}^{13}C_{aro}) - 11.65.$$

4. CONCLUSIONS

DST oil and gas samples from well 34/7-8 were characterised using organic geochemistry. The samples came from DST numbers 1a, 2 and 3. The composition of the three gas and oil samples is broadly similar, although it was noted that the abundance of gaseous components decreases from DST 1a to DST 3. The significance of this is uncertain at present.

The DST oils are relatively light oils of moderate thermal maturity, probably equivalent to a vitrinite reflectance of 0.6-0.9%. The oils appear to have a paraffinic/naphthenic composition. A common, upper jurassic source rock is proposed for these oils.

5. REFERENCES

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Previous IKU reports concerned with block 34/7 fluids:

05.1725.00/02/84: Fluid characterisation of well 34/7-1.
05.1728.00/02/85: Hydrocarbon characterisation of well 34/7-3.
22.1767.00/03/85: Hydrocarbon characterisation of well 34/7-4.
22.1771.00/03/85: Analysis of fluid and gas samples from well 34/7-5.
22.1779.00/03/85: Analysis of fluid and gas samples from well 34/7-6 (DST 2 and DST 3b).
22.1805.00/01/86: Analysis of fluid and gas samples from well 34/7-7.

Table 1a: Ratios obtained from C_1-C_8 gas/oil compositions.

IKU no.	DST no.	$\%CH_4$	%Wetness	iC_4/nC_4	P.I. 1
C-4630	1a	26.5	67.8	0.37	1.28
C-4603	2	29.4	64.8	0.37	1.15
C-4602	3	46.3*	51.3*	0.50*	1.28

%Wetness = $(\Sigma C_2\text{-}C_5/\Sigma C_1\text{-}C_5) \times 100$.

P.I. (after Thompson, 1978) = $2MeC_6+3MeC_6/diMeCyC_5$ (3 isomers).

* Values based on very low intensity peaks.

C1-C8 YIELD
WELL NO: 34/7-8
IKU NO,GAS: C4630
IKU NO,OIL: C4629
GOR = 54.9 SM3/M3

Table 1b:

Recombination of DST oil and gas (C_1-C_8 hydrocarbons): DST 1a.

COMPOUND	GAS MG/ML	GAS MG/54.9 ML	OIL MG/ML	TOTAL HC IN MG/ML OF RESERVOIR FLUID
Methane	0.229	12.572	0.000	12.572
Ethane	0.114	6.259	0.000	6.259
Propane	0.186	9.882	0.274	10.156
i-Butane	0.051	2.800	0.537	3.337
n-Butane	0.138	7.576	2.868	10.444
i-Pentane	0.047	2.580	4.069	6.649
n-Pentane	0.045	2.471	5.817	8.288
Cyclo-C5+				
2,3-diMeC4	0.005	0.275	1.301	1.576
2-MeC5	0.012	0.659	3.875	4.465
3-MeC5	0.007	0.384	2.791	3.175
n-Hexane	0.014	0.769	7.179	7.948
MeCyC5	0.007	0.384	4.966	5.344
Benzene	0.000	0.000	1.380	1.380
CycloC6	0.005	0.275	5.472	5.747
2-MeC6	0.002	0.110	2.560	2.671
2,3-diMeC5	0.001	0.055	1.198	1.253
3-MeC6	0.000	0.000	4.029	4.029
diMeCyC5	0.000	0.000	5.677	5.677
n-Heptane	0.000	0.000	7.736	7.736
MeCyC6	0.000	0.000	10.768	10.768
EtCyC5+				
2,5-diMeC6	0.000	0.000	1.722	1.722
2,4-diMeC6	0.000	0.000	1.094	1.094
triMeCyC5	0.000	0.000	1.183	1.183
Toluene	0.000	0.000	5.100	5.100
2-MeC7+				
4-MeC7	0.000	0.000	4.416	4.416
3-MeC7	0.000	0.000	2.428	2.428
diMeCyC6	0.000	0.000	5.531	5.531
n-Octane	0.000	0.000	8.317	8.317
2,4-diMeC7+				
diMeCyC6	0.000	0.000	2.142	2.142
EtCyC6	0.000	0.000	4.129	4.129
EtBenzene	0.000	0.000	2.010	2.010
m+p-xylene	0.000	0.000	4.545	4.545
2-MeC8+				
4-MeC8	0.000	0.000	2.396	2.396
O-Xylene	0.000	0.000	1.861	1.861
SUM	0.863	47.051	119.386	166.437

C1-C8 YIELD
WELL NO: 34/7-8
IKU NO,GAS: C4603
IKU NO,OIL: C4604
GOR = 84.2 SM3/M3

Table 1c:

Recombination of DST oil and gas (C_1-C_8 hydrocarbons): DST 2.

COMPOUND	GAS MG/ML	GAS MG/ 84.2ML	OIL MG/ML	TOTAL HC IN MG/ML OF RESERVOIR FLUID
Methane	0.120	10.104	0.0	10.104
Ethane	0.059	4.968	0.0	4.968
Propane	0.091	7.660	0.198	7.858
i-Butane	0.019	1.600	0.260	1.860
n-Butane	0.051	4.294	2.086	6.380
i-Pentane	0.016	1.431	3.814	5.161
n-Pentane	0.017	1.431	6.311	7.742
Cyclo-C5+				
2,3-diMeC4	0.019	1.600	1.610	3.210
2-MeC5	0.004	0.337	3.870	4.207
3-MeC5	0.002	0.108	2.711	2.819
n-Hexane	0.005	0.421	7.810	8.231
MeCyC5	0.003	0.253	5.259	5.512
Benzene	0.000	0.000	1.776	1.776
CycloC6	0.002	0.108	5.910	6.018
2-MeC6	0.000	0.000	2.594	2.594
2,3-diMeC5	0.000	0.000	1.097	1.097
3-MeC6	0.000	0.000	3.930	3.930
diMeCyC5	0.000	0.000	5.587	5.587
n-Heptane	0.000	0.000	8.157	8.157
MeCyC6	0.000	0.000	10.785	10.785
EtCyC5+				
2,5-diMeC6	0.000	0.000	1.775	1.775
2,4-diMeC6	0.000	0.000	1.050	1.050
triMeCyC5	0.000	0.000	1.107	1.107
Toluene	0.000	0.000	6.441	6.441
2-MeC7+				
4-MeC7	0.000	0.000	4.560	4.560
3-MeC7	0.000	0.000	2.437	2.437
diMeCyC6	0.000	0.000	5.331	5.331
n-Octane	0.000	0.000	8.847	8.847
2,4-diMeC7+				
diMeCyC6	0.000	0.000	1.989	1.989
EtCyC6	0.000	0.000	3.348	3.348
EtBenzene	0.000	0.000	2.528	2.528
m+p-xylene	0.000	0.000	5.325	5.325
2-MeC8+				
4-MeC8	0.000	0.000	2.827	2.827
O-Xylene	0.000	0.000	2.165	2.165
SUM	0.408	34.231	123.511	157.742

C1-C8 YIELD
WELL NO: 34/7-8
IKU NO,GAS: C4602
IKU NO,OIL: C4605
GOR = 81.3 SM3/M3

Table 1d:

Recombination of DST oil and gas (C_1-C_8 hydrocarbons): DST 3.

COMPOUND	GAS MG/ML	GAS MG/81.3 ML	OIL MG/ML	TOTAL HC IN MG/ML OF RESERVOIR FLUID
Methane	0.019	1.544	0.000	1.544
Ethane	0.007	0.569	0.000	0.569
Propane	0.009	0.732	0.000	0.732
i-Butane	0.002	0.163	0.187	0.350
n-Butane	0.004	0.325	0.599	0.924
i-Pentane	0.000	0.000	3.583	3.583
n-Pentane	0.000	0.000	3.936	3.936
Cyclo-C5+				
2,3-diMeC4	0.000	0.000	6.508	6.508
2-MeC5	0.000	0.000	1.631	1.631
3-MeC5	0.000	0.000	3.972	3.972
n-Hexane	0.000	0.000	2.717	2.717
MeCyC5	0.000	0.000	8.109	8.109
Benzene	0.000	0.000	5.502	5.502
CycloC6	0.000	0.000	1.729	1.729
2-MeC6	0.000	0.000	6.044	6.044
2,3-diMeC5	0.000	0.000	2.648	2.648
3-MeC6	0.000	0.000	1.050	1.050
diMeCyC5	0.000	0.000	4.008	4.008
n-Heptane	0.000	0.000	5.702	5.702
MeCyC6	0.000	0.000	8.490	8.490
EtCyC5+				
2,5-diMeC6	0.000	0.000	11.034	11.034
2,4-diMeC6	0.000	0.000	1.749	1.749
triMeCyC5	0.000	0.000	1.003	1.003
Toluene	0.000	0.000	1.094	1.094
2-MeC7+				
4-MeC7	0.000	0.000	6.230	6.230
3-MeC7	0.000	0.000	4.631	4.631
diMeCyC6	0.000	0.000	1.969	1.969
n-Octane	0.000	0.000	5.510	5.510
2,4-diMeC7+				
diMeCyC6	0.000	0.000	9.026	9.026
EtCyC6	0.000	0.000	1.894	1.894
EtBenzene	0.000	0.000	3.279	3.279
m+p-xylene	0.000	0.000	2.357	2.357
2-MeC8+				
4-MeC8	0.000	0.000	5.119	5.119
O-Xylene	0.000	0.000	2.001	2.001
SUM	0.041	3.333	126.183	129.516

IKU SINTEF-GRUPPEN

Table 2a:

C_2-C_8 hydrocarbon composition of DST 1a oil.

C 4629	area	ug	mg/ml	% of t.oil
nC3	13225	.082	.274	.032
iso-C4	25913	.161	.537	.062
nC4	138314	.860	2.868	.335
iso-C5	196202	1.220	4.069	.475
nC5	280486	1.745	5.817	.680
CyC5+2,3diMeC4	62758	.390	1.301	.152
2MeC5	186850	1.162	3.875	.453
3MeC5	134575	.837	2.791	.326
nC6	346172	2.153	7.179	.839
MeCyC5	239468	1.489	4.966	.580
benzene	66560	.414	1.380	.161
CyC6	263840	1.641	5.472	.639
2MeC6	123454	.768	2.560	.299
2,3diMeC5	57795	.359	1.198	.140
3MeC6	194281	1.208	4.029	.471
DiMeCyC5	273755	1.703	5.677	.663
nC7	373024	2.320	7.736	.904
MeCyC6	519225	3.230	10.768	1.258
EtCyC5+2,5diMeC6	83066	.516	1.722	.201
'2,4diMeC6	52776	.328	1.094	.127
triMeCyC5	57077	.355	1.183	.138
toluene	245906	1.530	5.100	.596
2+4MeC7	212967	1.325	4.416	.516
3MeC7	117075	.728	2.428	.283
DiMeCyC6	266723	1.659	5.531	.646
nC8	401043	2.495	8.317	.972
2,4diMeC7+diMeCyC6	103321	.642	2.142	.250
EtCyC6	199108	1.238	4.129	.482
EtBenzene	96940	.603	2.010	.235
m,p-Xylene	219172	1.363	4.545	.531
2+4MeC8	115548	.718	2.396	.280
o-xylene	89737	.558	1.861	.217
sum		35.815	119.386	13.956

tot.oil - ant ug inj.: 256.620ug

%C2-C8(tot.area)in tot.oil: 15.793%

IKU SINTEF-GRUPPEN

Table 2b:

C_2-C_8 hydrocarbon composition of DST 2 oil.

C 4604	area	ug	mg/ml	% of t.oil
nC3	9570	.059	.198	.023
iso-C4	12579	.078	.260	.030
nC4	100806	.625	2.086	.245
iso-C5	184336	1.144	3.814	.449
nC5	304967	1.893	6.311	.743
CyC5+2,3diMeC4	77808	.483	1.610	.189
2MeC5	187027	1.161	3.870	.456
3MeC5	131027	.813	2.711	.319
nC6	377386	2.343	7.810	.920
MeCyC5	254129	1.577	5.259	.619
benzene	85862	.533	1.776	.209
CyC6	285568	1.773	5.910	.696
2MeC6	125381	.778	2.594	.305
2,3diMeC5	53044	.329	1.097	.129
3MeC6	189906	1.179	3.930	.463
DiMeCyC5	269977	1.676	5.587	.658
nC7	394148	2.447	8.157	.961
MeCyC6	521144	3.235	10.785	1.270
EtCyC5+2,5diMeC6	85772	.532	1.775	.209
'2,4diMeC6	50738	.315	1.050	.123
triMeCyC5	53503	.332	1.107	.130
toluene	311268	1.932	6.441	.758
2+4MeC7	220358	1.368	4.560	.537
3MeC7	117800	.731	2.437	.287
DiMeCyC6	257615	1.599	5.331	.628
nC8	427489	2.654	8.847	1.042
2,4diMeC7+diMeCyC6	96139	.596	1.989	.234
EtCyC6	161807	1.004	3.348	.394
EtBenzene	122194	.758	2.528	.297
m,p-Xylene	257327	1.597	5.325	.627
2+4MeC8	136637	.848	2.827	.333
o-xylene	104638	.649	2.165	.255
sum		37.053	123.511	14.551

tot.oil - ant ug inj.: 254.640ug

%C2-C8(tot.area)in tot.oil: 16.569%

IKU SINTEF-GRUPPEN

Table 2c:

C_2-C_8 hydrocarbon composition of DST 3 oil.

C 4605	area	ug	mg/ml	% of t.oil
nC3	8885	.056	.187	.022
iso-C4	28490	.179	.599	.070
nC4	170167	1.074	3.583	.423
iso-C5	186927	1.180	3.936	.465
nC5	309059	1.952	6.508	.769
CyC5+2,3diMeC4	77490	.489	1.631	.192
2MeC5	188652	1.191	3.972	.469
3MeC5	129065	.815	2.717	.321
nC6	385102	2.432	8.109	.959
MeCyC5	261315	1.650	5.502	.650
benzene	82140	.518	1.729	.204
CyC6	287057	1.813	6.044	.714
2MeC6	125767	.794	2.648	.313
2,3diMeC5	49878	.315	1.050	.124
3MeC6	190337	1.202	4.008	.473
DiMeCyC5	270784	1.710	5.702	.674
nC7	403188	2.547	8.490	1.004
MeCyC6	523996	3.310	11.034	1.304
EtCyC5+2,5diMeC6	83091	.524	1.749	.206
'2,4diMeC6	47634	.300	1.003	.118
triMeCyC5	51968	.328	1.094	.129
toluene	295876	1.869	6.230	.736
2+4MeC7	219958	1.389	4.631	.547
3MeC7	93531	.590	1.969	.232
DiMeCyC6	261699	1.653	5.510	.651
nC8	428664	2.708	9.026	1.067
2,4diMeC7+diMeCyC6	89950	.568	1.894	.223
EtCyC6	155751	.983	3.279	.387
EtBenzene	111944	.707	2.357	.278
m,p-Xylene	243136	1.535	5.119	.605
2+4MeC8	135698	.857	2.857	.337
o-xylene	95071	.600	2.001	.236
sum		37.855	126.183	14.922

tot.oil - ant ug inj.: 253.680ug

%C2-C8(tot.area)in tot.oil: 16.975%

Table 3: Stable isotope data for DST gases.

DST nr.	IKU nr.	C_1		C_2	C_3	$i\text{-}C_4$	$n\text{-}C_4$
		$\delta^{13}C$ PDB	δD SMOW	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB	$\delta^{13}C$ PDB
DST 1A	C-4630	-50.4	-178	-32.1	-30.9	-22.2	-30.8
DST 2	C-4603	-49.2	-175	-32.0	-30.8	-21.8	-30.7
DST 3	C-4602	-50.8	-170	-32.8	-31.4	-23.8	-31.8

Project No.: 22.1830
Date : 27-6-86

Table 4:

API GRAVITY OF OIL SAMPLE

IKU-No	CODE	API GRAVITY (DENSITY)	
		Crude oil	>210'C
34/7-8			
C-4629	DST 1a	33.9 (0.8554)	23.2 (0.9145)
C-4604	DST 2	35.2 (0.8456)	29.0 (0.9031)
C-4605	DST 3	35.8 (0.8488)	25.2 (0.8814)

Project No.: 22.1830
Date : 27-6-86

Table 5:

CONTENT OF SULPHUR, NICKEL AND VANADIUM IN OIL >210'C

IKU-No	CODE	S	Ni	V
		%	(mg/kg)	(mg/kg)
34/7-8				
C-4629	DST 1a	0.49	2.33-2.22	3.45
C-4604	DST 2	0.47	3.49-3.31	3.81-3.77
C-4605	DST 3	0.42	2.49-2.54	2.87-2.95

Project No.: 22.1830
Date : 20 - 7 - 86

Table 6:

FRACTION BOILING BELOW 210 C

IKU No	CODE	Crude Oil (mg)	EOM >210 C (mg)	Low Molecular Weight Compounds (mg)	Low Molecular Weight Compounds (%)
34/7-8					
C 4629	DST 1a	576.1	368.7	207.4	36.0
C 4604	DST 2	799.1	457.9	341.2	42.7
C 4605	DST 3	646.1	405.1	241.0	37.3

Project no.: 22.1830
DATE : 9 - 7 - 86

Table 7:

AMOUNT OF ASPHALTENES AND NSO'S IN OIL

IKU No	DST No	Crude Oil (mg)	Asphaltenes (mg)	Asphaltenes (%)	NSO (mg)	NSO (%)
34/7-8						
C-4629	1a	576.1	12.3	2.1	83.3	14.5
C-4604	2	799.1	7.5	0.9	98.3	12.3
C-4605	3	646.1	5.7	0.9	81.6	12.6

Project No.: 22.1830
Well : 34/7-8
Date : 20 - 7 - 86

Table 8a:

CONCENTRATION OF OIL CHROMATOGRAPHIC FRACTIONS

IKU No	CODE	Crude Oil (mg)	EOM >210C (mg)	Sat. (mg)	Aro. (mg)	HC (mg)	Non HC (mg)
C 4629	DST 1a	576.1	368.7	154.0	80.5	234.5	134.2
C 4604	DST 2	799.1	457.9	124.4	152.3	276.7	181.2
C 4605	DST 3	646.1	405.1	160.8	136.8	297.6	107.5

Project No.: 22.1830
Well : 34/7-8
Date : 20 - 7 - 86

Table 8b:

COMPOSITION OF OIL

IKU No	CODE	Sat. / EOM %	Aro. / EOM %	HC / EOM %	Sat. / Aro. x 100	Non HC / EOM %	HC / Non HC x 100
C 4629	DST 1a	41.8	21.8	63.6	191.3	36.4	174.7
C 4604	DST 2	27.2	33.3	60.5	81.7	39.6	152.7
C 4605	DST 3	39.7	33.8	73.5	117.5	26.5	276.8

Table 9:

TABULATION OF DATA FROM THE GASCHROMATOGRAMS

IKU No.	DEPTH (m)	PRISTANE / PHYTANE = A	PRISTANE / n-C17 = B	PHYTANE / n-C18	A / B	n-C17 / n-C27	CPI
C 4629	DST 1a	1.3	0.9	0.8	1.2	2.1	1.0
C 4604	DST 2	1.3	0.9	0.6	1.5	1.3	0.9
C 4605	DST 3	1.4	0.8	0.6	1.3	2.2	1.0

DATE : 20 - 7 - 86.

IKU SINTEF-GRUPPEN

Table 10:

Ratios from aromatic gas chromatograms

IKU no.	DST no.	MPI-1	MPI-2
C-4629	1a	1.07	1.00
C-4604	2	1.05	0.93
C-4605	3	0.99	0.80

MPI-1 = 1.5(2-MP+3-MP)/P+1-MP+9-MP

MPI-2 = 3(2-MP)/P+1-MP+9-MP

Table 11: Molecular ratios from sterane and terpane mass chromatograms. Maturity ratios.

IKU code	Well no.	αβ/αβ+βα[1)]	%22S[2)]	%ββ[3)]	%20S[4)]
C-4629	34/7-8 DST 1A	0.90	59.4	75.8	41.3
C-4604	34/7-8, DST 2	0.93	61.6	74.8	42.6
C-4605	34/7-8, DST 3	0.93	58.8	73.9	47.2

1) E/E+F in m/z 191

2) Average % distribution between first and second eluting isomers of extended hopanes (G-M in m/z 191)

3) 2(r+s)/(q+t+2(r+s)) in m/z 217

4) q/q+t in m/z 217

Table 12: Molecular ratios from terpane and sterane mass chromatograms. Maturity and source characteristic ratios.

IKU no.	Well no.	Q/E[1)]	Tm/Ts[2)]	X/E[3)]	Z/E[4)]	a/a+j[5)]
C-4629	34/7-8, DST 1a	0.04	0.88	0.06	0.27	0.60
C-4604	34/7-8, DST 2	0.09	1.17	0.10	0.30	0.69
C-4605	34/7-8, DST 3	0.05	0.83	0.07	0.28	0.69

1) Relative abundance of tricyclic terpanes (Q/E in m/z 191)
2) B/A in m/z 191
3) Relative abundance of unknown (X/E in m/z 191)
4) Relative abundance of bisnorhopane (Z/E in m/z 191)
5) Relative abundance of C_{27} rearranged steranes (a/a+j in m/z 217)

Table 13: Molecular ratios from mass chromatograms of aromatic fractions.

IKU no.	Well no.	% $C_{20}/C_{26,27}$ [1)]	% $C_{21}/C_{28,29}$ [2)]
C-4629	34/7-8, DST 1a	21.4	17.2*
C-4604	34/7-8, DST 2	23.5	19.3
C-4605	34/7-8, DST 3	22.7	23.1

1) Relative abundance of low molecular weight triaromatic steranes (M/M+P in m/z 231).

2) Relative abundance of low molecular weight monoaromatic steranes (a/a+h in m/z 253).

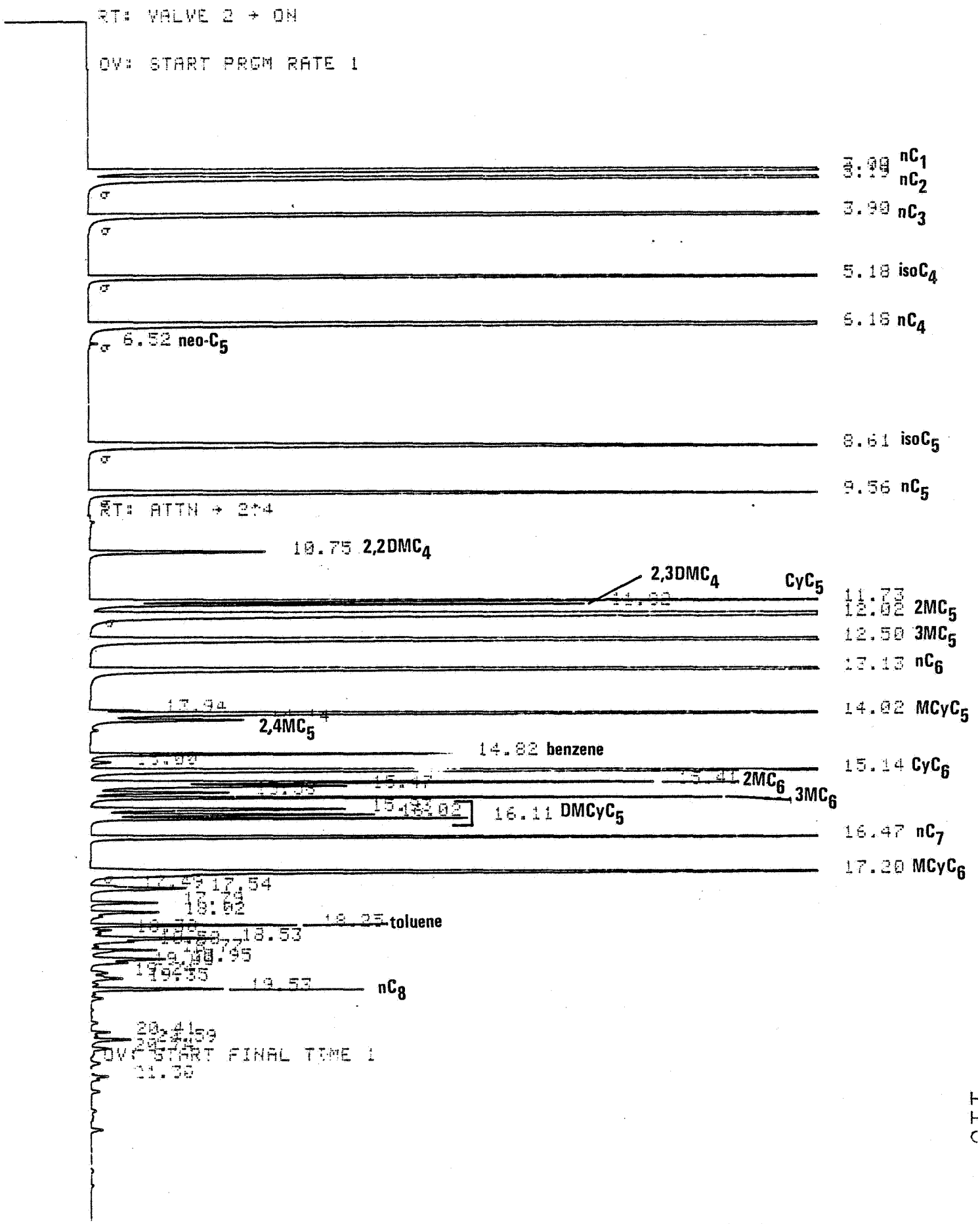
* Low intensity of C_{21} (a) in the chromatogram.

Table 14: $\delta^{13}C$ isotope data for DST oil fractions.

IKU no.	DST no.	SAT	AROM	NSO	ASF
C-4629	1a	-30.1	-29.3	-35.1	-29.7
C-4604	2	-30.1	-29.4	-28.6	-30.2
C-4605	3	-30.2	-28.9	-28.3	-29.9

LIST OVEN TEMP
OVEN TEMP=-25°C SETPT=-30°C LIMIT=405°C

Figure 2.
$C_1 - C_8$ Hydrocarbons
DST 1A
C – 4630



LIST OVEN TEMP
OVEN TEMP=-20°C SETPT=-30°C LIMIT=405°C

Figure 2.
$C_1 - C_8$ Hydrocarbons
DST 2
C – 4603

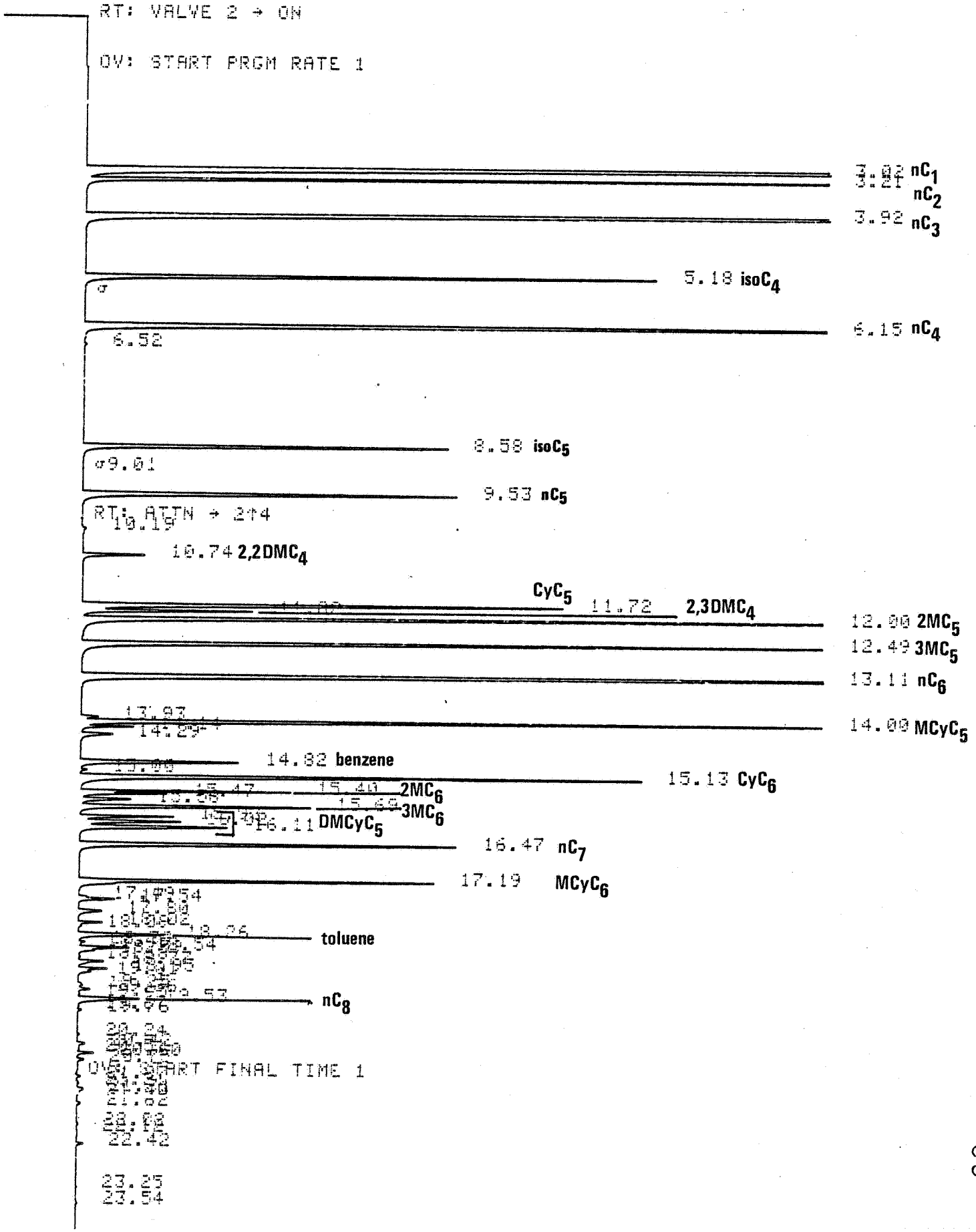


Figure 2.
$C_1 - C_8$ Hydrocarbons
DST 3
C – 4602

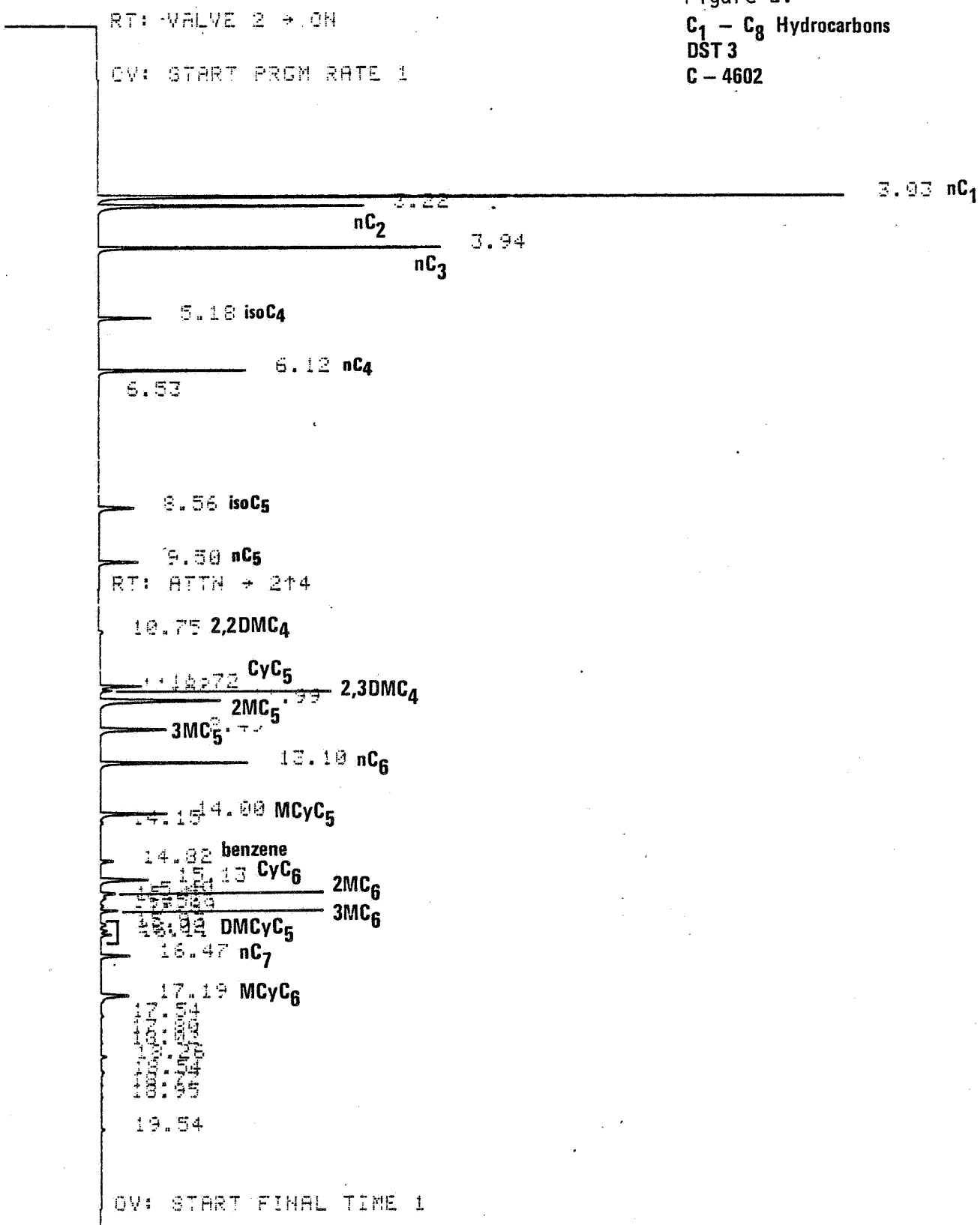
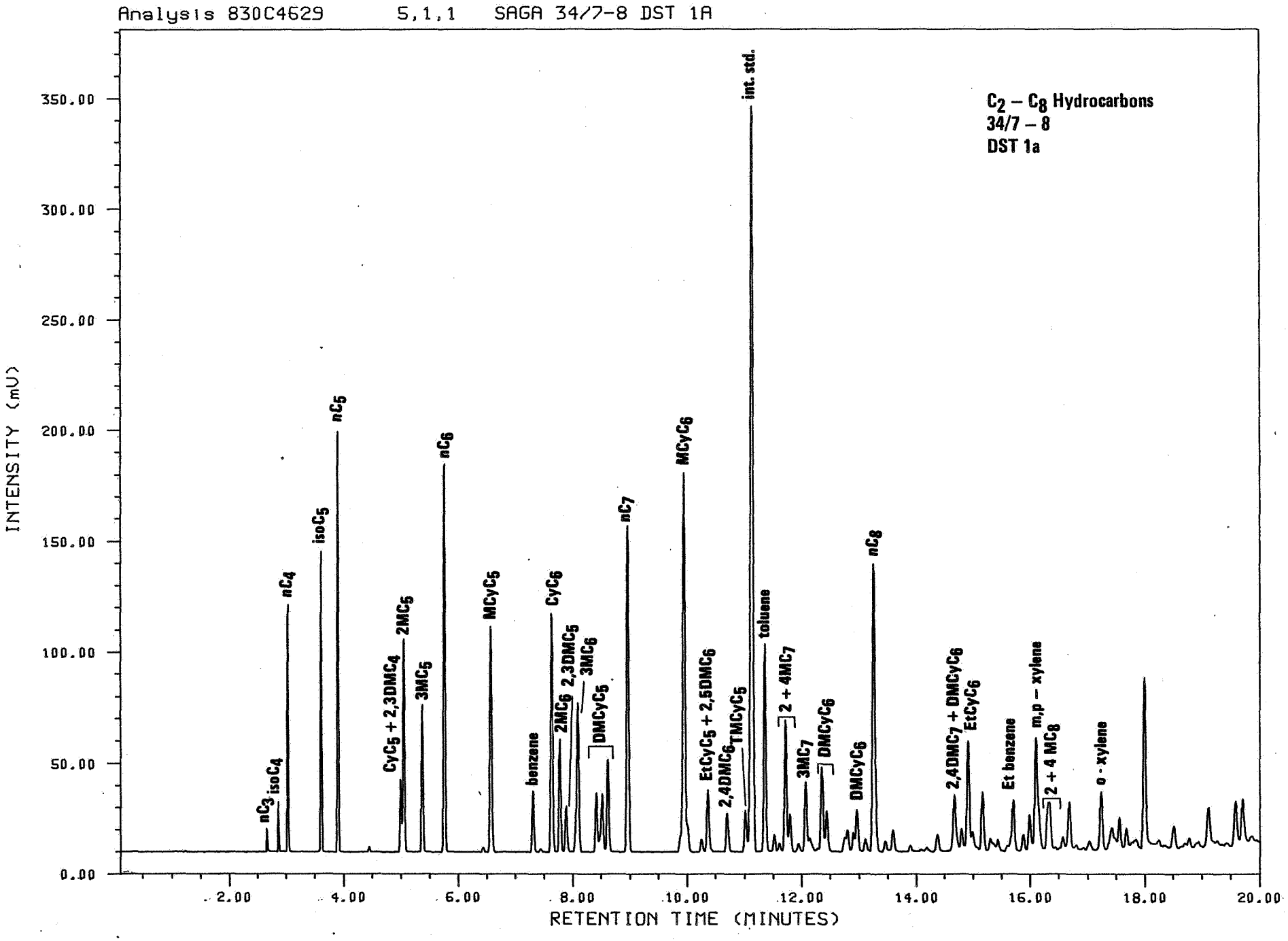
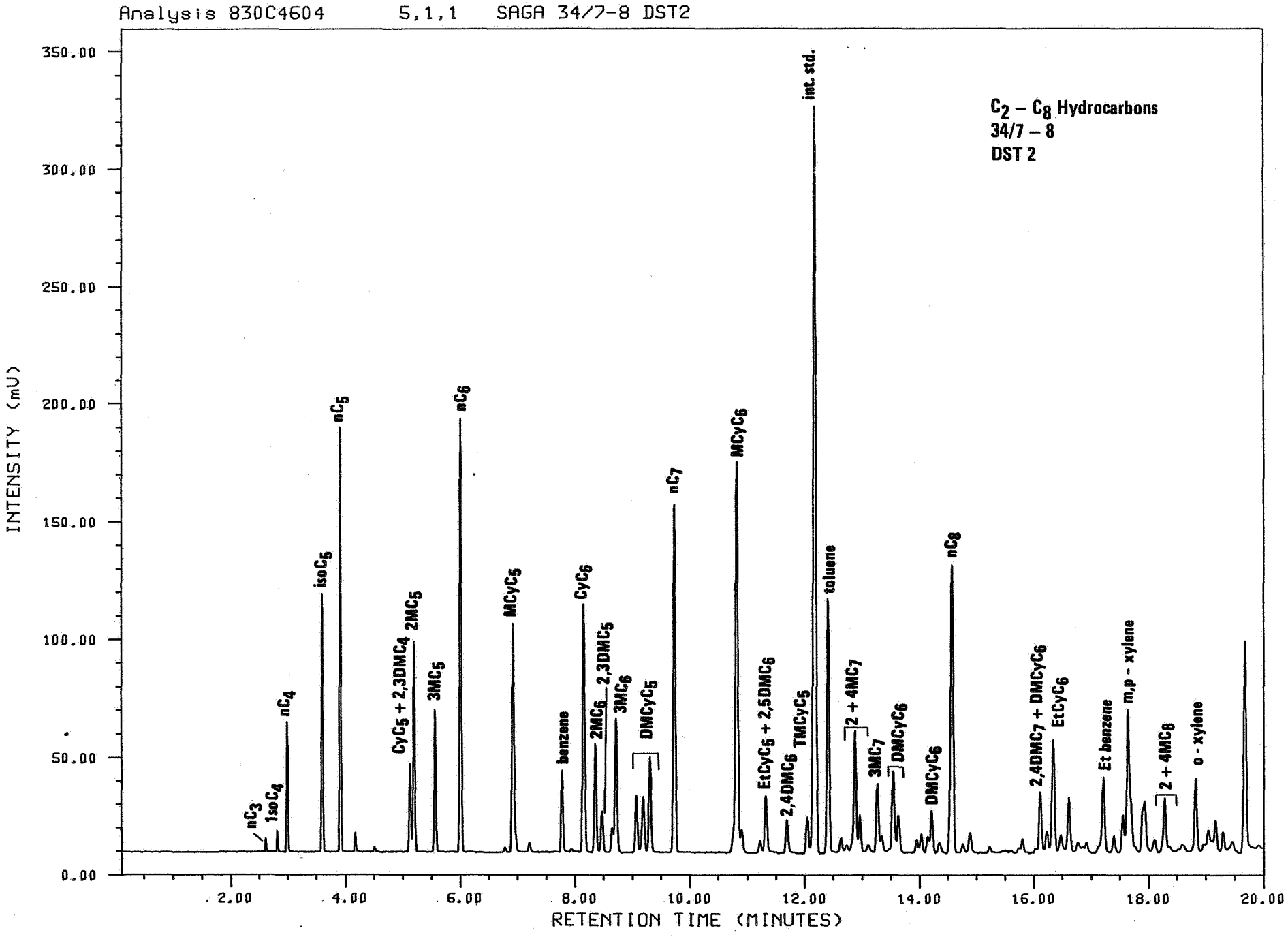
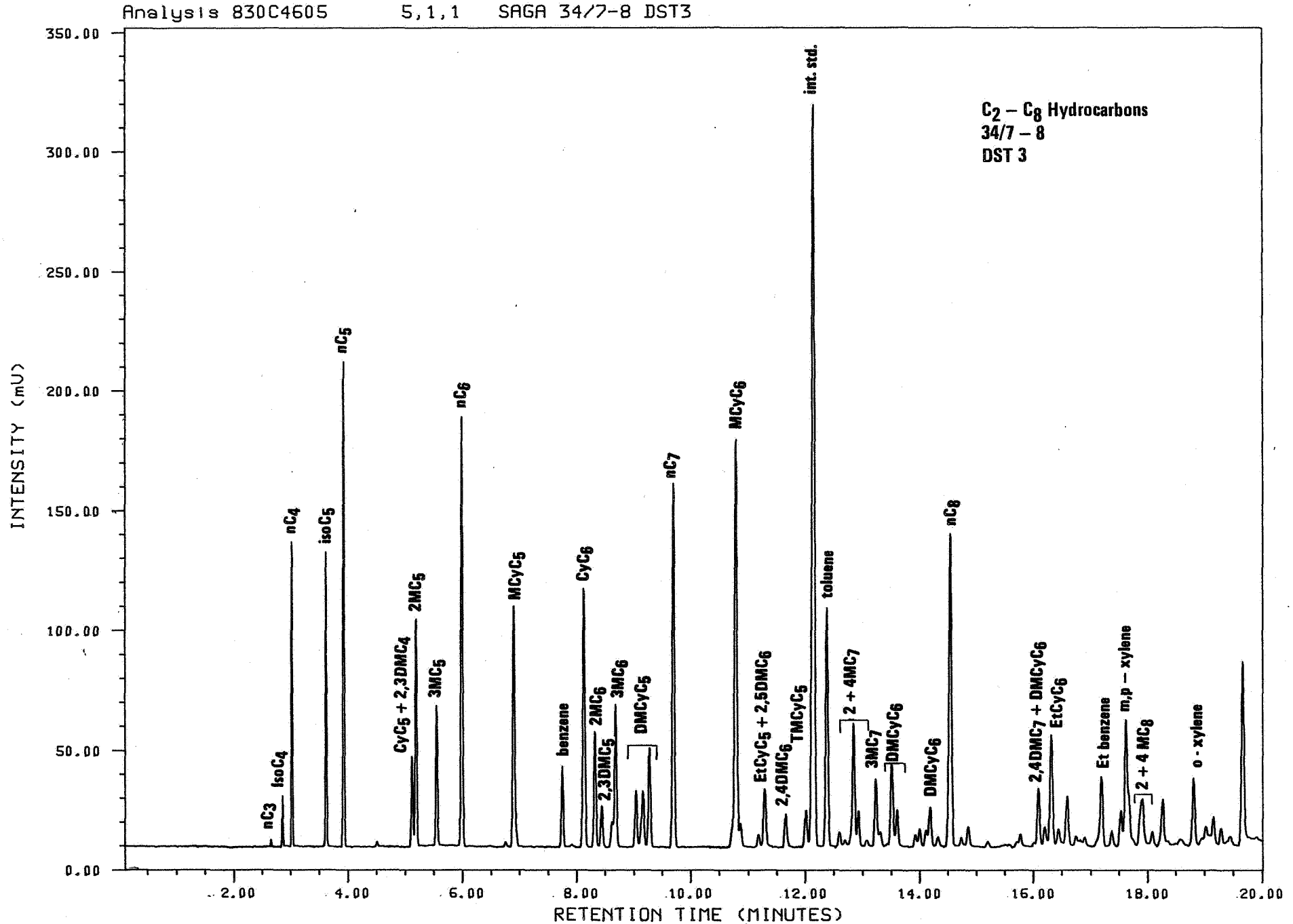


FIGURE 3

GAS CHROMATOGRAMS OF C_1-C_8 HYDROCARBONS IN DST OILS


Analysis 830C4629 5,1,1 SAGA 34/7-8 DST 1A
$C_2 - C_8$ Hydrocarbons
34/7 – 8
DST 1a
INTENSITY (mV)
RETENTION TIME (MINUTES)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
nC3
isoC4
nC4
isoC5
nC5
CyC5 + 2,3DMC4
2MC5
3MC5
nC6
MCyC5
benzene
CyC6
2MC6
2,3DMC5
3MC6
DMCyC5
nC7
MCyC6
EtCyC5 + 2,5DMC6
2,4DMC6
TMCyC5
int. std.
toluene
2 + 4MC7
3MC7
DMCyC6
DMCyC6
nC8
2,4DMC7 + DMCyC6
EtCyC6
Et benzene
m,p – xylene
2 + 4 MC8
o - xylene


Analysis 830C4604 5,1,1 SAGA 34/7-8 DST2
$C_2 - C_8$ Hydrocarbons
34/7 – 8
DST 2
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
nC3
iso C4
nC4
iso C5
nC5
CyC5 + 2,3DMC4
2MC5
3MC5
nC6
MCyC5
benzene
CyC6
2MC6
2,3DMC5
3MC6
DMCyC5
nC7
MCyC6
EtCyC5 + 2,5DMC6
2,4DMC6
TMCyC5
int. std.
toluene
2 + 4MC7
3MC7
DMCyC6
DMCyC6
nC8
2,4DMC7 + DMCyC6
EtCyC6
Et benzene
m,p - xylene
2 + 4MC8
o - xylene


Analysis 830C4605 5,1,1 SAGA 34/7-8 DST3
$C_2 - C_8$ Hydrocarbons
34/7 – 8
DST 3
INTENSITY (mU)
RETENTION TIME (MINUTES)
nC3
isoC4
nC4
isoC5
nC5
CyC5 + 2,3DMC4
2MC5
3MC5
nC6
MCyC5
benzene
CyC6
2MC6
2,3DMC5
3MC6
DMCyC5
nC7
MCyC6
EtCyC5 + 2,5DMC6
2,4DMC6
TMCyC5
int. std.
toluene
2 + 4MC7
3MC7
DMCyC6
DMCyC6
nC8
2,4DMC7 + DMCyC6
EtCyC6
Et benzene
m,p – xylene
2 + 4 MC8
o - xylene

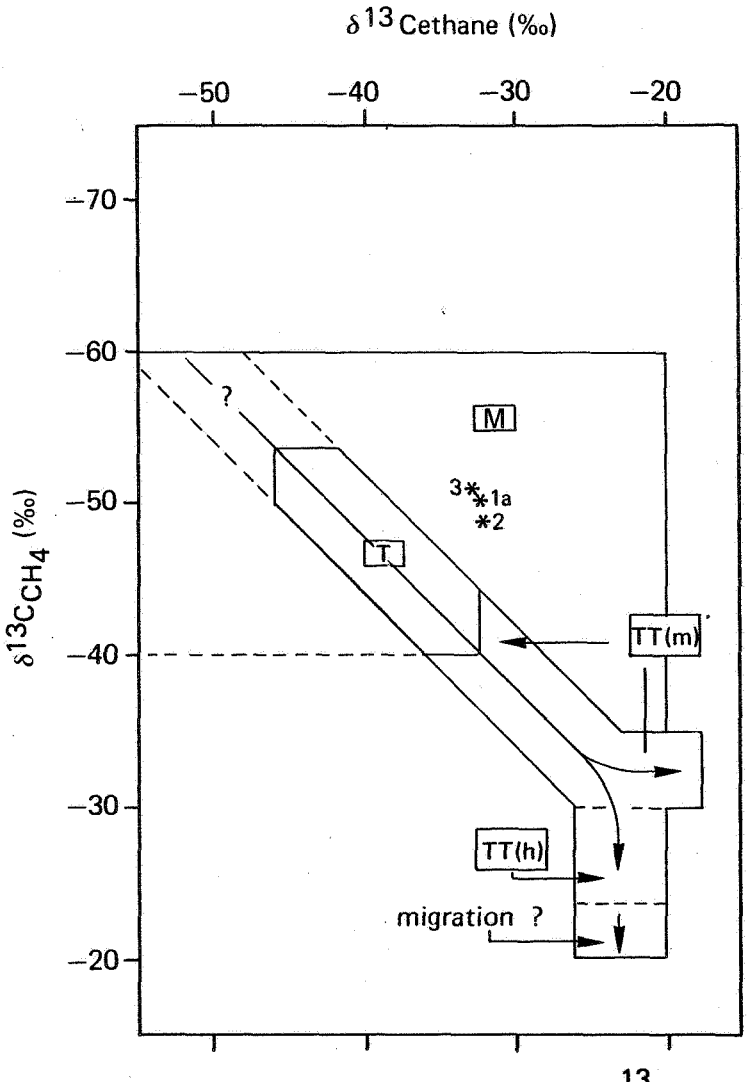


Figure 4a: The three DST gas samples have $\delta^{13}C$ isotope values which plot close to the zone of gases associated with oil/condensate, but lie just inside the zone normally associated with mixed catagenic/biogenic gases. (After Schoell,1983).

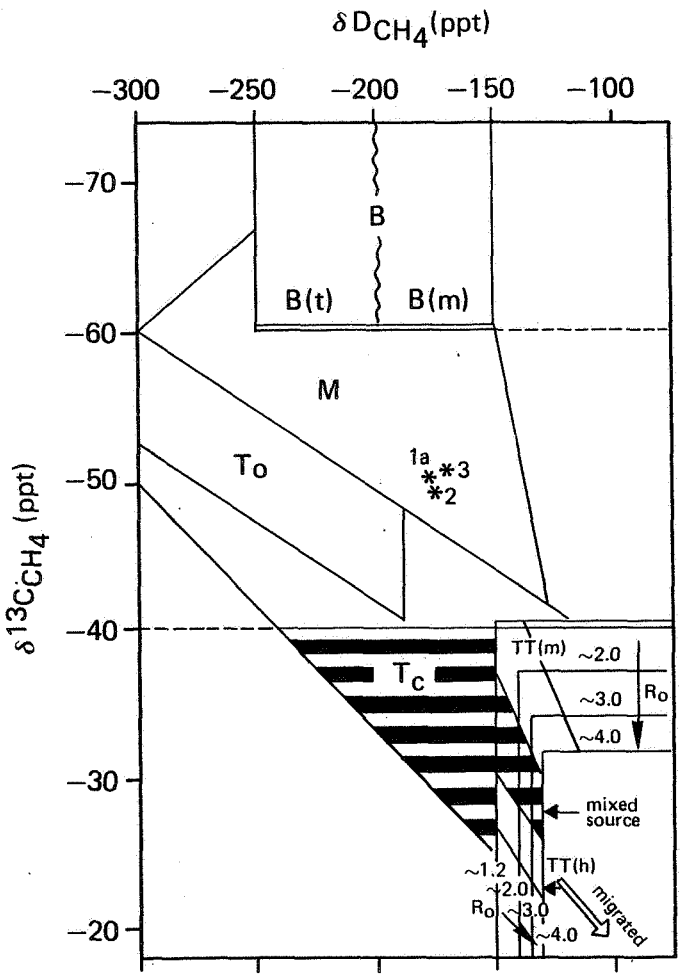
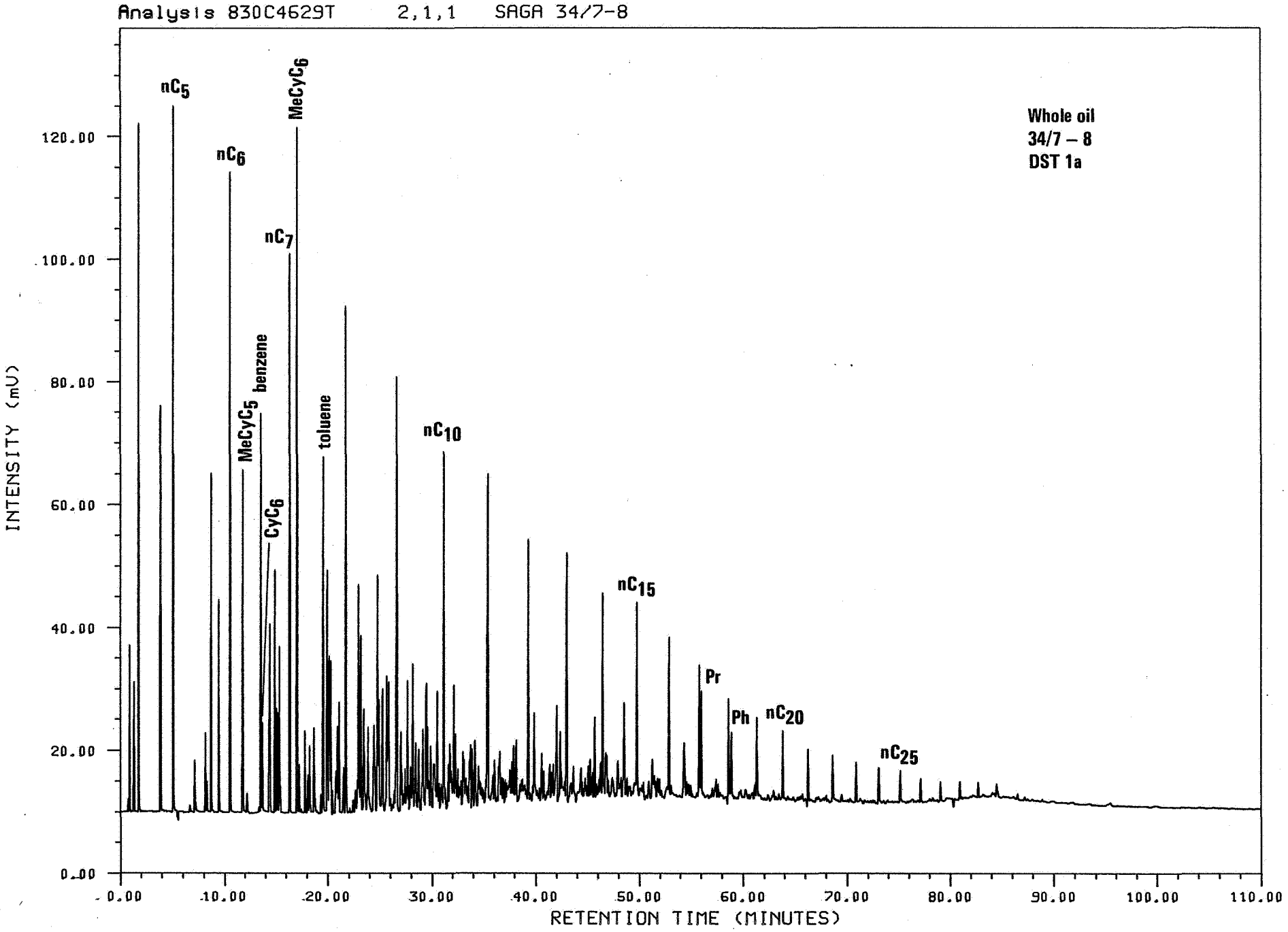


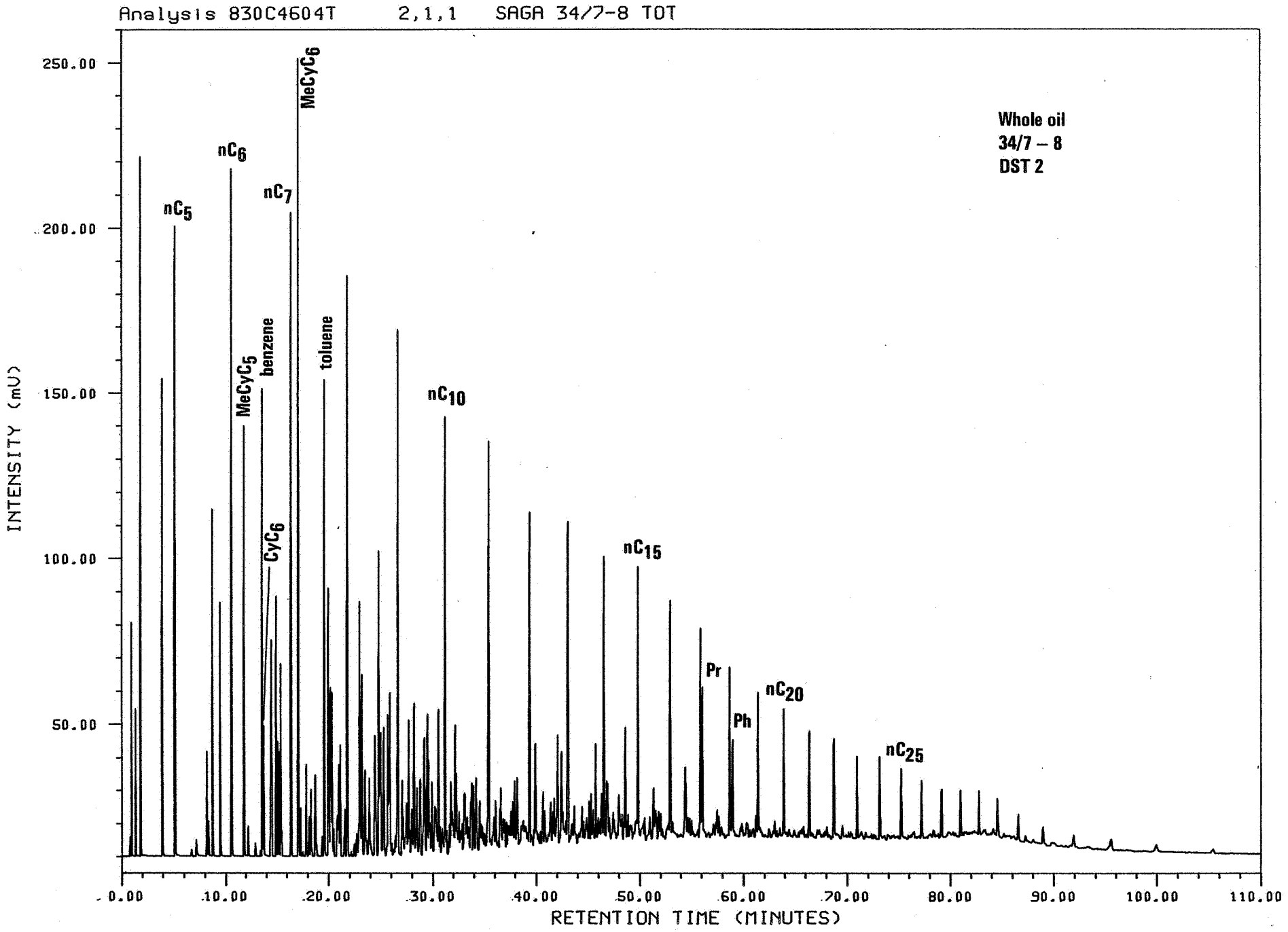
Figure 4b: All three DST gases plot close to each other in the zone of mixed biogenic/catagenic gas close to the boundary of the field associated with oil-associated gases. (After Schoell, 1983).

FIGURE 5

WHOLE OIL GAS CHROMATOGRAMS OF DST OILS

C_{10} etc.	-	n-alkanes
Cy-C_6	-	cyclohexane
MeCy-C_6	-	methylcyclohexane
Pr	-	pristane
Ph	-	phytane


Analysis 830C4629T 2,1,1 SAGA 34/7-8
Whole oil
34/7 – 8
DST 1a
nC5
nC6
MeCyC5
benzene
nC7
MeCyC6
CyC6
toluene
nC10
nC15
Pr
Ph
nC20
nC25
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
10.00
30.00
50.00
70.00
90.00
110.00


Analysis 830C4604T 2,1,1 SAGA 34/7-8 TOT
Whole oil
34/7 – 8
DST 2
nC5
nC6
MeCyC5
benzene
nC7
CyC6
MeCyC6
toluene
nC10
nC15
Pr
Ph
nC20
nC25
INTENSITY (mV)
RETENTION TIME (MINUTES)
250.00
200.00
150.00
100.00
50.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
100.00
110.00

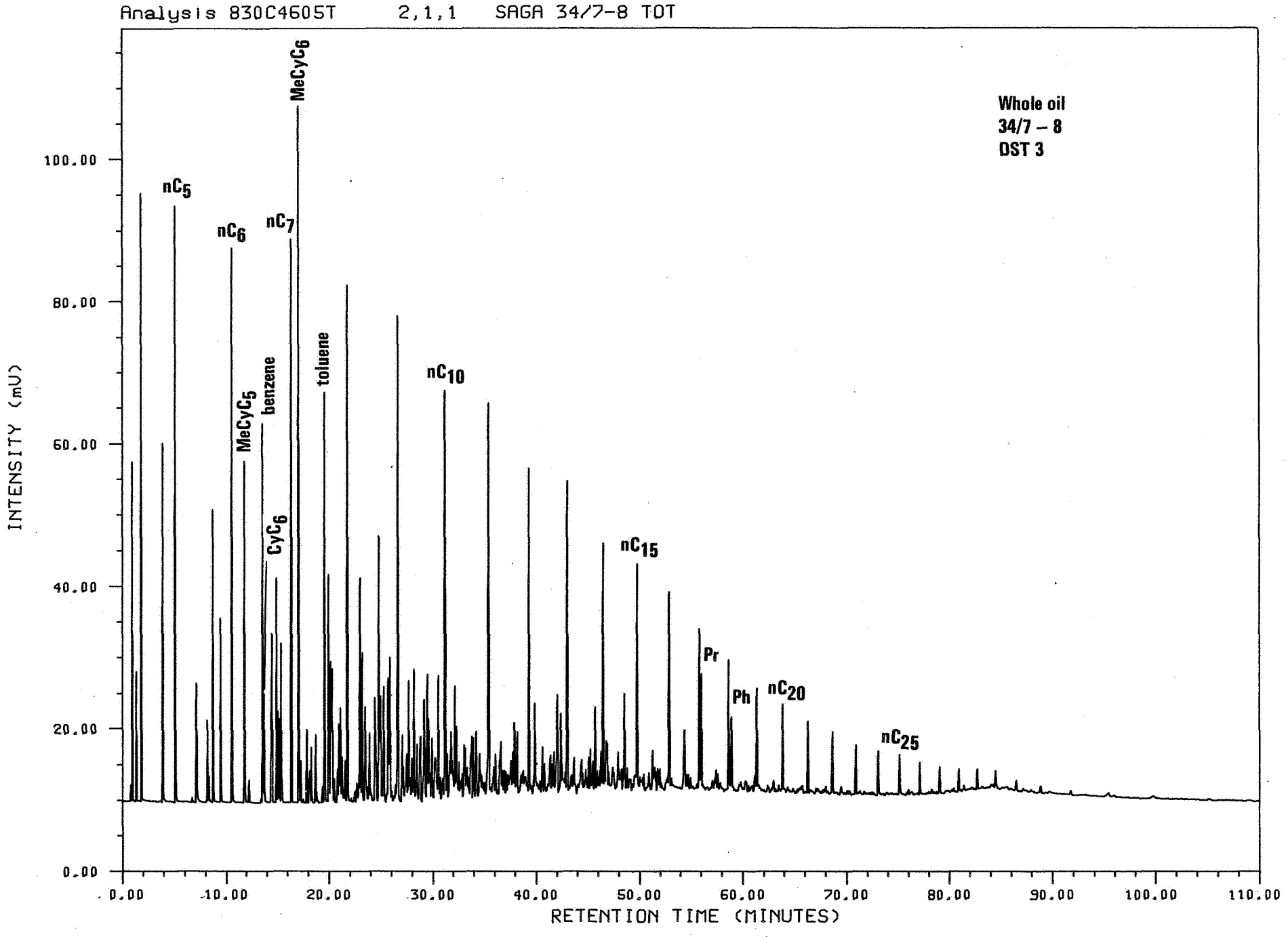
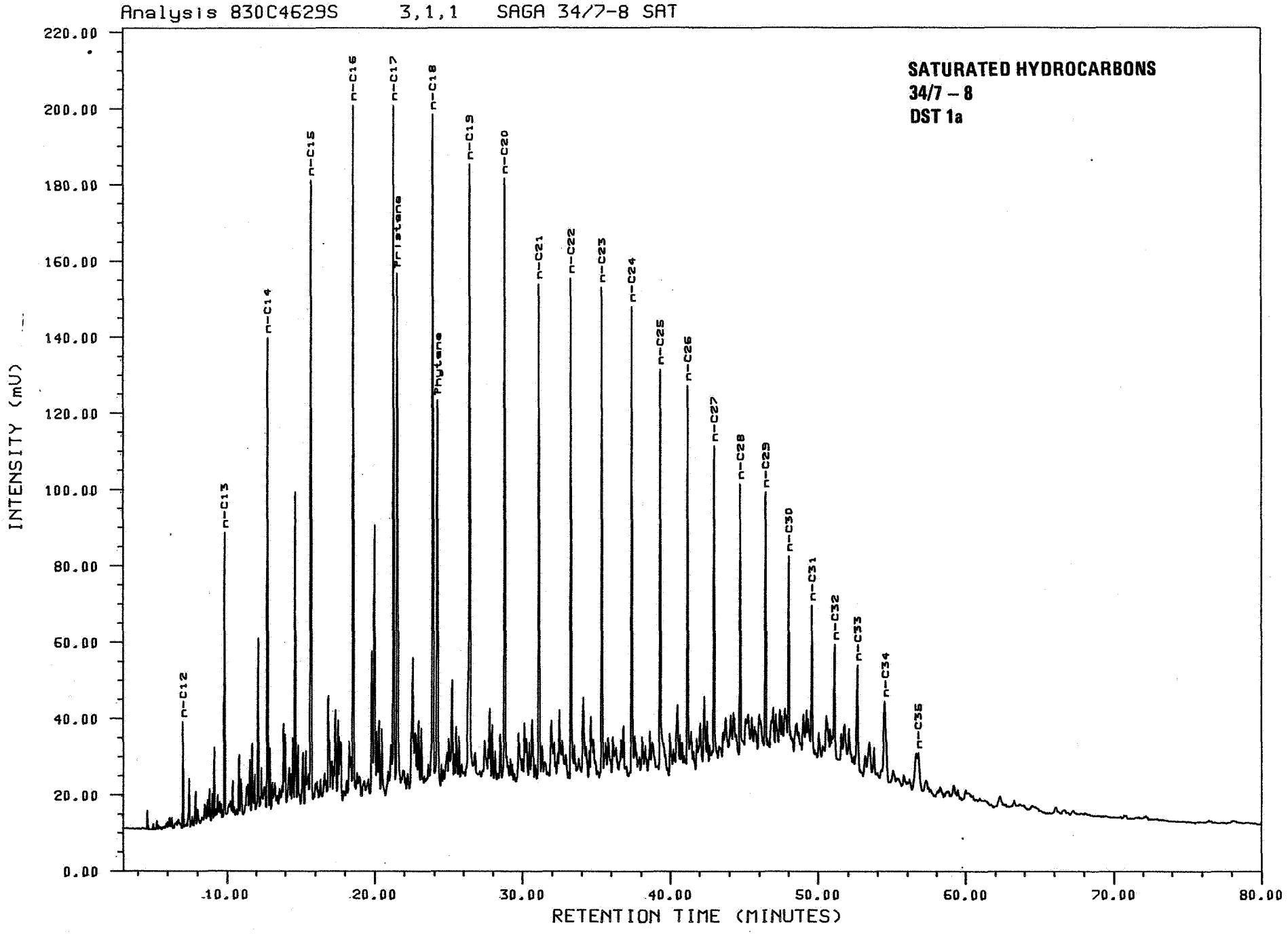
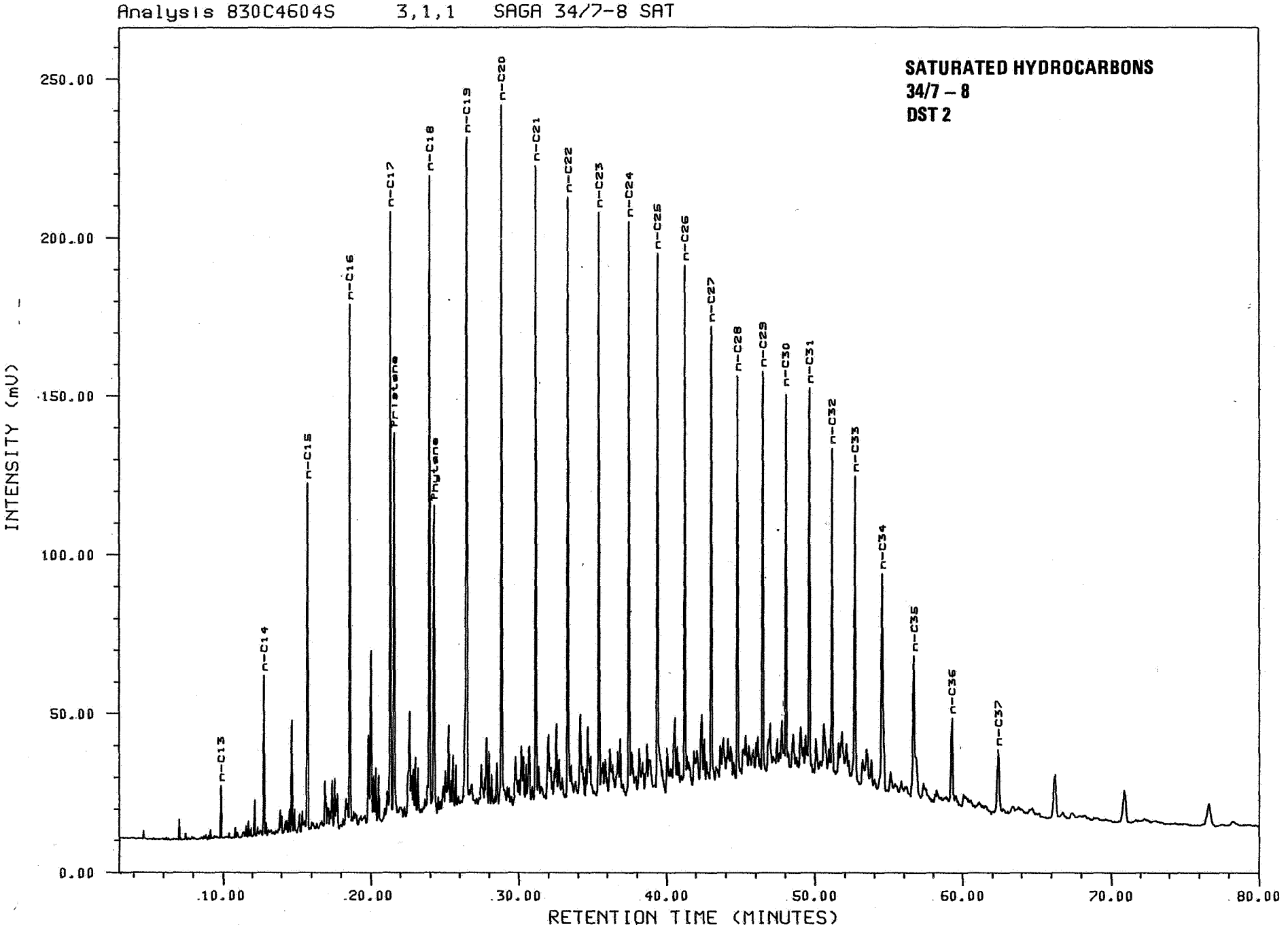

Analysis 830C4605T 2,1,1 SAGA 34/7-8 TOT
Whole oil
34/7 – 8
DST 3
nC5
nC6
MeCyC5
nC7
benzene
CyC6
MeCyC6
toluene
nC10
nC15
Pr
Ph
nC20
nC25
INTENSITY (mV)
RETENTION TIME (MINUTES)
0.00
20.00
40.00
60.00
80.00
100.00
10.00
30.00
50.00
70.00
90.00
110.00

FIGURE 6

GAS CHROMATOGRAMS OF SATURATED HYDROCARBONS

$n\text{-}C_{15}$ etc. - n-alkanes
Pr - pristane
Ph - phytane
* - other acyclic isoprenoids


Analysis 830C4629S 3,1,1 SAGA 34/7-8 SAT
SATURATED HYDROCARBONS
34/7 – 8
DST 1a
INTENSITY (mU)
RETENTION TIME (MINUTES)
n-C12
n-C13
n-C14
n-C15
n-C16
n-C17
Pristane
n-C18
Phytane
n-C19
n-C20
n-C21
n-C22
n-C23
n-C24
n-C25
n-C26
n-C27
n-C28
n-C29
n-C30
n-C31
n-C32
n-C33
n-C34
n-C35


Analysis 830C4604S 3,1,1 SAGA 34/7-8 SAT
SATURATED HYDROCARBONS
34/7 – 8
DST 2
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
50.00
100.00
150.00
200.00
250.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
n-C13
n-C14
n-C15
n-C16
n-C17
Pristane
n-C18
Phytane
n-C19
n-C20
n-C21
n-C22
n-C23
n-C24
n-C25
n-C26
n-C27
n-C28
n-C29
n-C30
n-C31
n-C32
n-C33
n-C34
n-C35
n-C36
n-C37

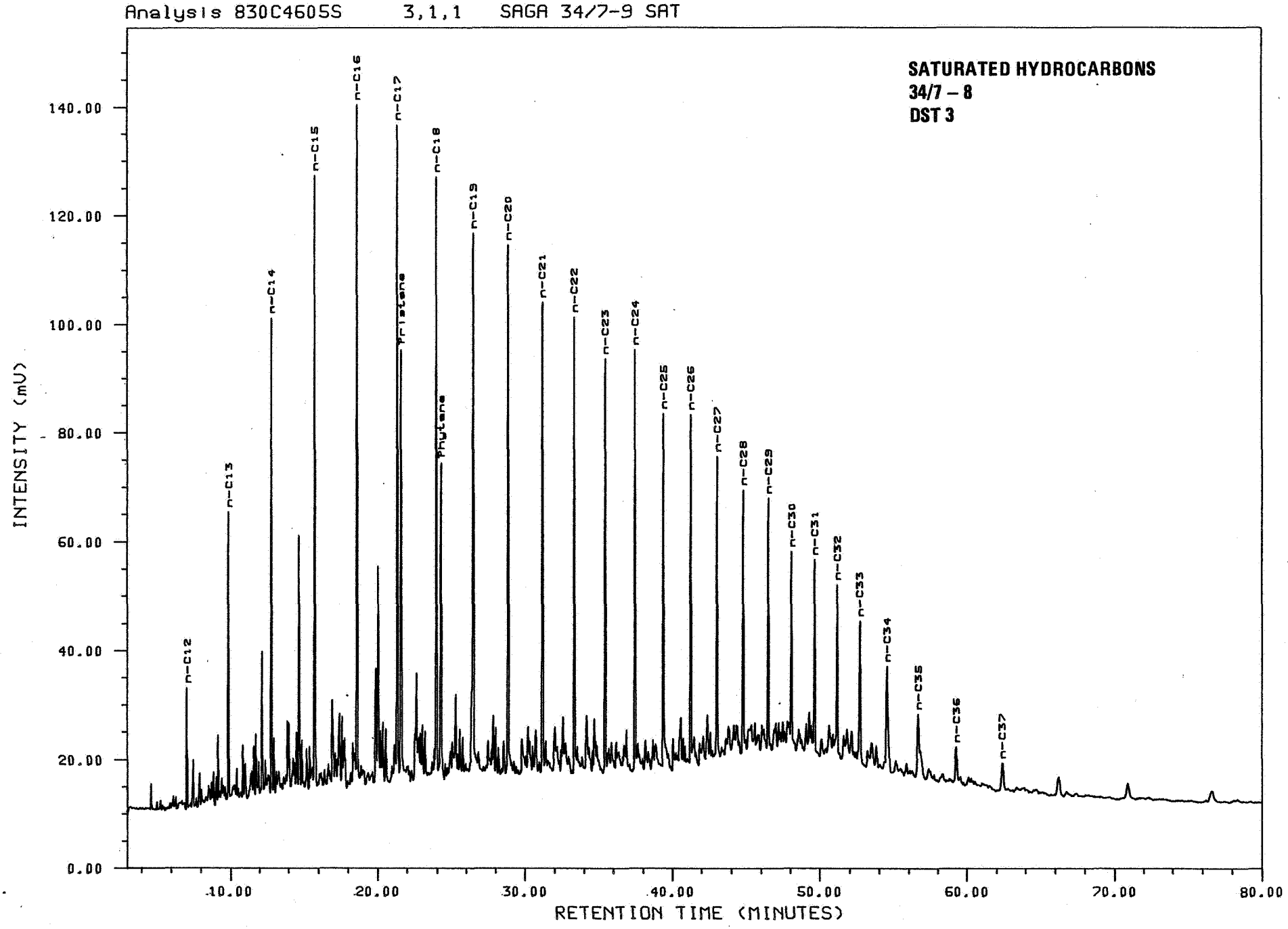
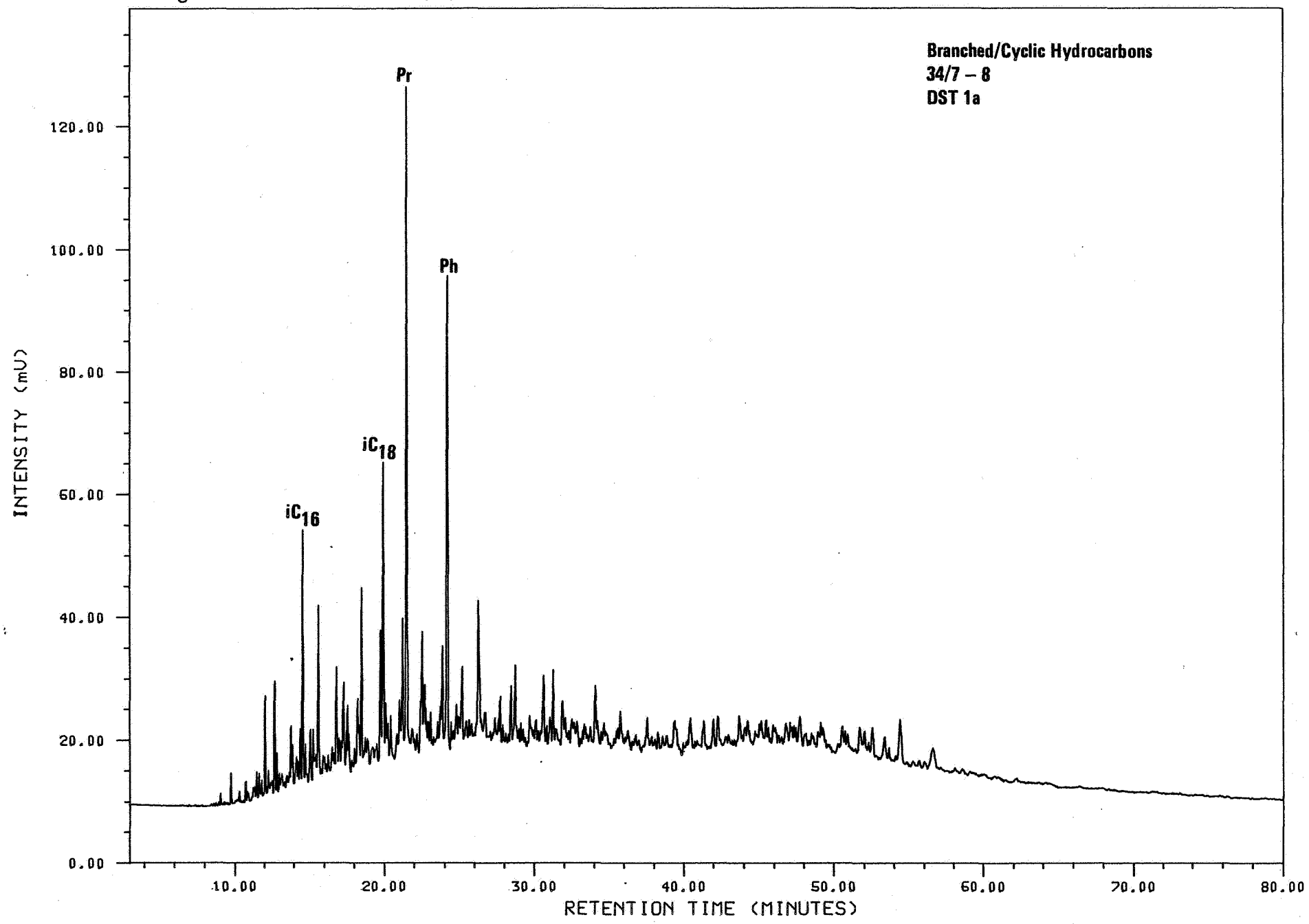
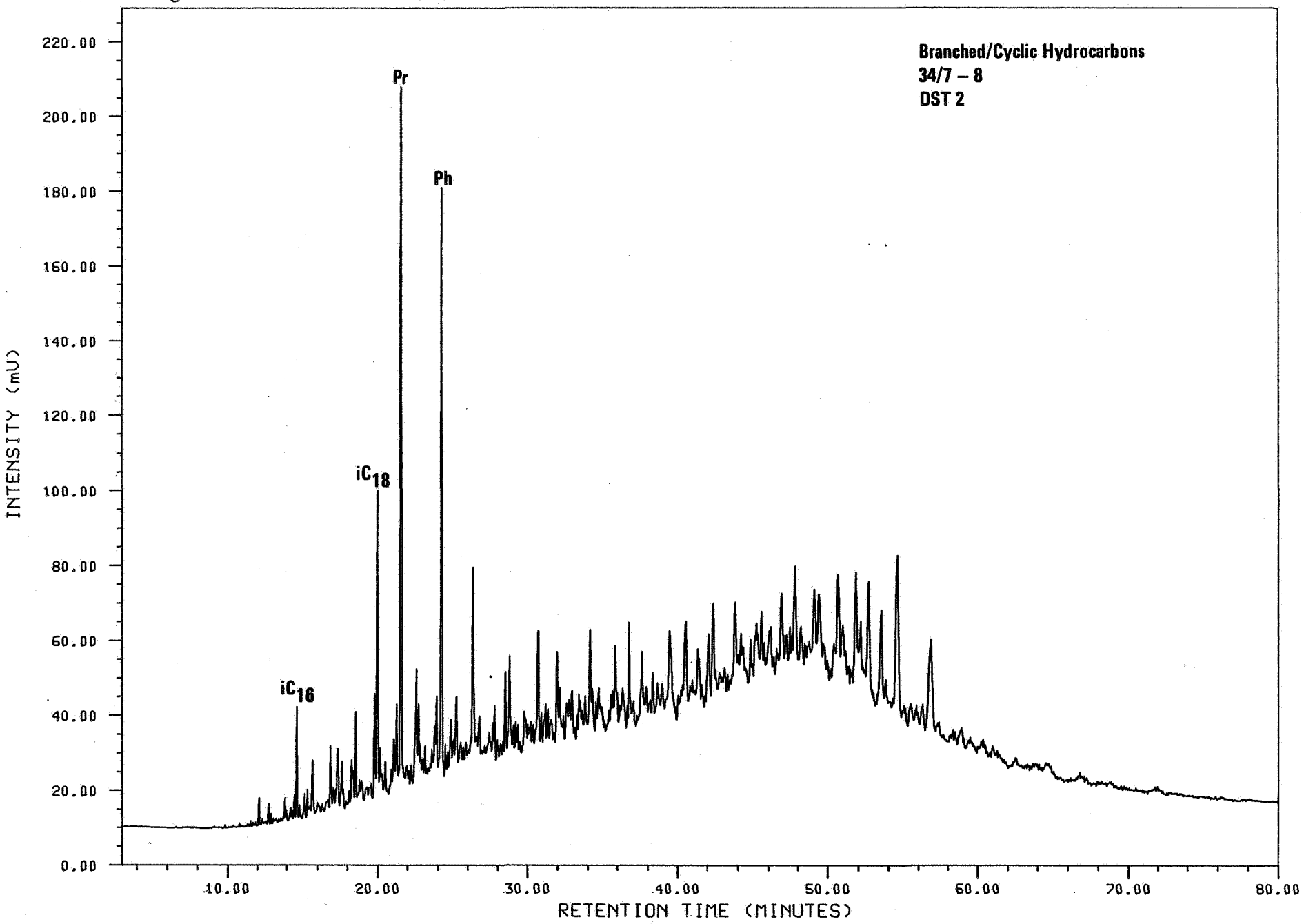

Analysis 830C4605S 3,1,1 SAGA 34/7-9 SAT
SATURATED HYDROCARBONS
34/7 – 8
DST 3
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
n-C12
n-C13
n-C14
n-C15
n-C16
n-C17
Pristane
n-C18
Phytane
n-C19
n-C20
n-C21
n-C22
n-C23
n-C24
n-C25
n-C26
n-C27
n-C28
n-C29
n-C30
n-C31
n-C32
n-C33
n-C34
n-C35
n-C36
n-C37

FIGURE 7

GAS CHROMATOGRAMS OF BRANCHED/CYCLIC HYDROCARBONS

iC_{16}	- C_{16} isoprenoid
iC_{18}	- C_{18} isoprenoid
Pr	- pristane
Ph	- phytane
isopr.C_{18} etc.	- isoprenoids
*	- n-alkanes remaining after adduction


Analysis 830C4629B 3,1,1 SAGA 34/7-8
Branched/Cyclic Hydrocarbons
34/7 – 8
DST 1a
Pr
Ph
iC18
iC16
INTENSITY (mU)
120.00
100.00
80.00
60.00
40.00
20.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)


Analysis 830C4604B 3,1,1 SAGA 34/7-8 B/C
Branched/Cyclic Hydrocarbons
34/7 – 8
DST 2
Pr
Ph
iC18
iC16
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
180.00
200.00
220.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

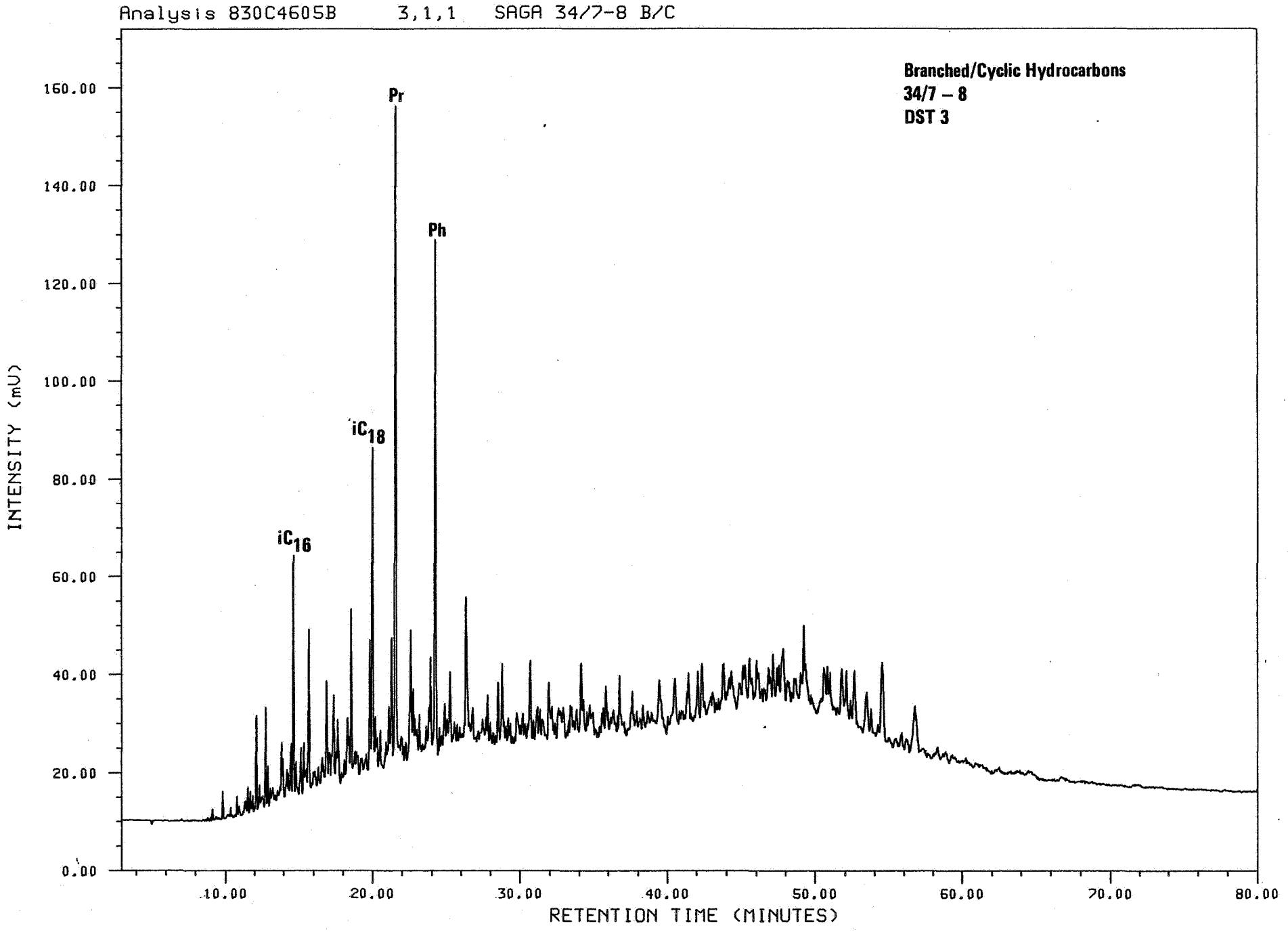
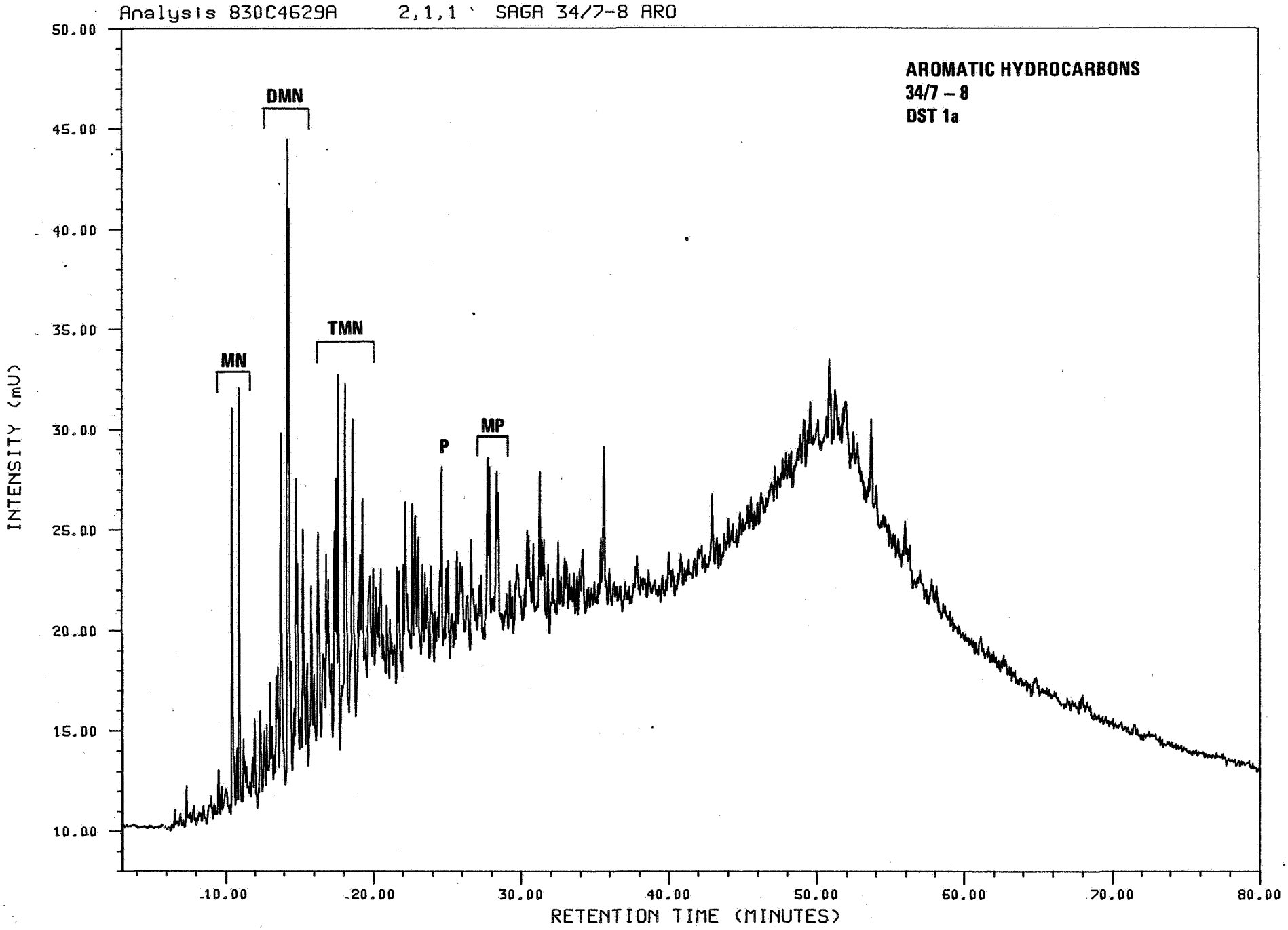
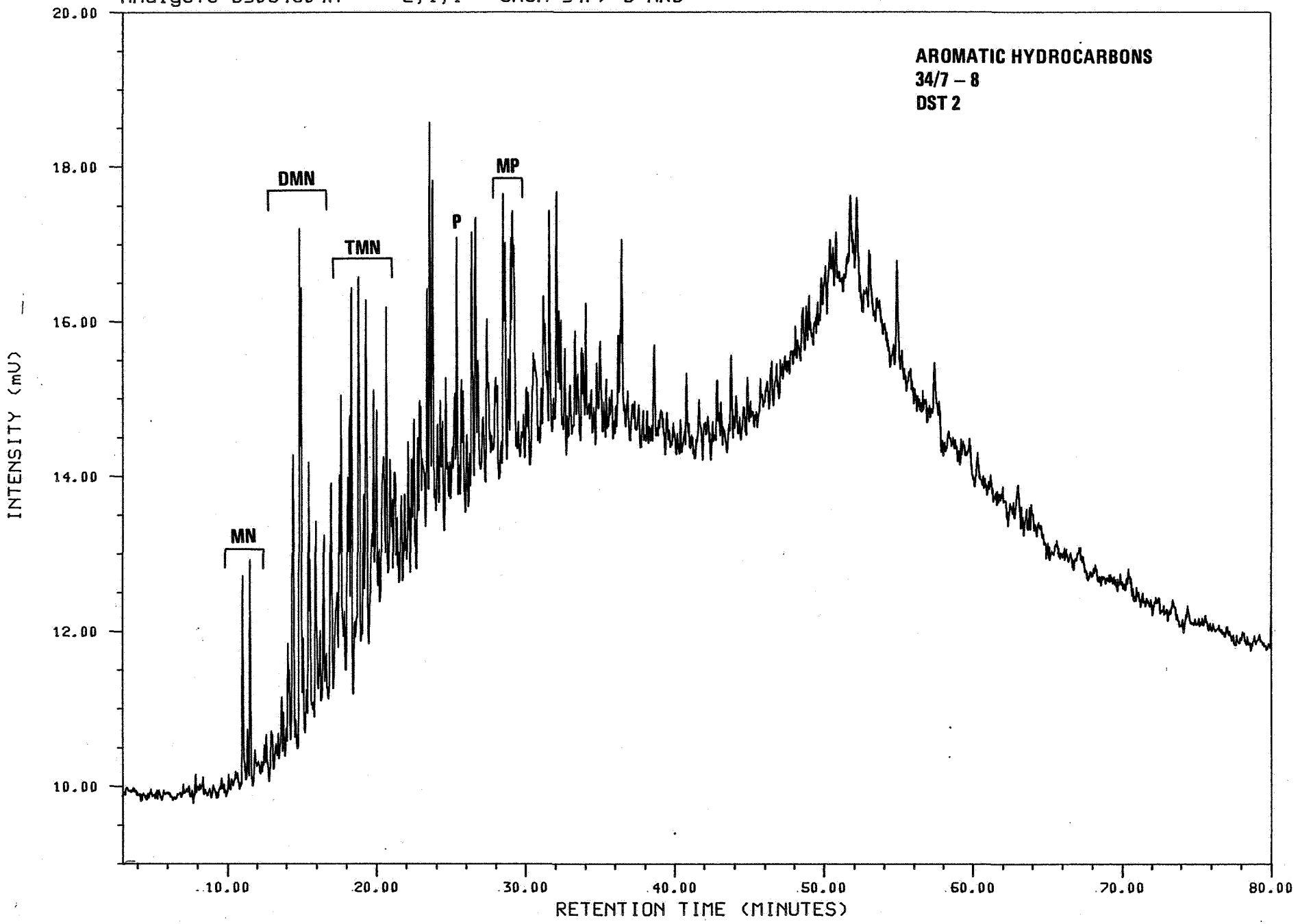

Analysis 830C4605B 3,1,1 SAGA 34/7-8 B/C
Branched/Cyclic Hydrocarbons
34/7 – 8
DST 3
Pr
Ph
iC18
iC16
INTENSITY (mU)
RETENTION TIME (MINUTES)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
160.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00

FIGURE 8

AROMATIC HYDROCARBON GAS CHROMATOGRAMS
FID DETECTION

N,MN,DMN,TMN	- naphthalene and alkylated homologs
P,MP,DMP	- phenanthrene and alkylated homologs


Analysis 830C4629A 2,1,1 SAGA 34/7-8 ARO
AROMATIC HYDROCARBONS
34/7 – 8
DST 1a
DMN
MN
TMN
P
MP
INTENSITY (mU)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)


Analysis 830C4604A 2,1,1 SAGA 34/7-8 ARO
AROMATIC HYDROCARBONS
34/7 – 8
DST 2
MN
DMN
TMN
P
MP
INTENSITY (mU)
20.00
18.00
16.00
14.00
12.00
10.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

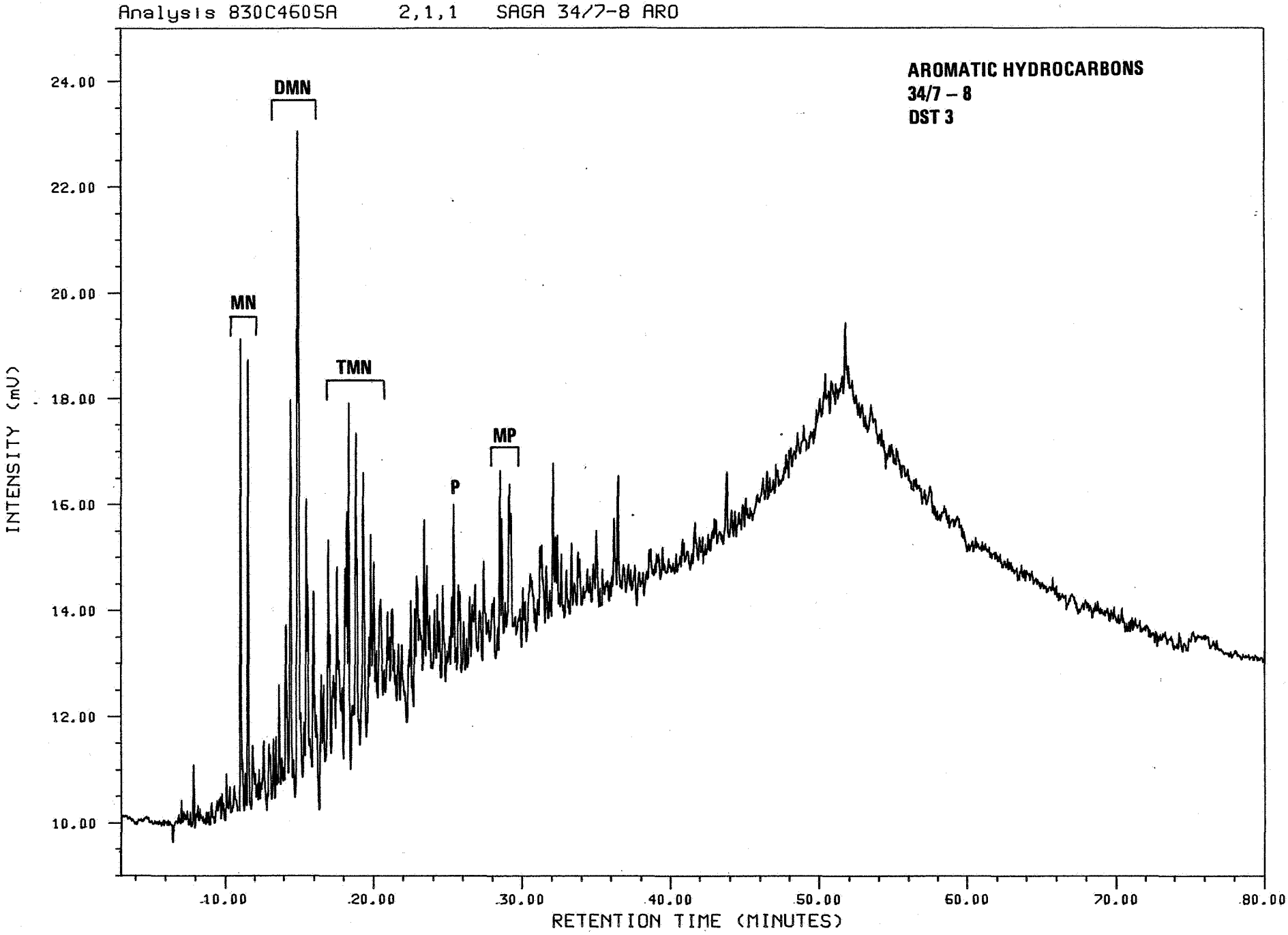
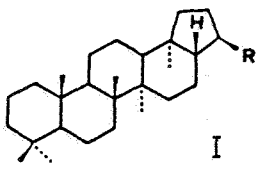

Analysis 830C4605A 2,1,1 SAGA 34/7-8 ARO
AROMATIC HYDROCARBONS
34/7 – 8
DST 3
DMN
MN
TMN
P
MP
INTENSITY (mU)
24.00
22.00
20.00
18.00
16.00
14.00
12.00
10.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
RETENTION TIME (MINUTES)

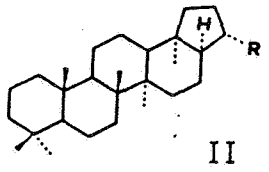
Figure 9

Mass chromatograms representing terpanes (m/z 191)

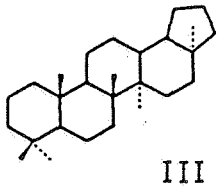
A	T_s, 18α(H)-trisnorneohopane	$C_{27}H_{46}$	(III)
B	T_m, 17α(H)-trisnorhopane	$C_{27}H_{46}$	(I,R=H)
C	17α(H)-norhopane	$C_{29}H_{50}$	(I,R=C_2H_5)
D	17β(H)-normoretane	$C_{29}H_{50}$	(II,R=C_2H_5)
E	17α(H)-hopane	$C_{30}H_{52}$	(I,R=C_3H_7)
F	17β(H)-moretane	$C_{30}H_{52}$	(II,R=C_3H_7)
G	17α(H)-homohopane (22S)	$C_{31}H_{54}$	(I,R=C_4H_9)
H	17α(H)-homohopane (22R)	$C_{31}H_{54}$	(I,R=C_4H_9)
	+ unknown triterpane (gammacerane?)		
I	17β(H)-homomoretane	$C_{31}H_{54}$	(II,R=C_4H_9)
J	17α(H)-bishomohopane (22S,22R)	$C_{32}H_{56}$	(I,R=C_5H_{11})
K	17α(H)-trishomohopane (22S,22R)	$C_{33}H_{58}$	(I,R=C_6H_{13})
L	17α(H)-tetrakishomohopane (22S,22R)	$C_{34}H_{60}$	(I,R=C_7H_{15})
M	17α(H)-pentakishomohopane (22S,22R)	$C_{35}H_{62}$	(I,R=C_8H_{17})
Z	bisnorhopane	$C_{28}H_{48}$	
X	unknown triterpane	$C_{30}H_{52}$	
P	tricyclic terpane	$C_{23}H_{42}$	(IV,R=C_4H_9)
Q	tricyclic terpane	$C_{24}H_{44}$	(IV,R=C_5H_{11})
R	tricyclic terpane (17R,17S)	$C_{25}H_{46}$	(IV,R=C_6H_{13})
S	tetracyclic terpane	$C_{24}H_{42}$	(V)
T	tricyclic terpane (17R,17S)	$C_{26}H_{48}$	(IV,R=C_7H_{15})



I



II



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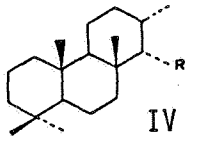
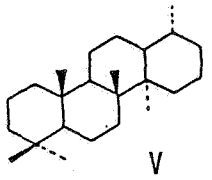
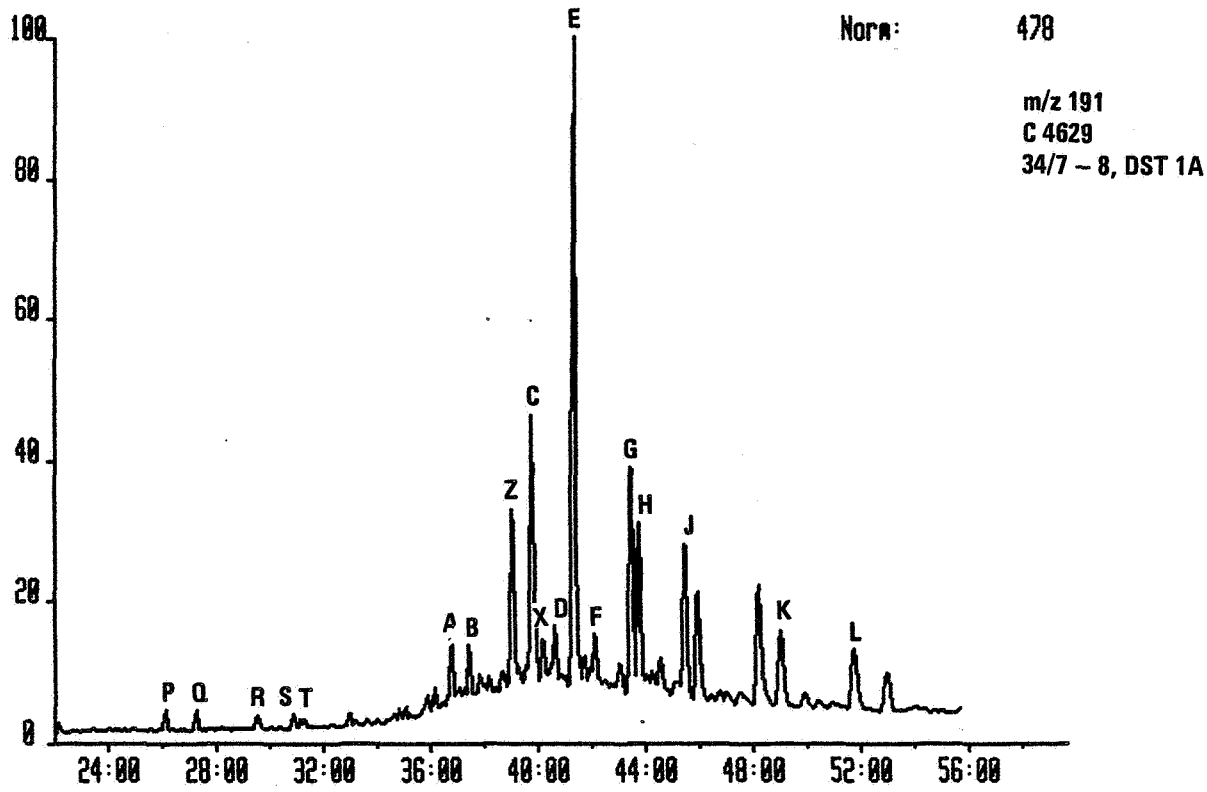


IV

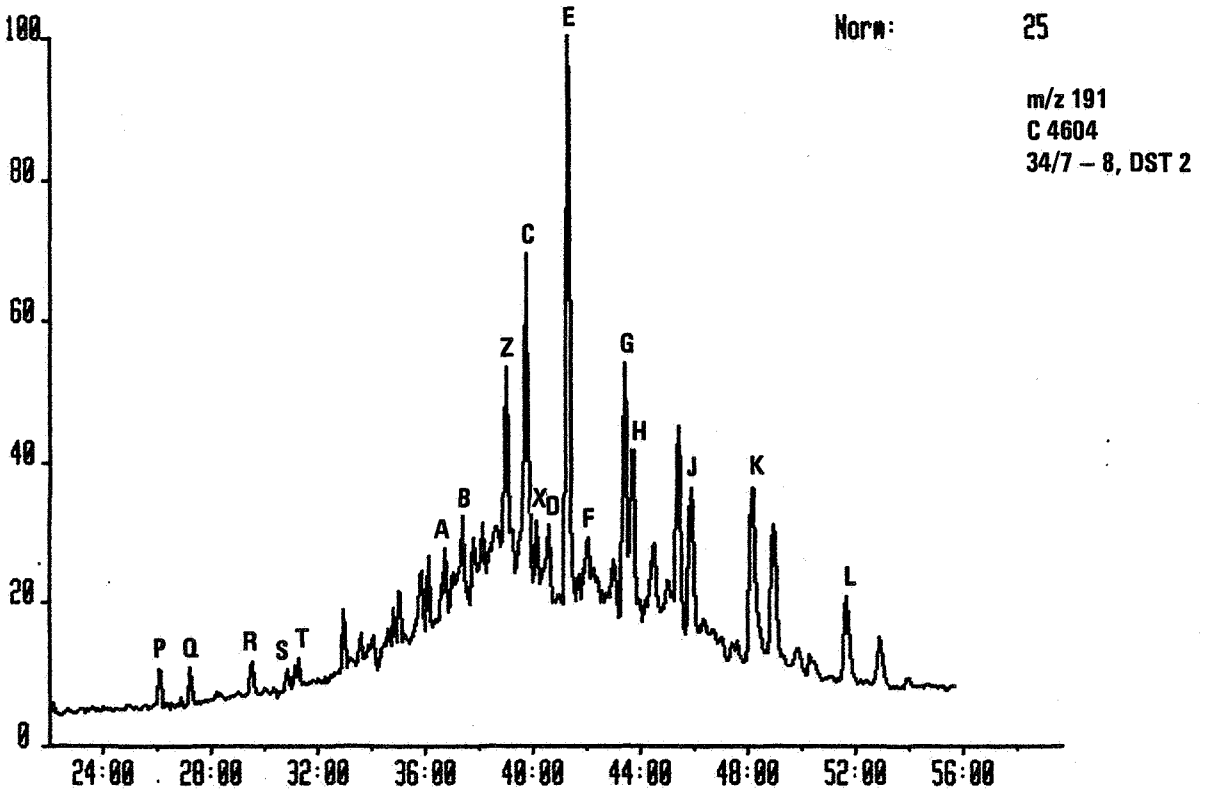


V

C4629SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 191.1000
Text:



C4604SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 191.1000
Text:



C4605SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 191.1000
Text:

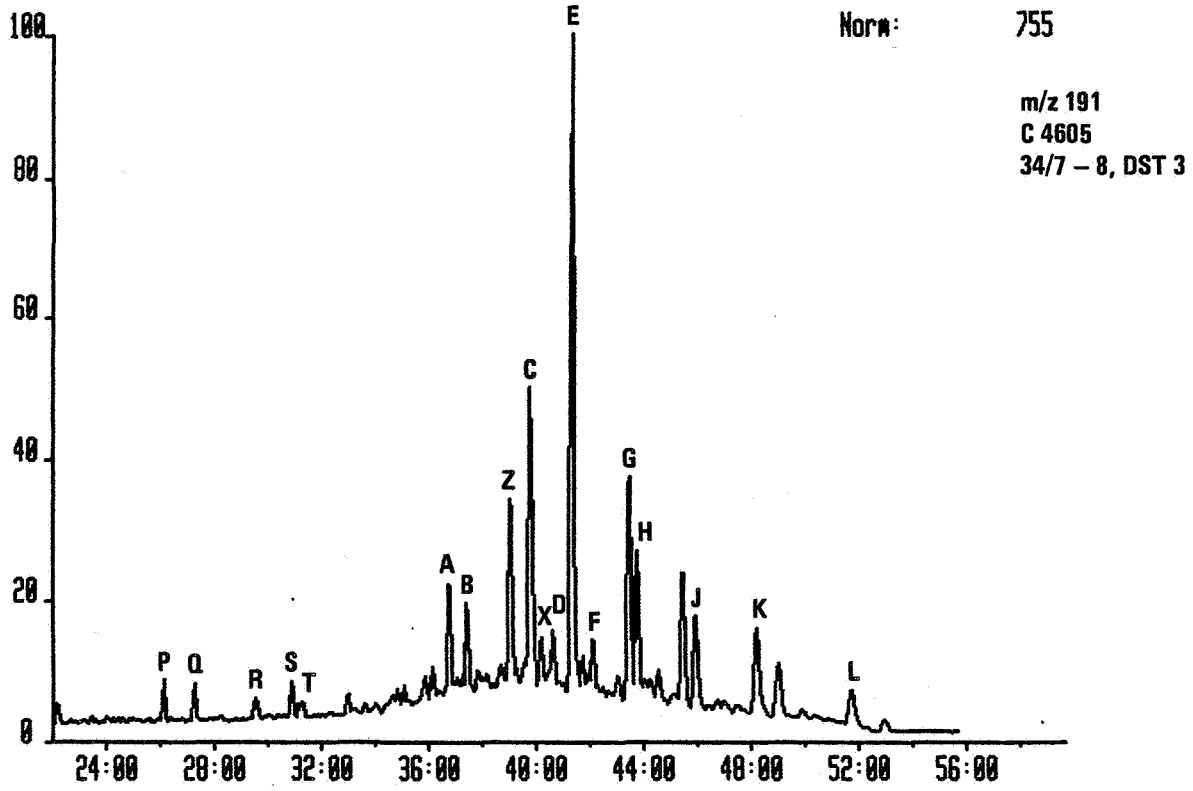
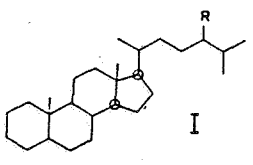


Figure 10.

Mass chromatograms representing steranes (m/z 217 and 218)

a	13β(H),17α(H)-diasterane (20S)	$C_{27}H_{48}$	(III,R=H)
b	13β(H),17α(H)-diasterane (20R)	$C_{27}H_{48}$	(III,R=H)
c	13α(H),17β(H)-diasterane (20S)	$C_{27}H_{48}$	(IV,R=H)
d	13α(H),17β(H)-diasterane (20R)	$C_{27}H_{48}$	(IV,R=H)
e	13β(H),17α(H)-diasterane (20S)	$C_{28}H_{50}$	(III,R=CH_3)
f	13β(H),17α(H)-diasterane (20R)	$C_{28}H_{50}$	(III,R=CH_3)
g	13α(H),17β(H)-diasterane (20S)	$C_{28}H_{50}$	(IV,R=CH_3)
	+ 14α(H),17α(H)-sterane (20S)	$C_{27}H_{48}$	(I,R=H)
h	13β(H),17α(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 14β(H),17β(H)-sterane (20R)	$C_{27}H_{48}$	(II,R=H)
i	14β(H),17β(H)-sterane (20S)	$C_{27}H_{48}$	(II,R=H)
	+ 13α(H),17β(H)-diasterane (20R)	$C_{28}H_{50}$	(IV,R=CH_3)
j	14α(H),17α(H)-sterane (20R)	$C_{27}H_{48}$	(I,R=H)
k	13β(H),17α(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C_2H_5)
l	13α(H),17β(H)-diasterane (20S)	$C_{29}H_{52}$	(III,R=C_2H_5)
m	14α(H),17α(H)-sterane (20S)	$C_{28}H_{50}$	(I,R=CH_3)
n	13α(H),17β(H)-diasterane (20R)	$C_{29}H_{52}$	(III,R=C_2H_5)
	+ 14β(H),17β(H)-sterane (20R)	$C_{28}H_{50}$	(II,R=CH_3)
o	14β(H),17β(H)-sterane (20S)	$C_{28}H_{50}$	(II,R=CH_3)
p	14α(H),17α(H)-sterane (20R)	$C_{28}H_{50}$	(I,R=CH_3)
q	14α(H),17α(H)-sterane (20S)	$C_{29}H_{52}$	(I,R=C_2H_5)
r	14β(H),17β(H)-sterane (20R)	$C_{29}H_{52}$	(II,R=C_2H_5)
	+ unknown sterane		
s	14β(H),17β(H)-sterane (20S)	$C_{29}H_{52}$	(II,R=C_2H_5)
t	14α(H),17α(H)-sterane (20R)	$C_{29}H_{52}$	(I,R=C_2H_5)
u	5α(H)-sterane	$C_{21}H_{36}$	(V,R=C_2H_5)
v	5α(H)-sterane	$C_{22}H_{38}$	(IV,R=C_3H_7)



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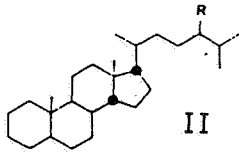
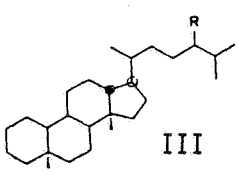
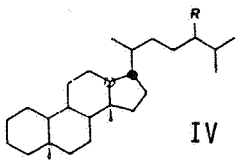


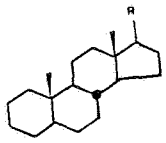
II



III

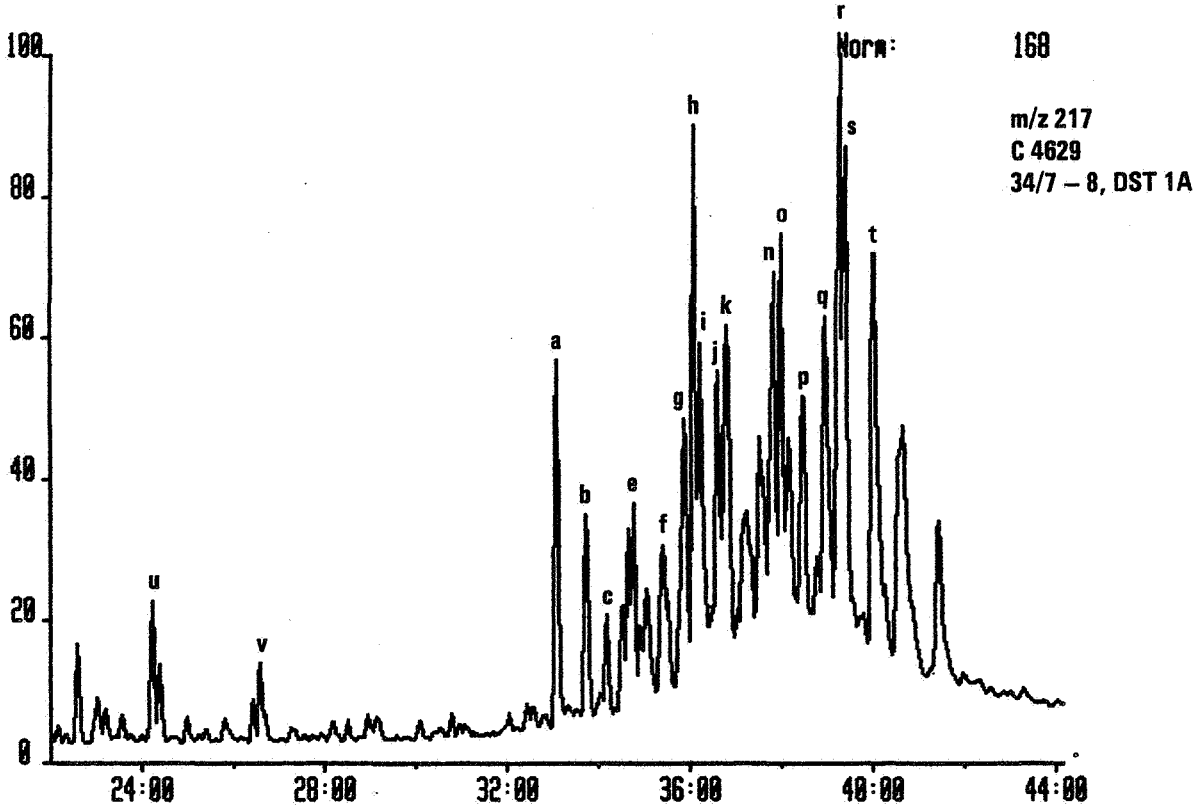


IV

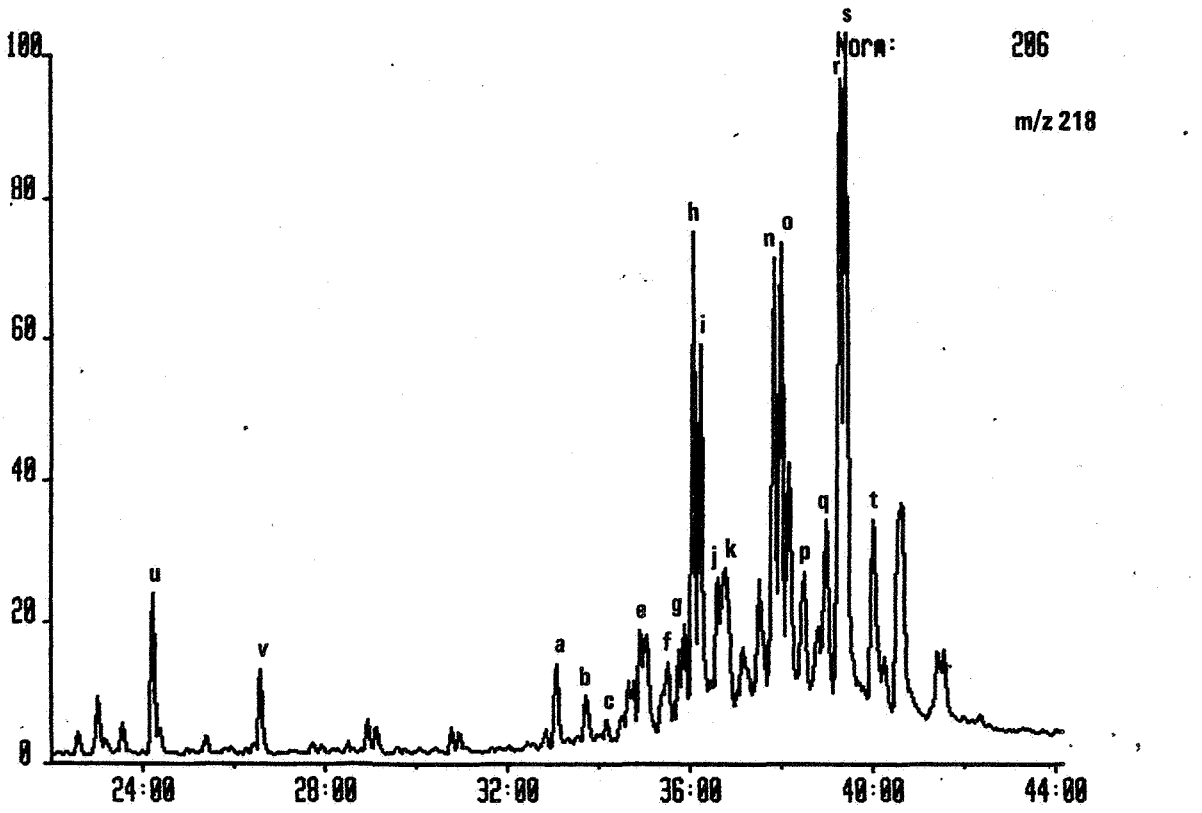


V

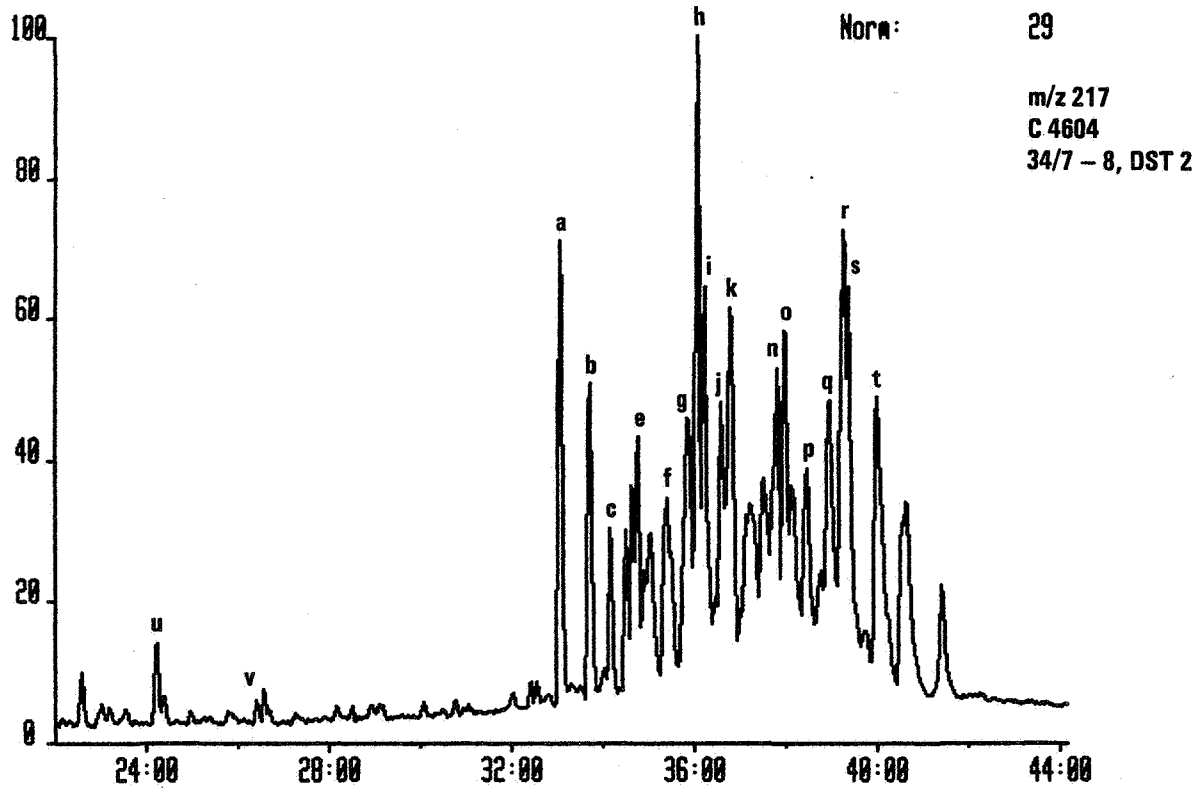
C4629SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 217.1000
Text:



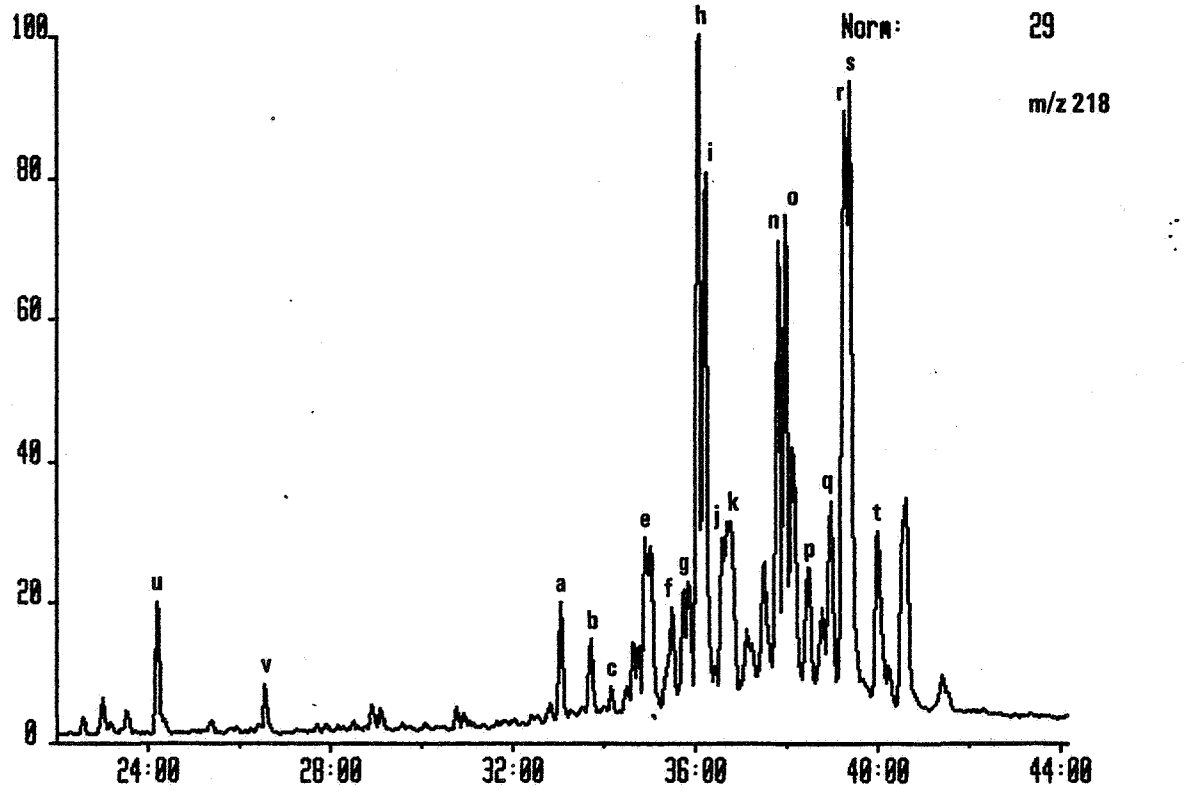
C4629SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 218.1000
Text:



C4604SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUANTID
Sample 1 Injection 1 Group 1 Mass 217.1000
Text:

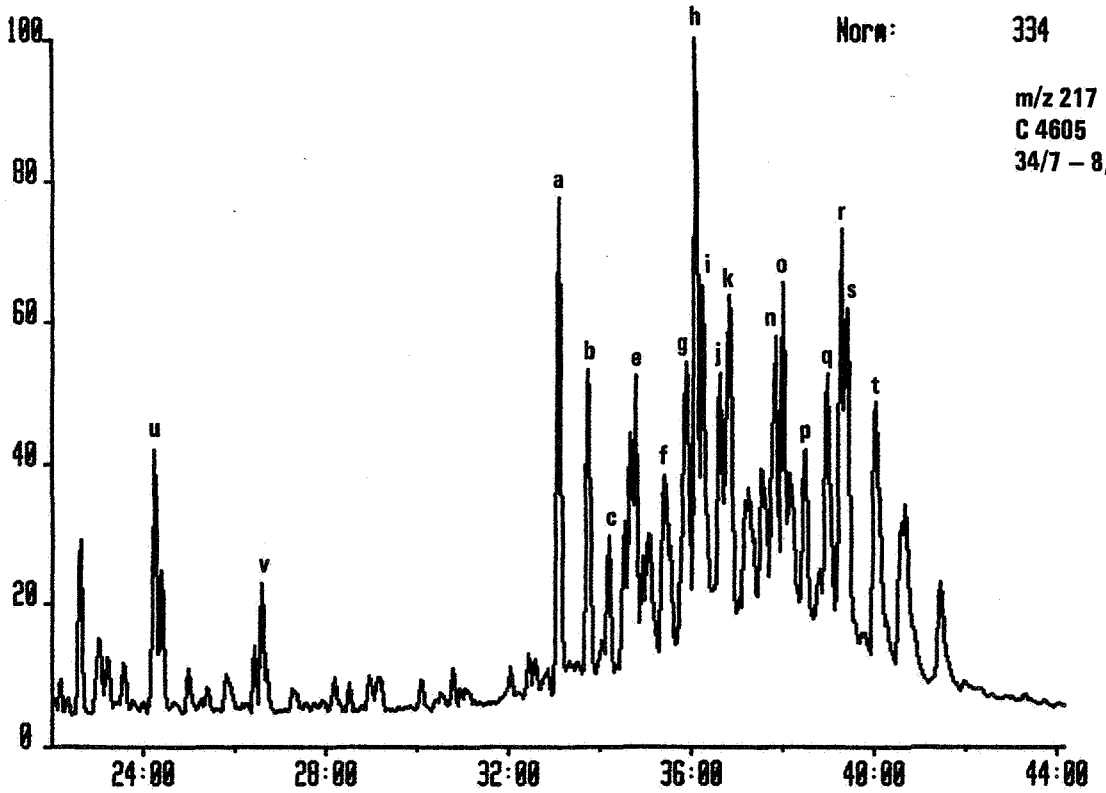


C4604SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUANTID
Sample 1 Injection 1 Group 1 Mass 218.1000
Text:



IKU SINTEF-GRUPPEN

C4605SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 217.1000
Text:



C4605SAT 30-JUN-86 Sir:Voltage 12-250 Acnt:IKU System:QUAMID
Sample 1 Injection 1 Group 1 Mass 218.1000
Text:

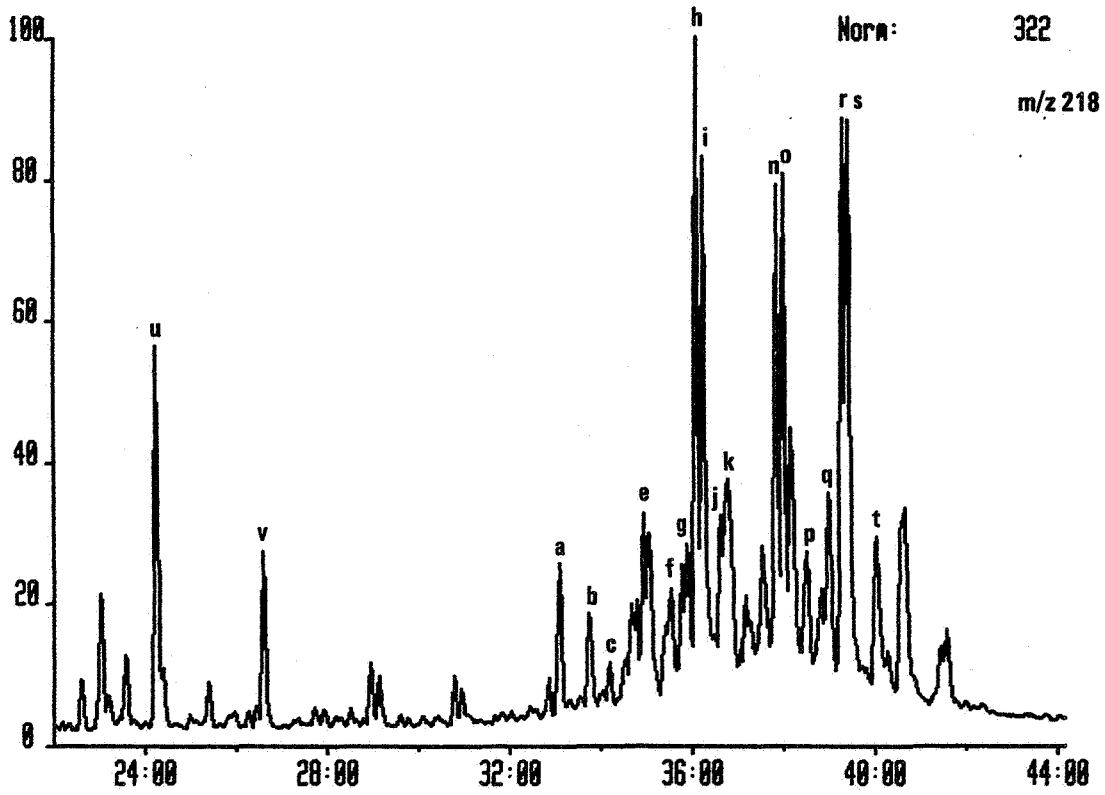


FIGURE 11

MASS CHROMATOGRAMS REPRESENTING AROMATIC HYDROCARBONS

TIC	- total ion current chromatogram
m/z 92,106	- alkylbenzenes
m/z 142,156,170	- alkylnaphthalenes
m/z 178,192,206	- phenanthrene and alkylphenanthrenes
m/z 184,198,212	- dibenzothiophene and alkyldibenzothiophenes
m/z 231	- triaromatic steranes
m/z 253	- monoaromatic steranes

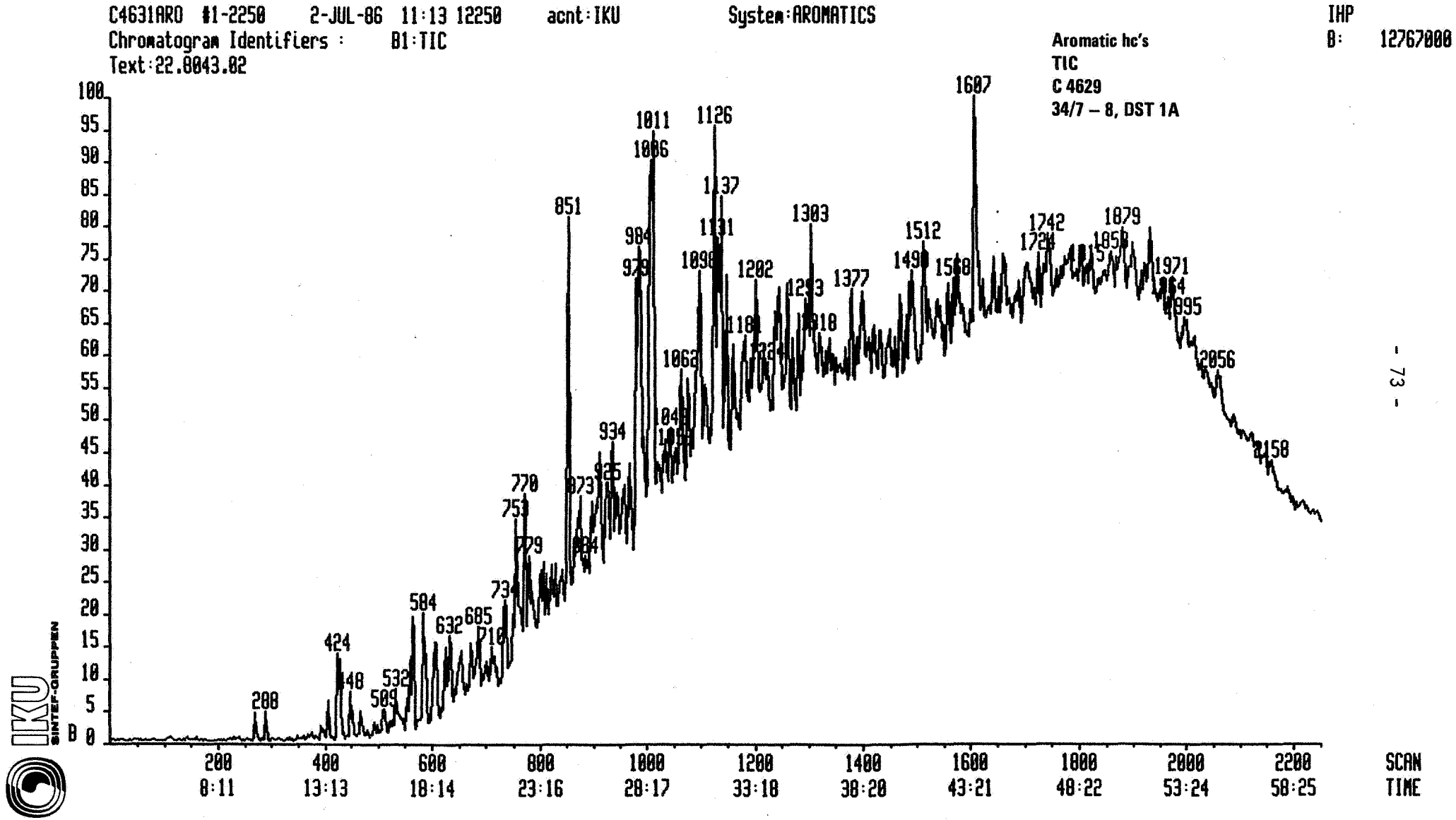
Mass chromatograms representing monoaromatic (m/z 239 and 253) and triaromatic (m/z 231) steranes.

m/z 253

a - C_{21} monoaromatic sterane
b - C_{22} monoaromatic sterane
c - unidentified
d - C_{27} monoaromatic sterane
e - C_{27} monoaromatic sterane
f - C_{28} monoaromatic sterane
g - C_{27} monoaromatic sterane
h - C_{28} + C_{29} monoaromatic sterane
i - C_{29} monoaromatic sterane
j - C_{29} monoaromatic sterane
k - unidentified
l - unidentified

m/z 231

M - C_{20} triaromatic sterane
N - C_{21} triaromatic sterane
O - C_{26} triaromatic sterane
P - C_{26} + C_{27} triaromatic sterane
Q - C_{28} triaromatic sterane
R - C_{27} triaromatic sterane
S - C_{28} triaromatic sterane

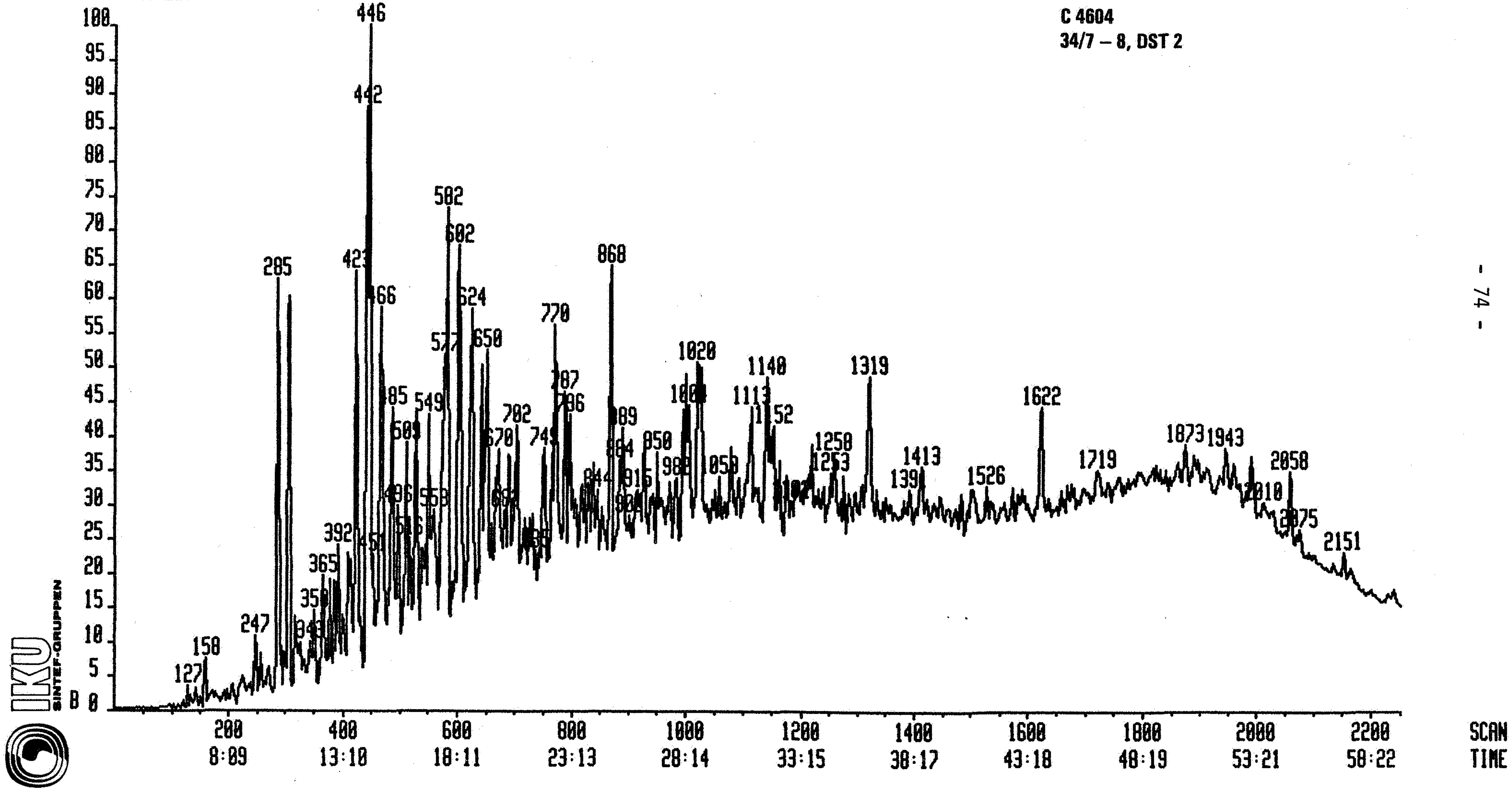

C4631ARO #1-2250 2-JUL-86 11:13 12250 acnt:IKU System:AROMATICS
Chromatogram Identifiers : B1:TIC
Text:22.8043.82
IHP
B: 12767000
Aromatic hc's
TIC
C 4629
34/7 – 8, DST 1A
B
SCAN
TIME
IKU
SINTEF-GRUPPEN

C4629ARO #1-2250 2-JUL-86 09:51 12250 acnt:IKU System:AROMATICS IHP

Chromatogram Identifiers : B1:TIC B: 25711000

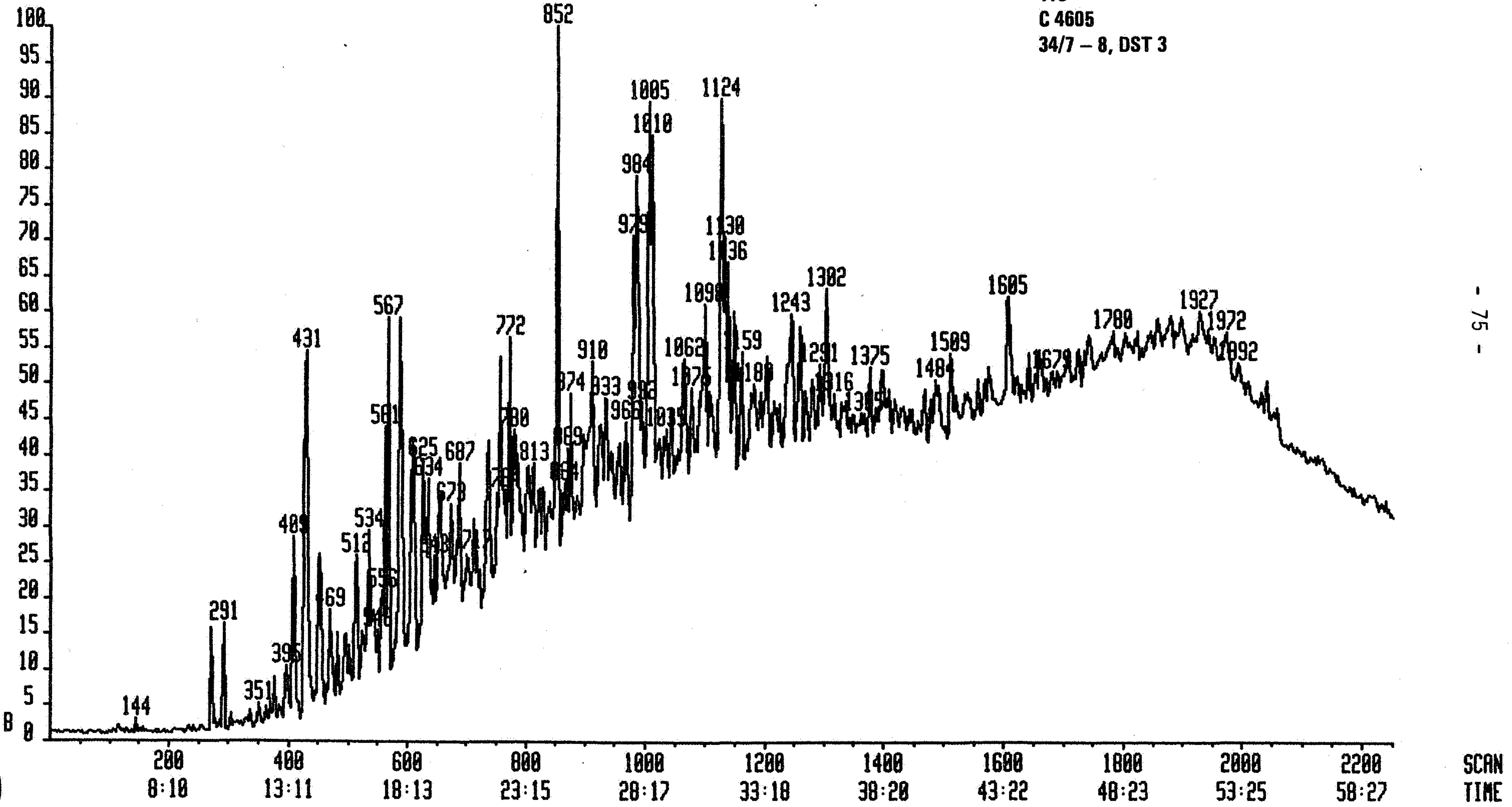
Text:22.0043.02

Aromatic hc's
TIC
C 4604
34/7 – 8, DST 2



C4607ARO #1-2250 1-JUL-86 16:10 12250 acnt:IKU System:AROMATICS IHP
Chromatogram Identifiers : B1:TIC B: 12761000
Text:22.8043.02

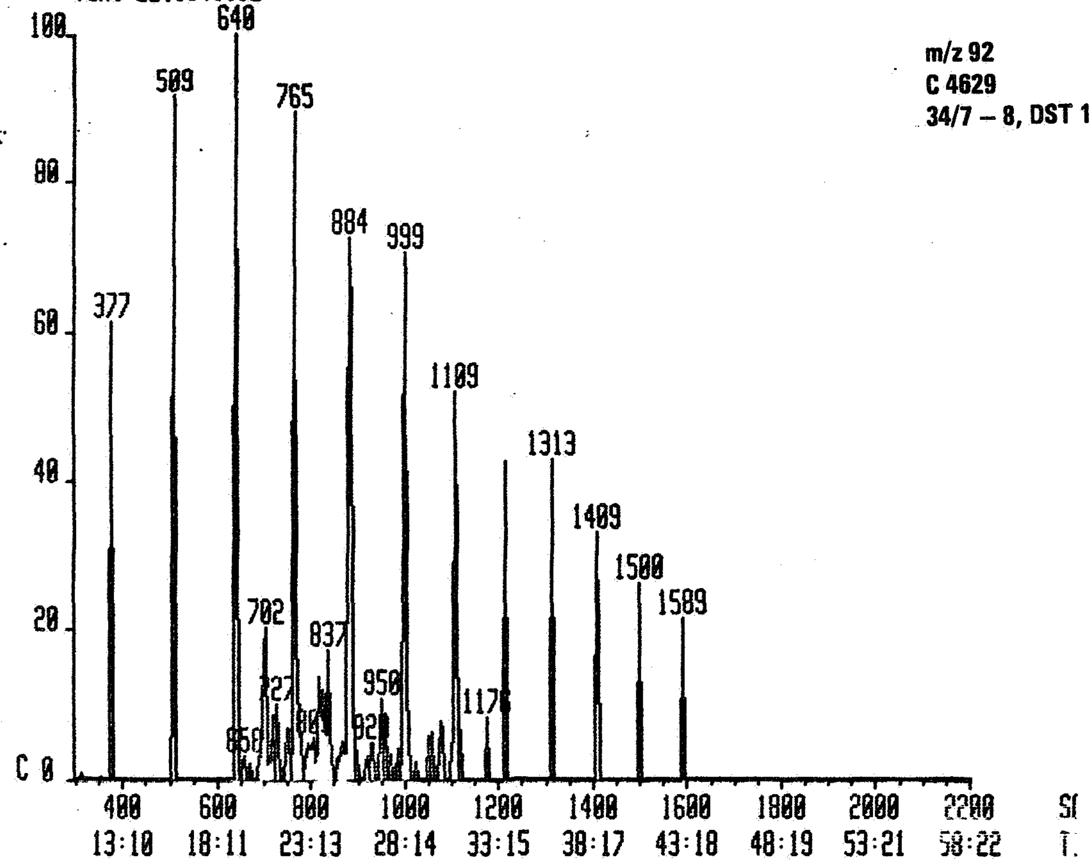
Aromatic hc's
TIC
C 4605
34/7 – 8, DST 3



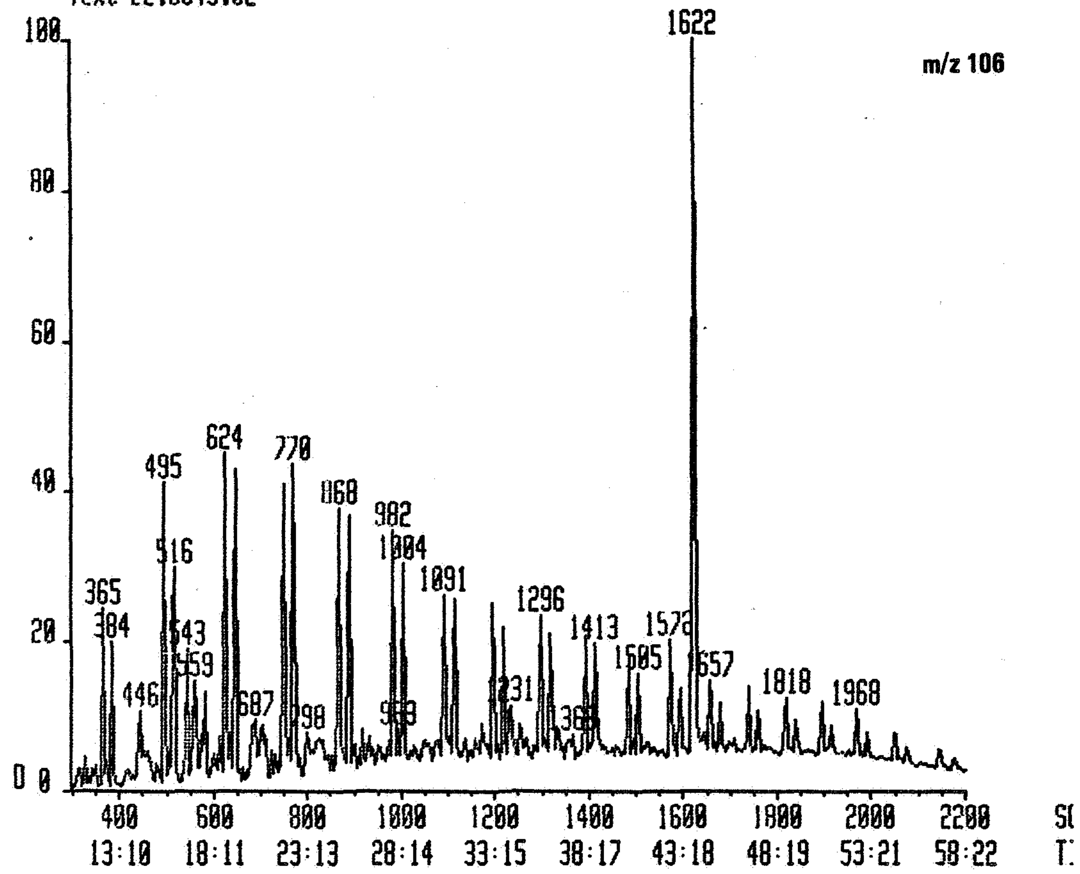
IKU SINTEF-GRUPPEN

IKU
SINTEF-GRUPPEN

C4629ARO #300-2200 2-JUL-86 09:51 12250 acnt:IKU SystemPAROMATICS
Chromatogram Identifiers : C1:92 C: 2092000
Text:22.8043.02

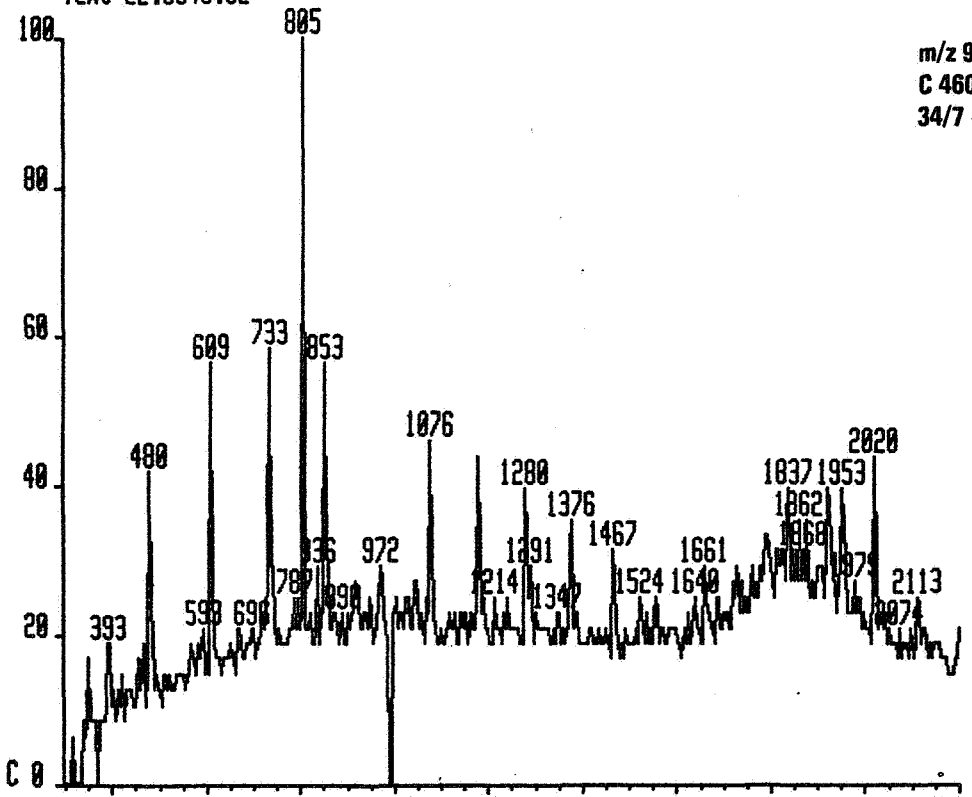


C4629ARO #300-2200 2-JUL-86 09:51 12250 acnt:IKU SystemPAROMA
Chromatogram Identifiers : D1:106 D: 2
Text:22.8043.02



IKU
SINTEF-GRUPPEN

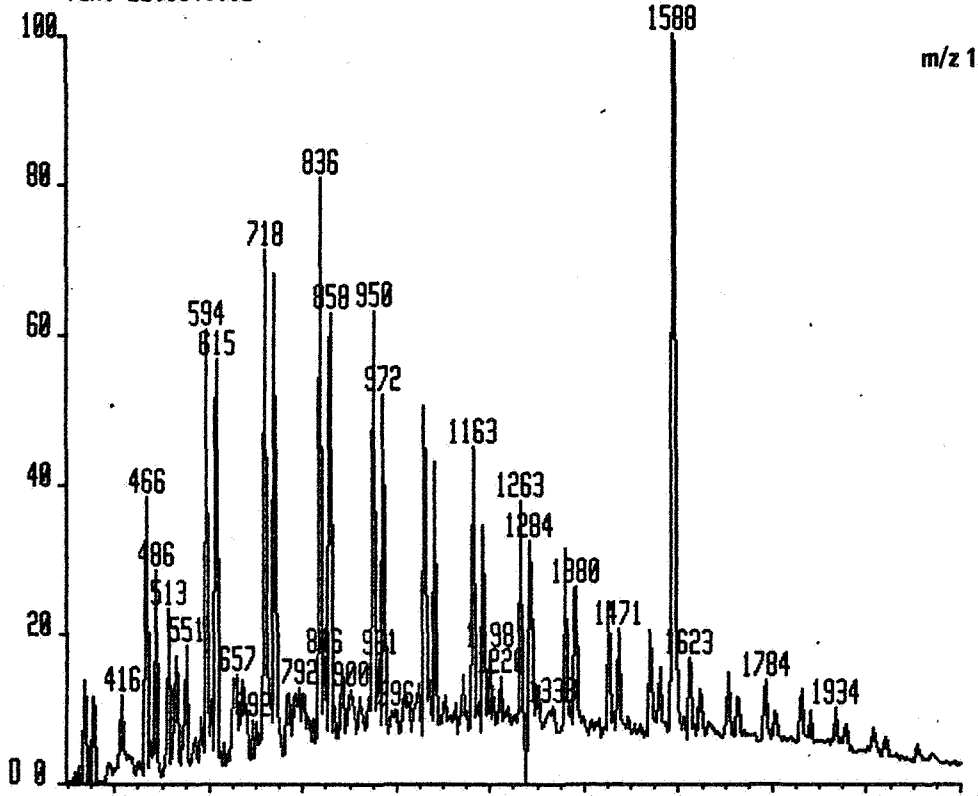
C4604ARO #300-2200 1-JUL-86 10:52 12250 acnt:IKU Syst@WPAROMATICS
Chromatogram Identifiers : C1:92 C: 40000
Text:22.8043.02



m/z 92
C 4604
34/7 – 8, DST 2

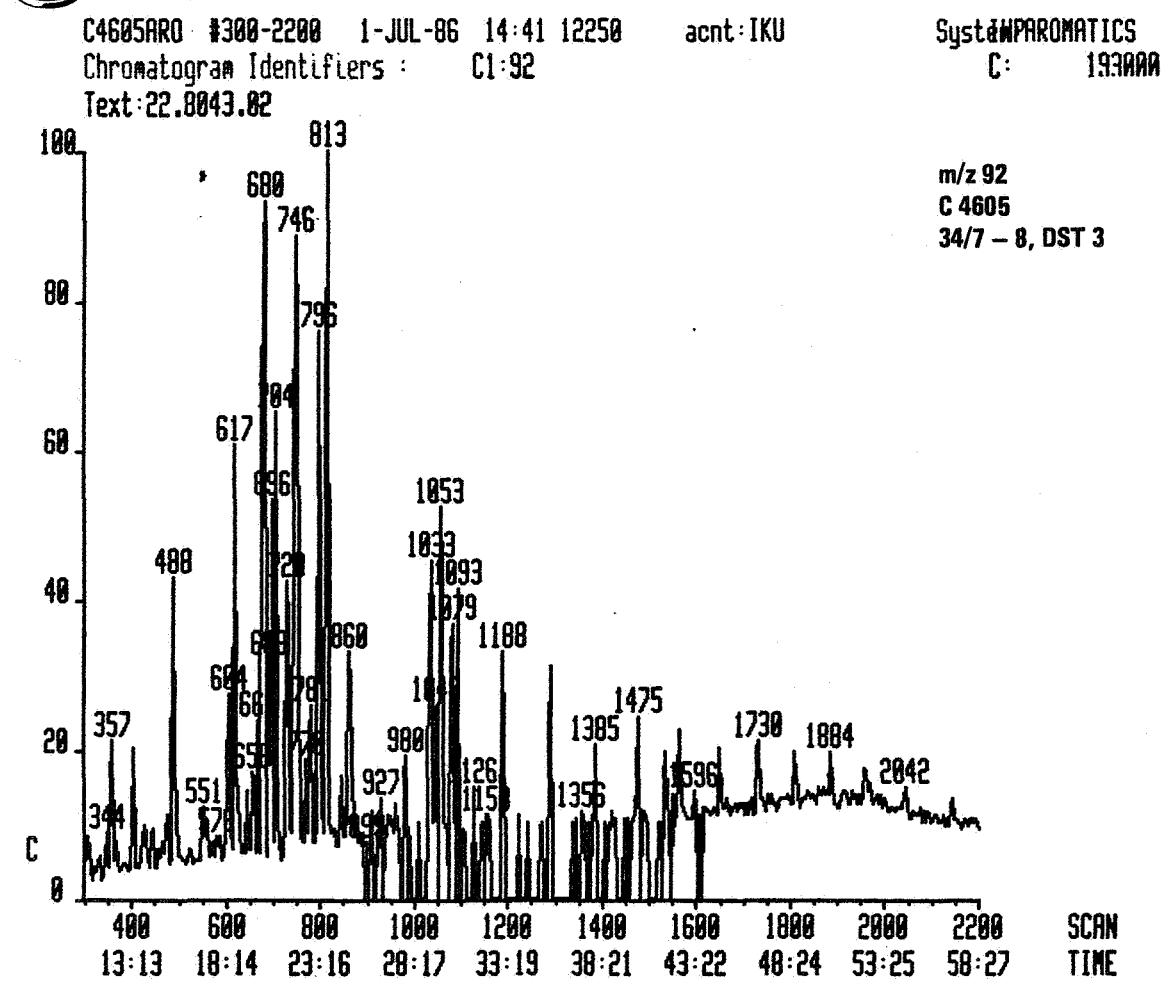
400 600 800 1000 1200 1400 1600 1800 2000 2200 SCAN
13:00 18:09 23:11 28:12 33:13 38:15 43:16 48:17 53:18 58:20 TIME

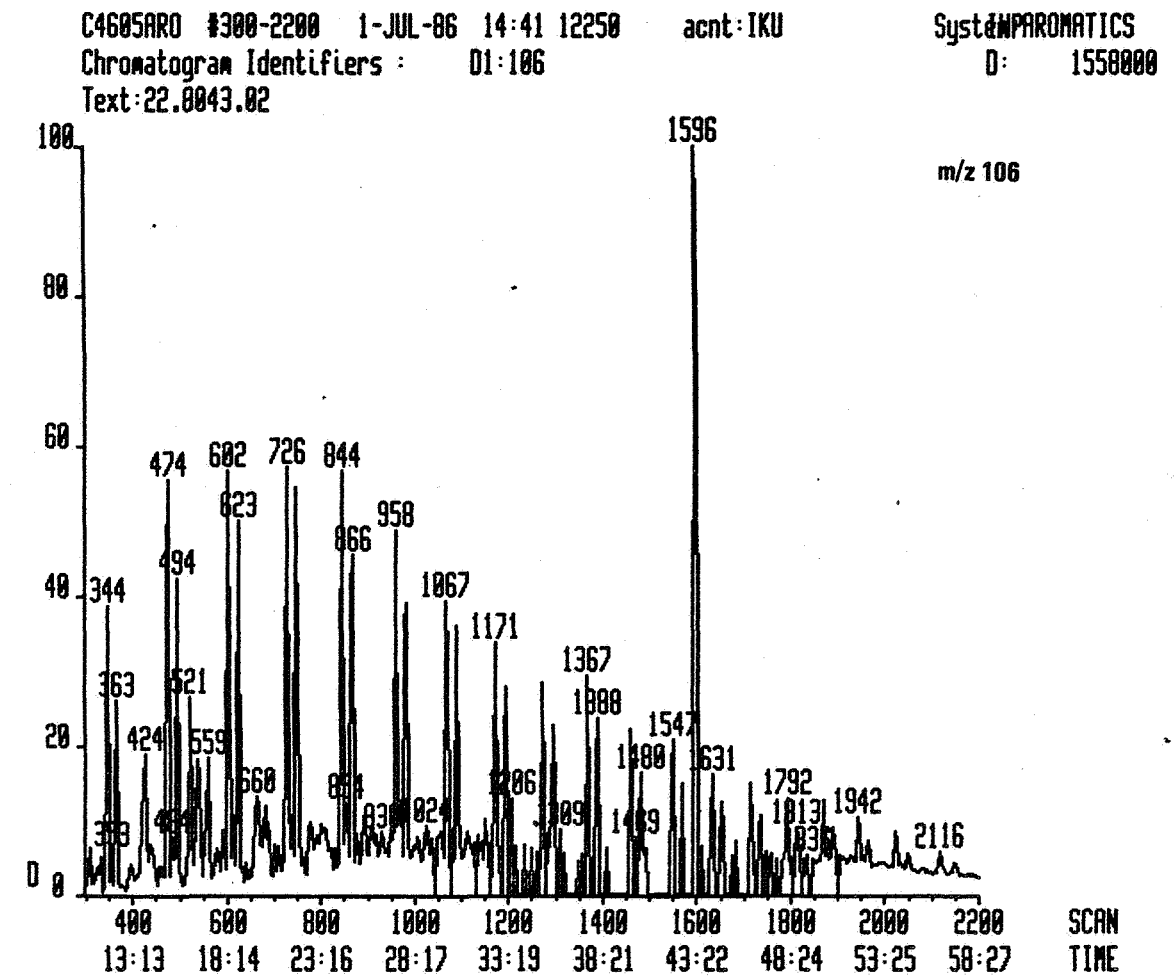
C4604ARO #300-2200 1-JUL-86 10:52 12250 acnt:IKU Syst@WPAROMATICS
Chromatogram Identifiers : D1:106 D: 371000
Text:22.8043.02



m/z 106

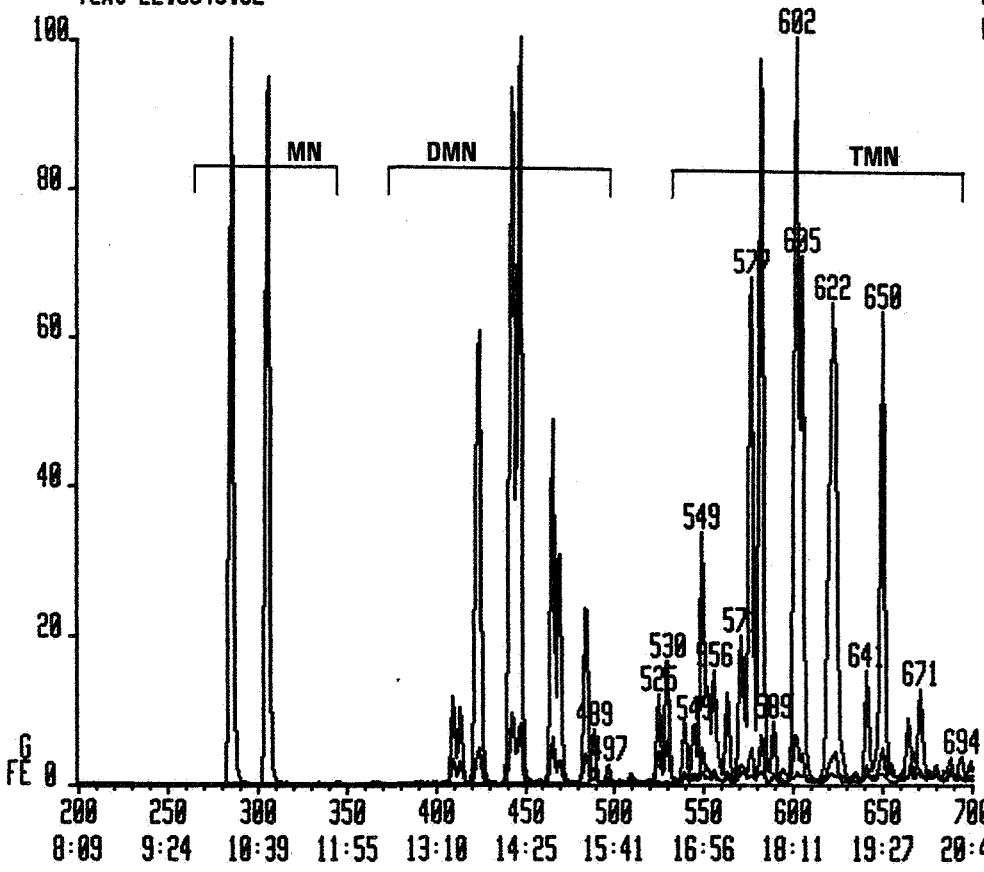
400 600 800 1000 1200 1400 1600 1800 2000 2200 SCAN
13:00 18:09 23:11 28:12 33:13 38:15 43:16 48:17 53:18 58:20 TIME


C4605ARO #300-2200 1-JUL-86 14:41 12250 acnt:IKU
Chromatogram Identifiers : C1:92
Text:22.0043.02
m/z 92
C 4605
34/7 – 8, DST 3
C
SCAN
TIME


C4605ARO #300-2200 1-JUL-86 14:41 12250 acnt:IKU
Chromatogram Identifiers : D1:106
Text:22.0043.02
m/z 106
D
SCAN
TIME

IKU
SINTEF-GRUPPEN

C4629ARO #200-700 2-JUL-86 09:51 12250 acnt:IKU Syst#WPAROMATICS
Chromatogram Identifiers : E1:142 F1:156 G1:170
Text:22.8043.02
E: 5859000
F: 5881000
G: 2757000



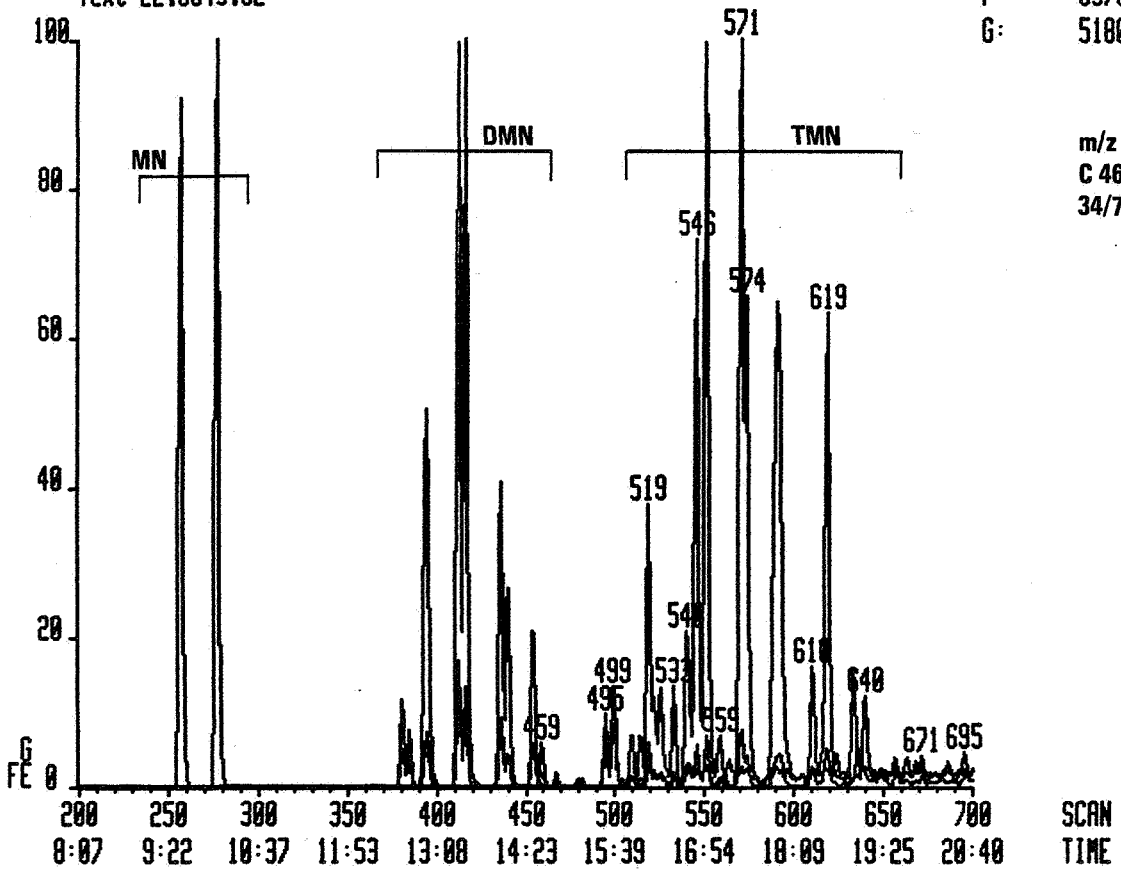
m/z 142, 156, 170
C 4629
34/7 – 8, DST 1A

IKU SINTEF-GRUPPEN

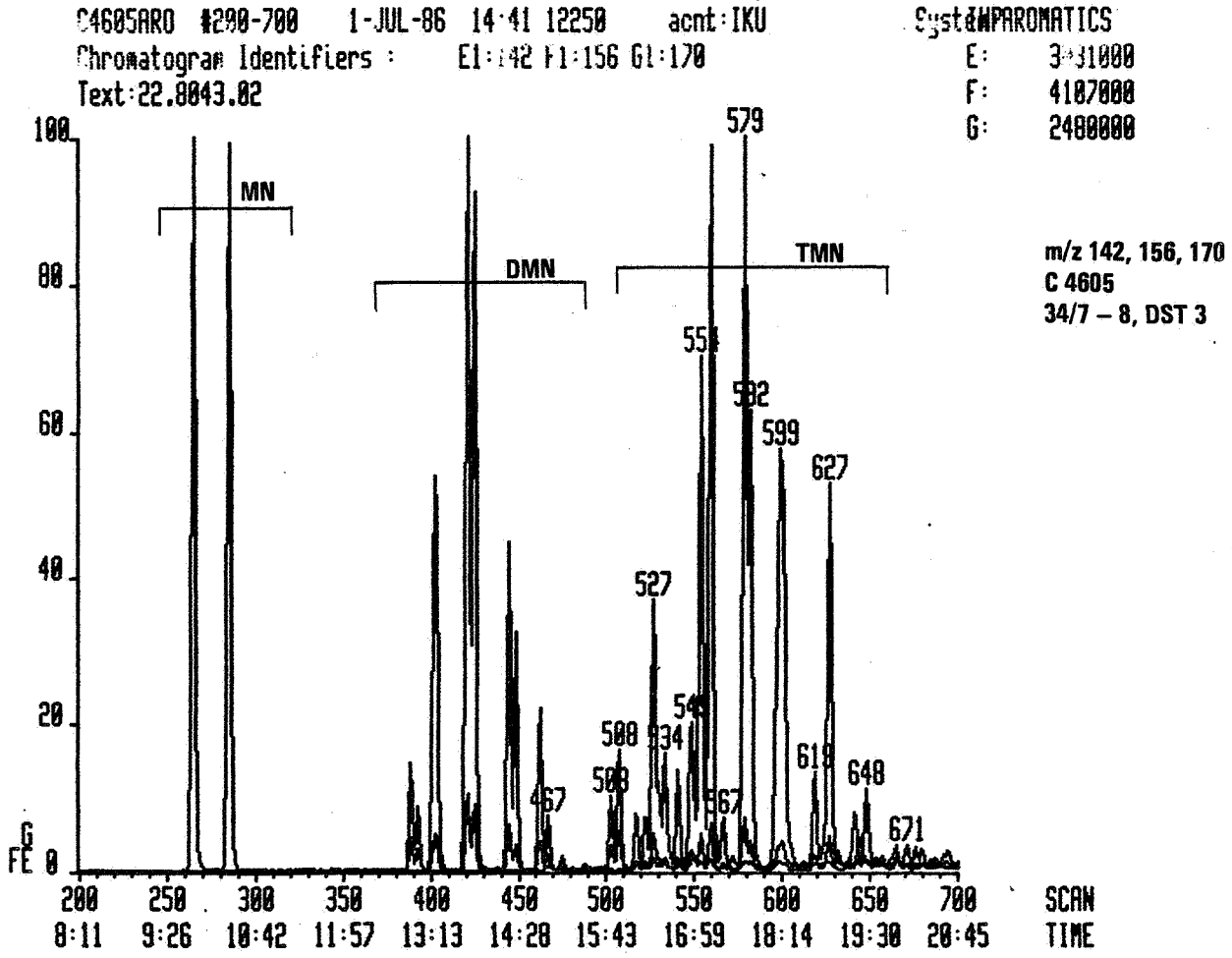
C4604ARO #200-700 1-JUL-86 10:52 12250 acnt:IKU
Chromatogram Identifiers : E1:142 F1:156 G1:170
Text:22.0043.02

Syst&NPAROMATICS
E: 397000
F: 837000
G: 518000

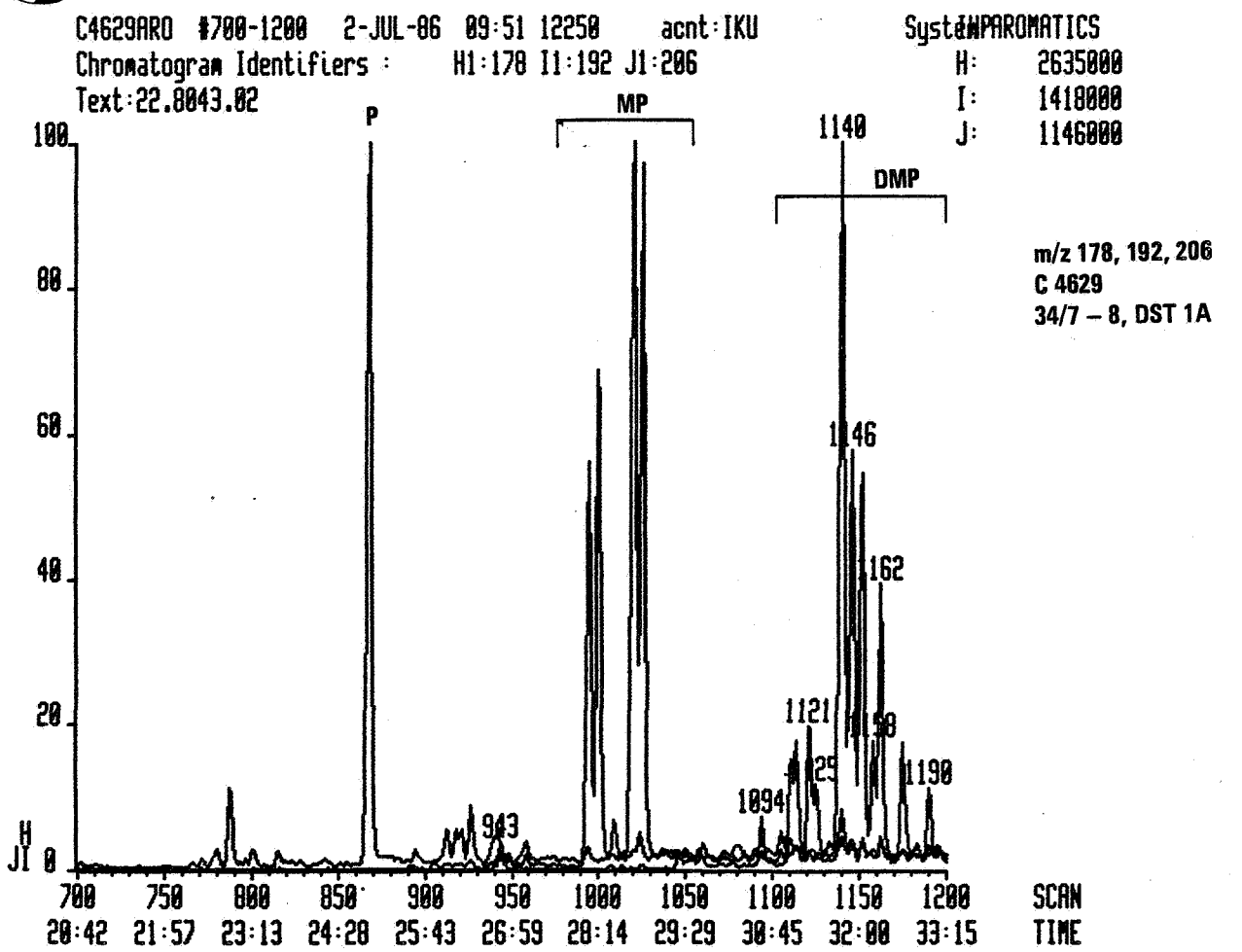
m/z 142, 156, 170
C 4604
34/7 – 8, DST 2



IKU
SINTEF-GRUPPEN

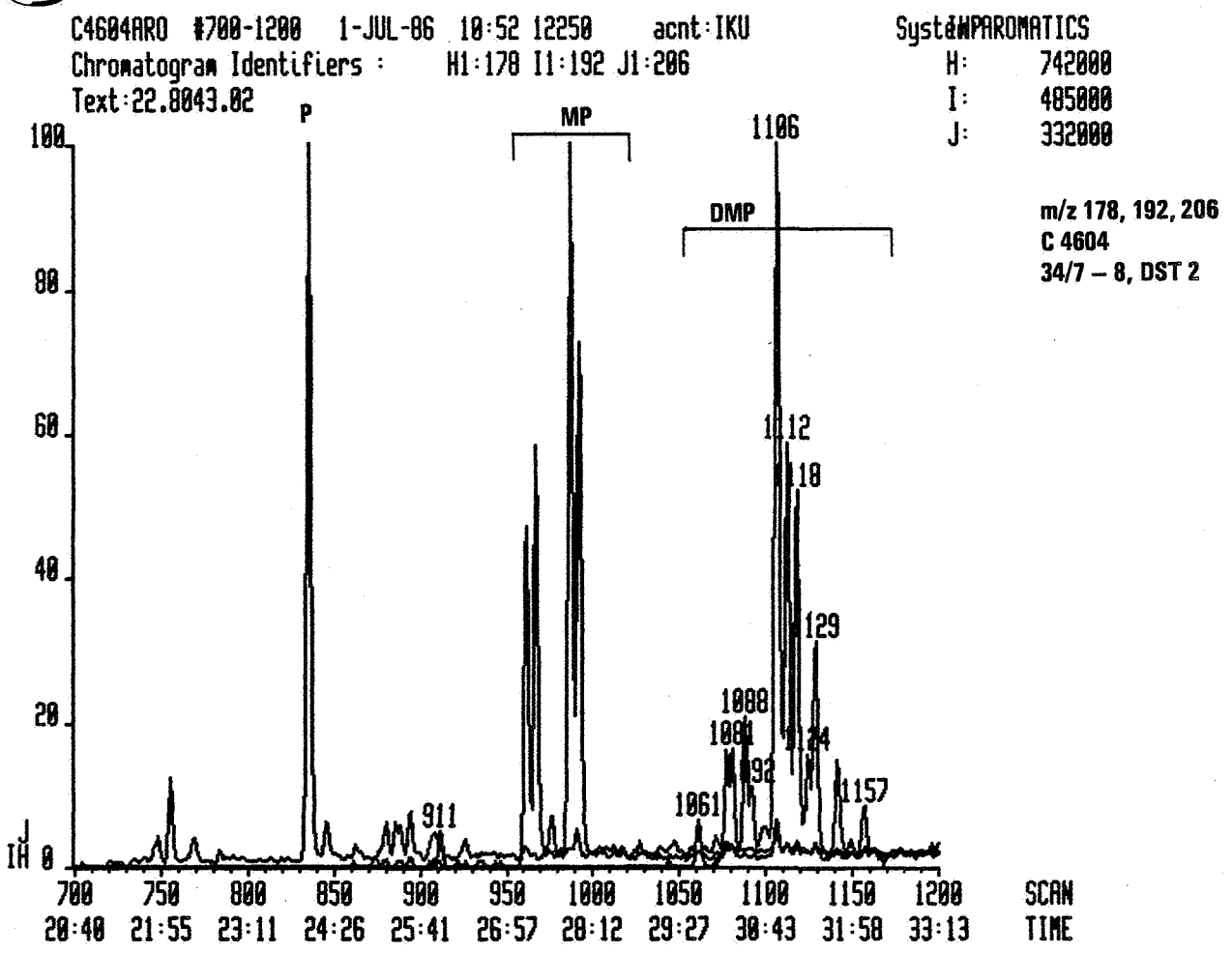


IKU
SINTEF-GRUPPEN

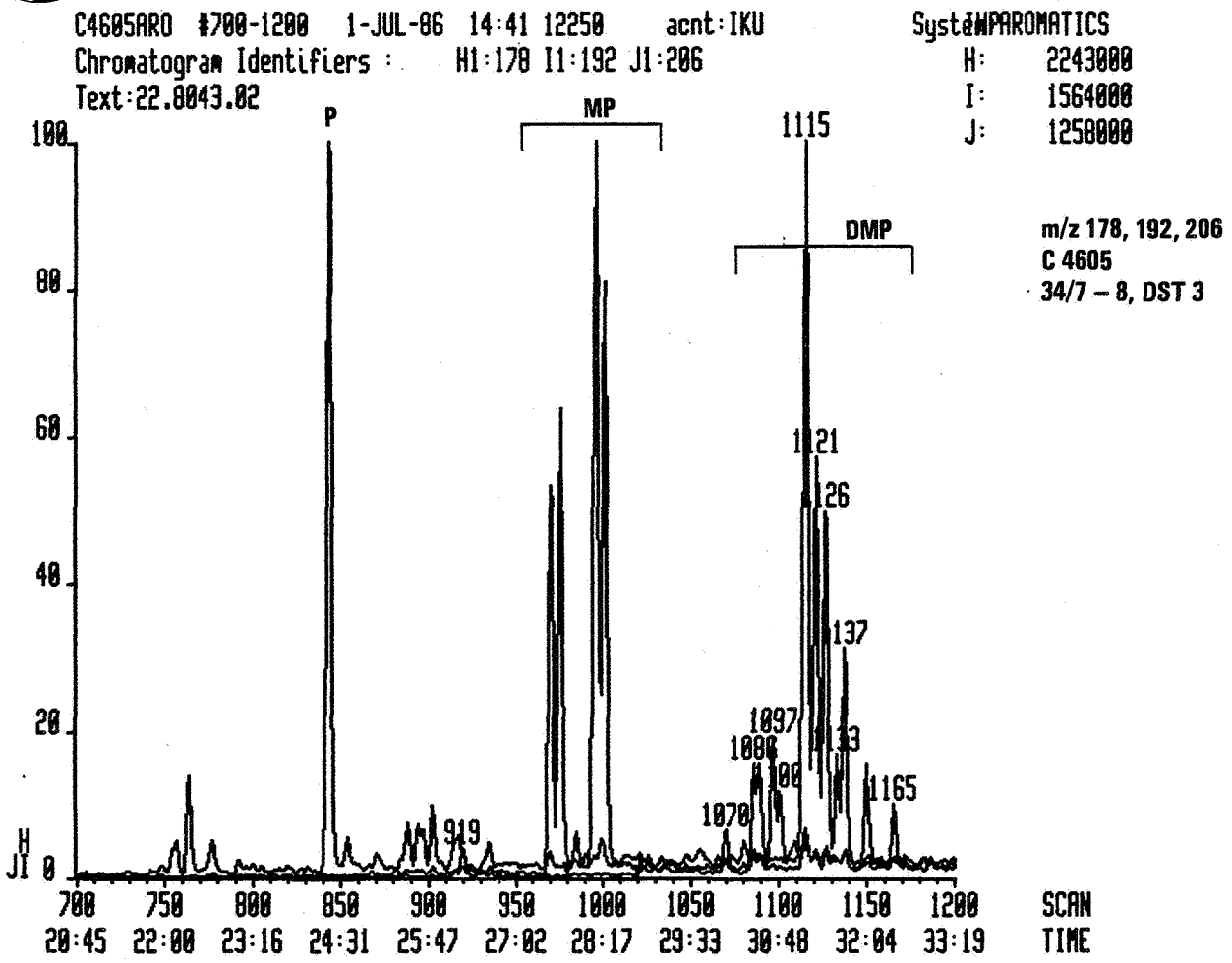


m/z 178, 192, 206
C 4629
34/7 – 8, DST 1A

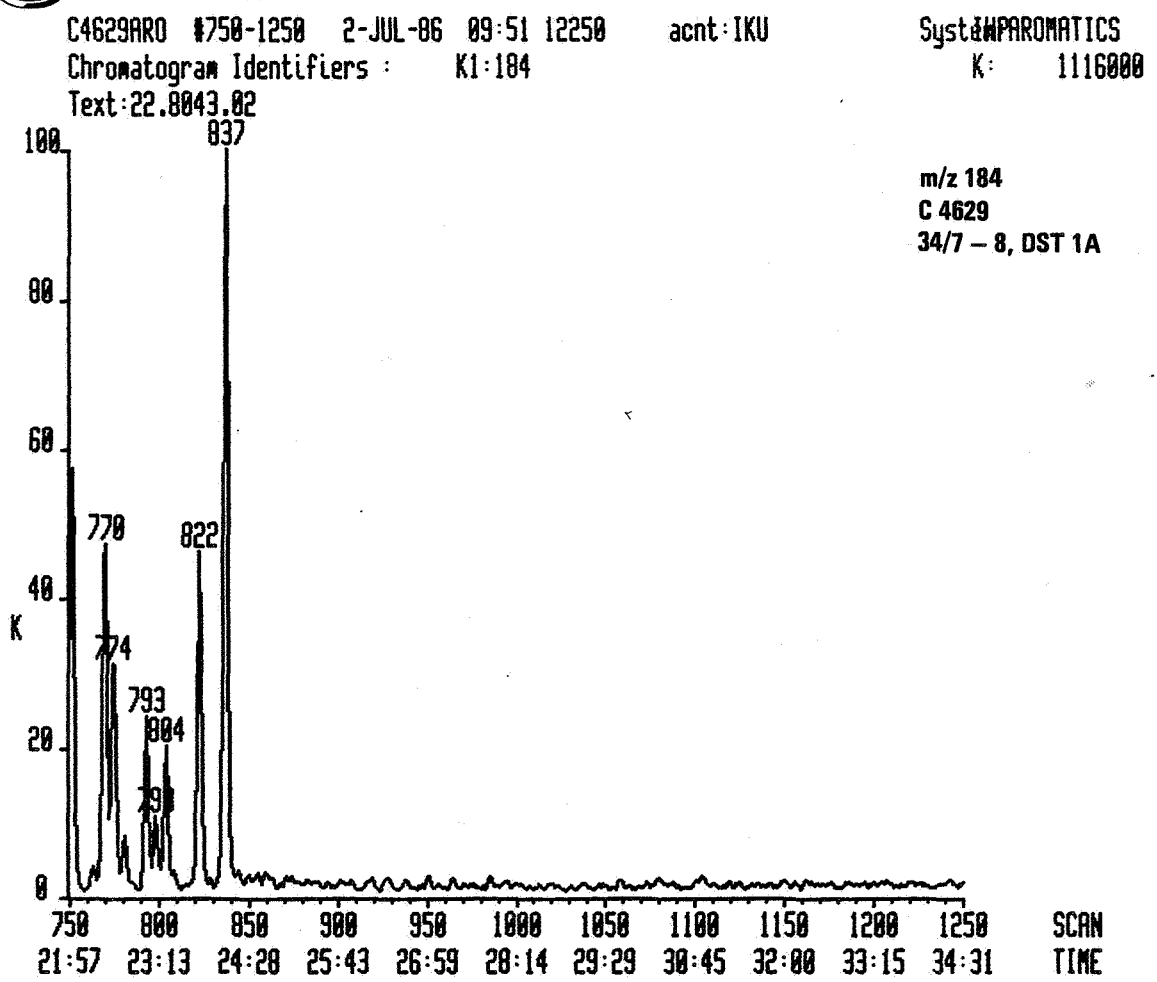
IKU
SINTEF-GRUPPEN

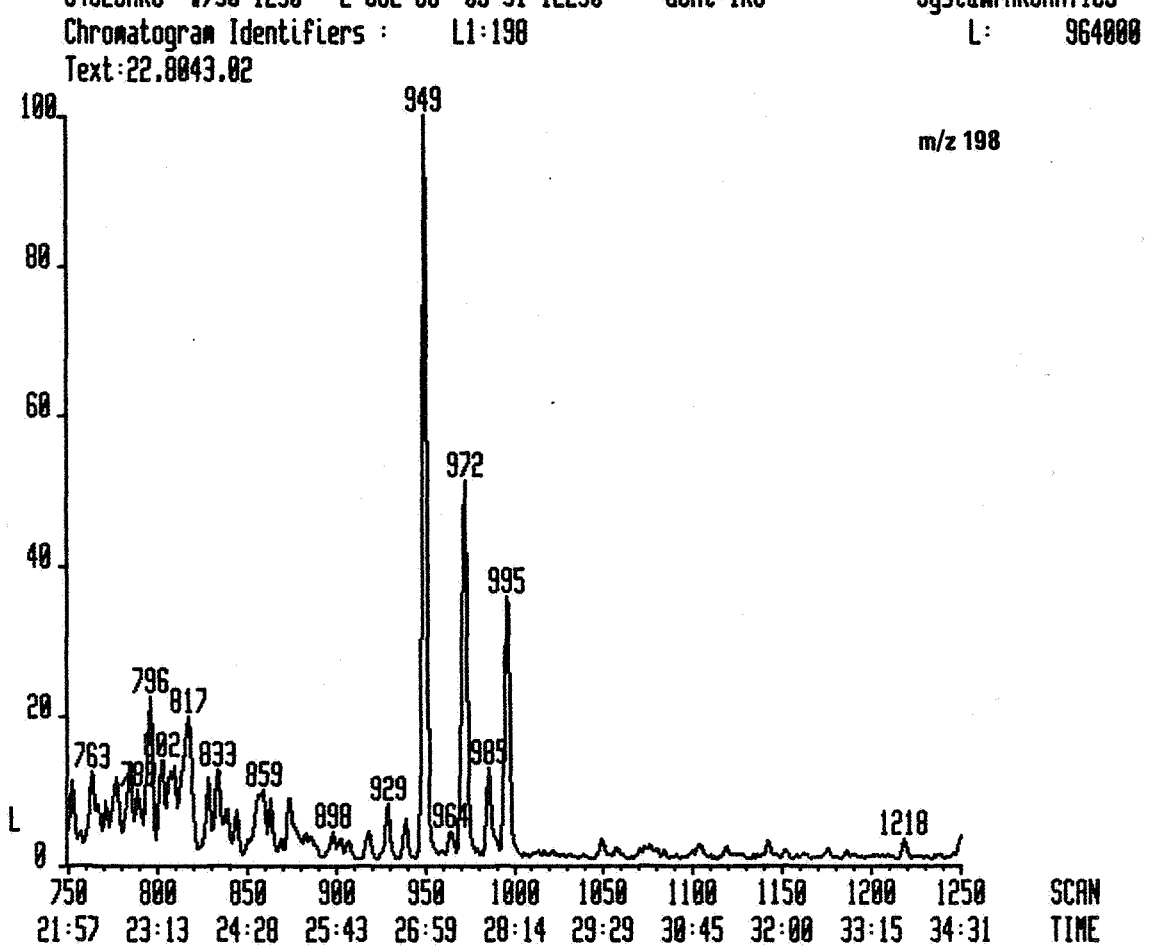


IKU
SINTEF-GRUPPEN

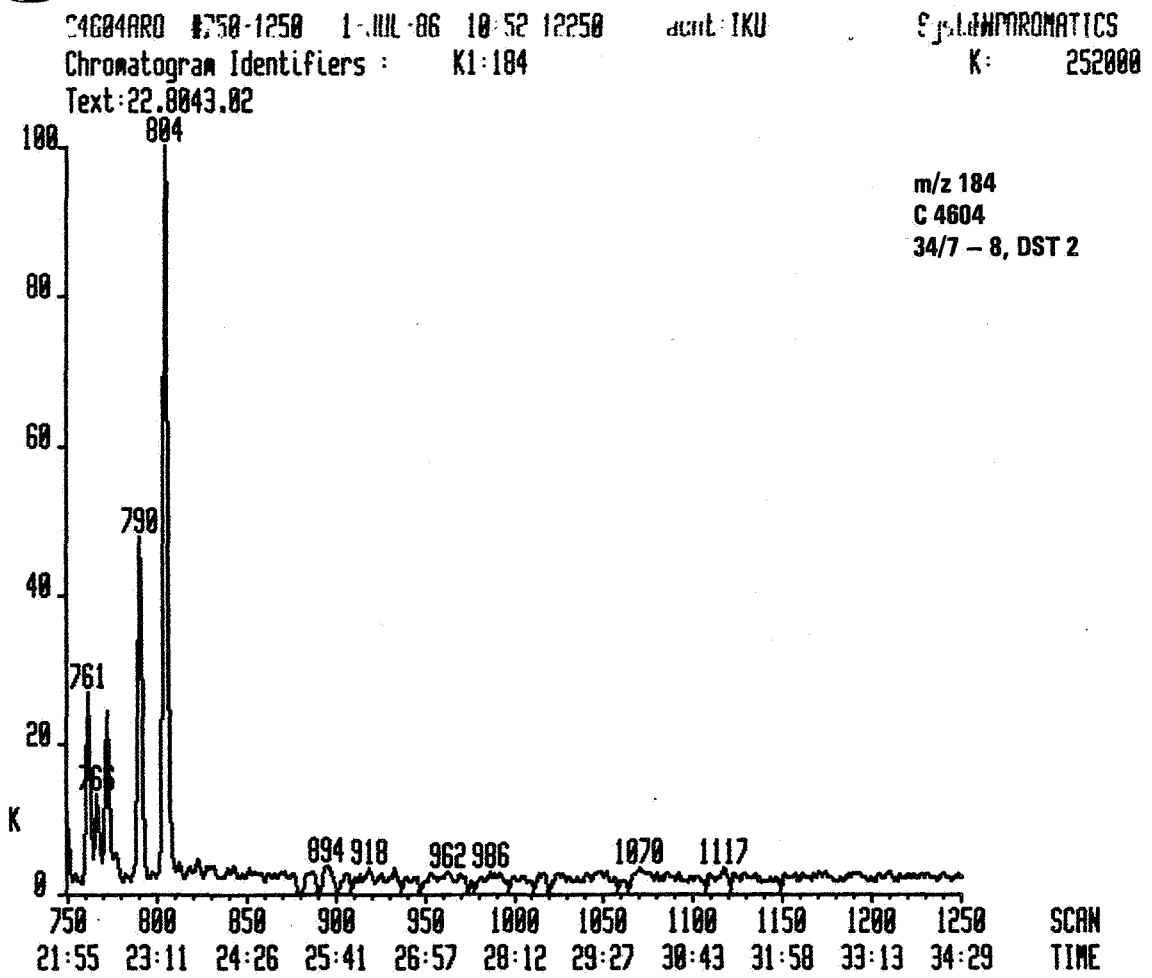


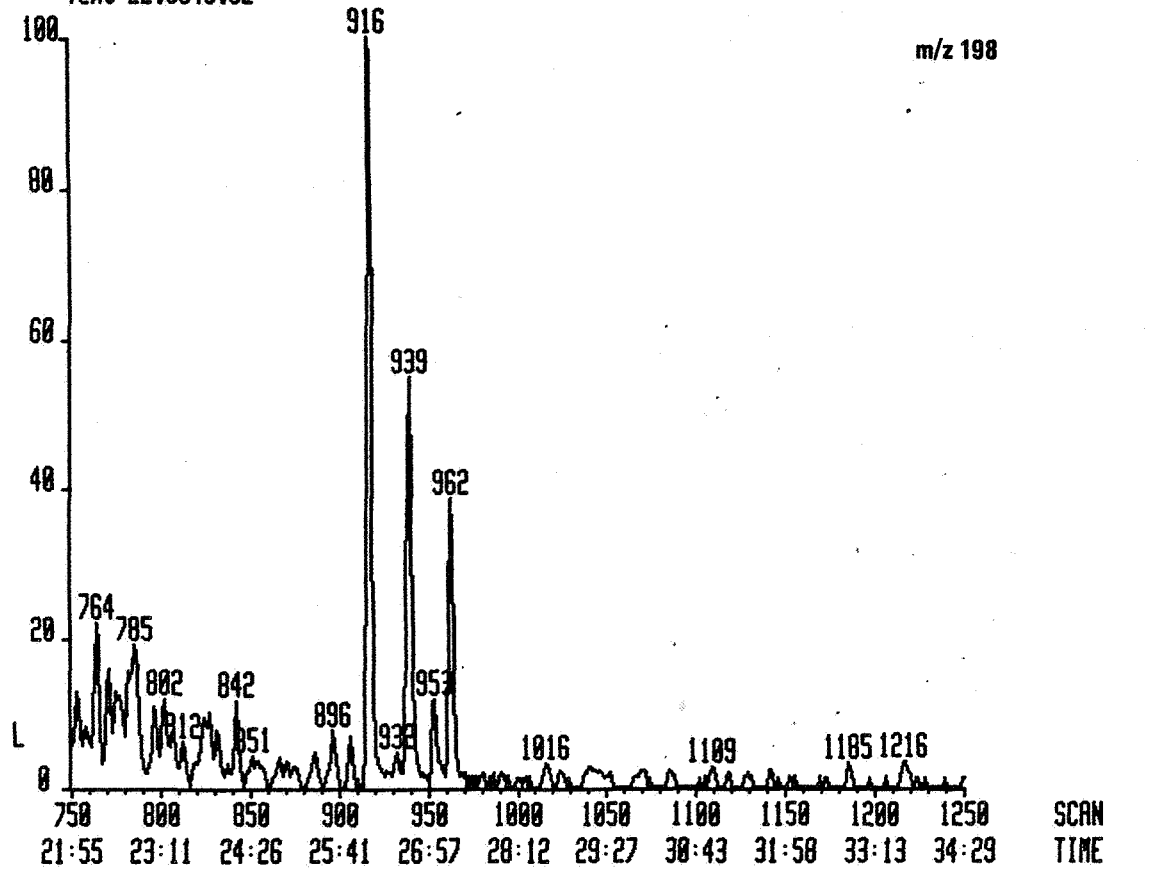
IKU
SINTEF-GRUPPEN



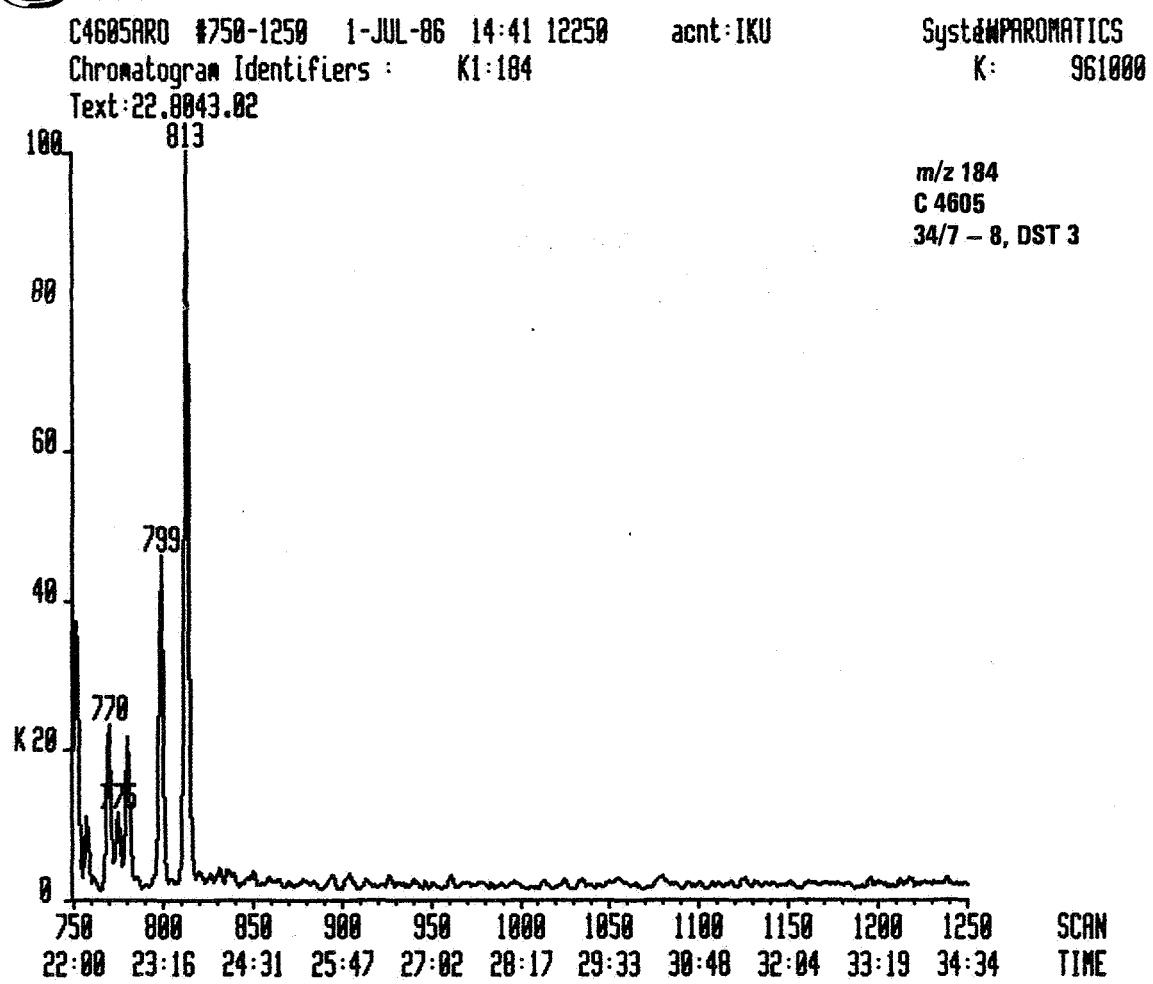


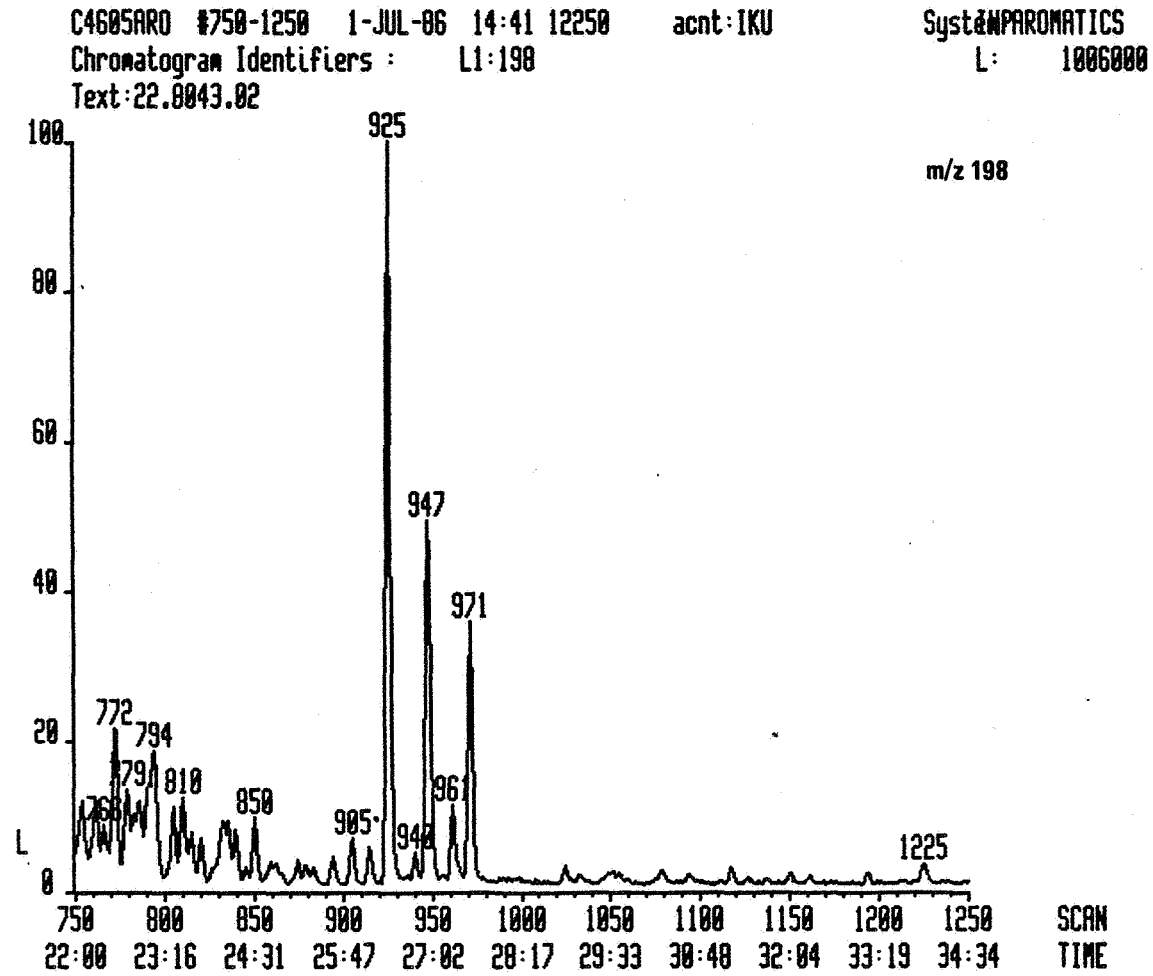
IKU
SINTEF-GRUPPEN





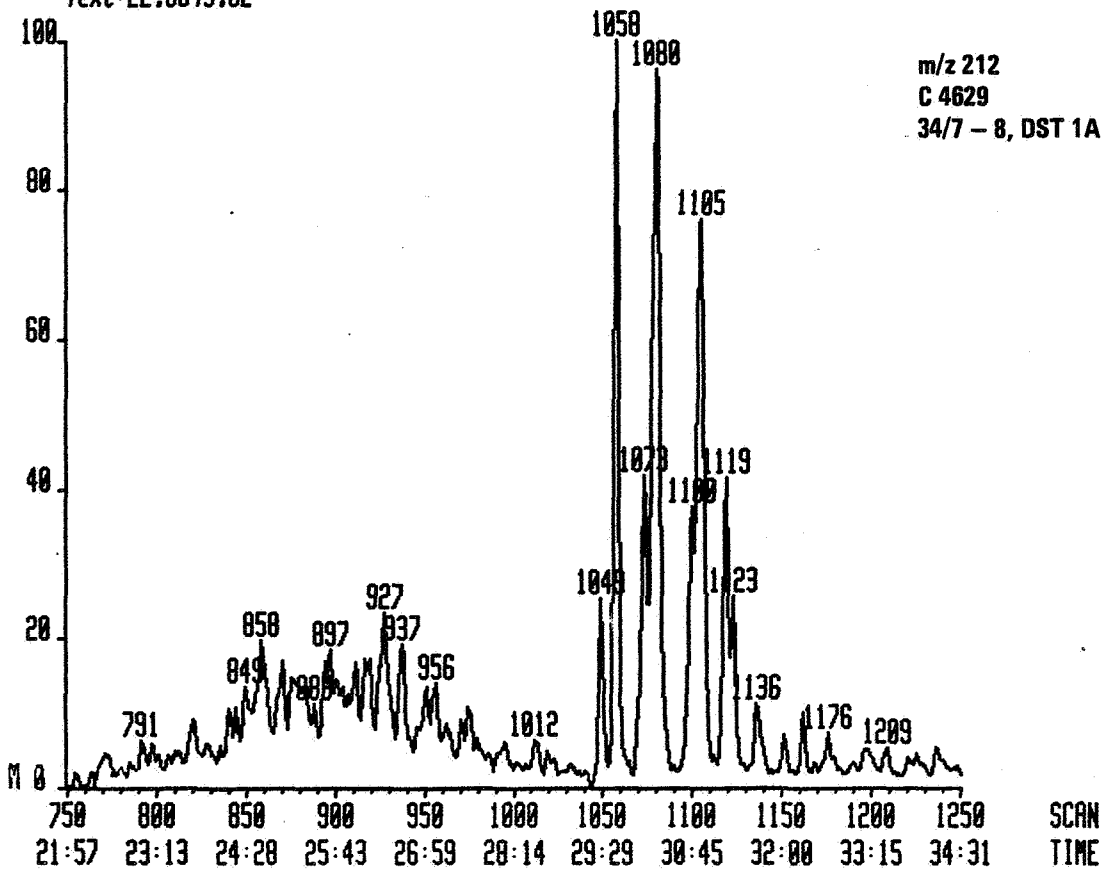
IKU
SINTEF-GRUPPEN





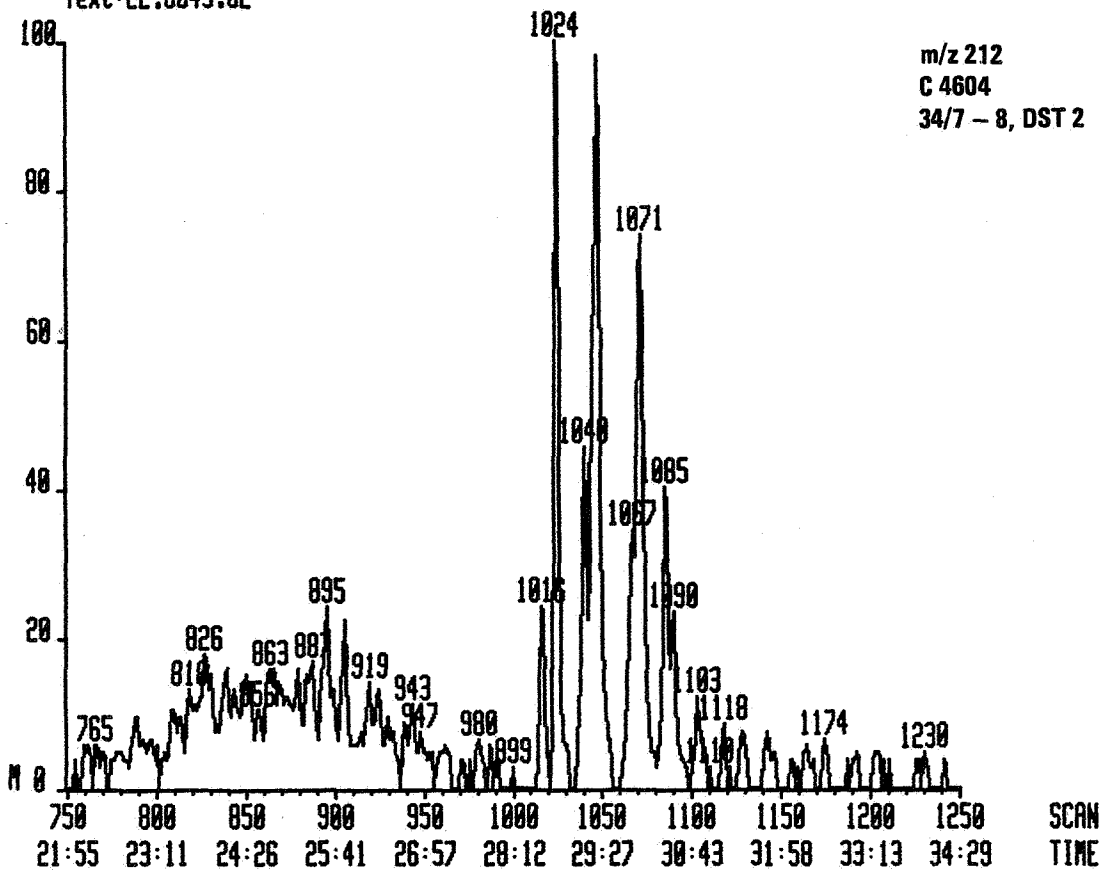
IKU
SINTEF-GRUPPEN

C4629ARO #750-1250 2-JUL-86 09:51 12250 acnt:IKU Syst#AROMATICS
Chromatogram Identifiers : M1:212 M: 409000
Text:22.8043.02



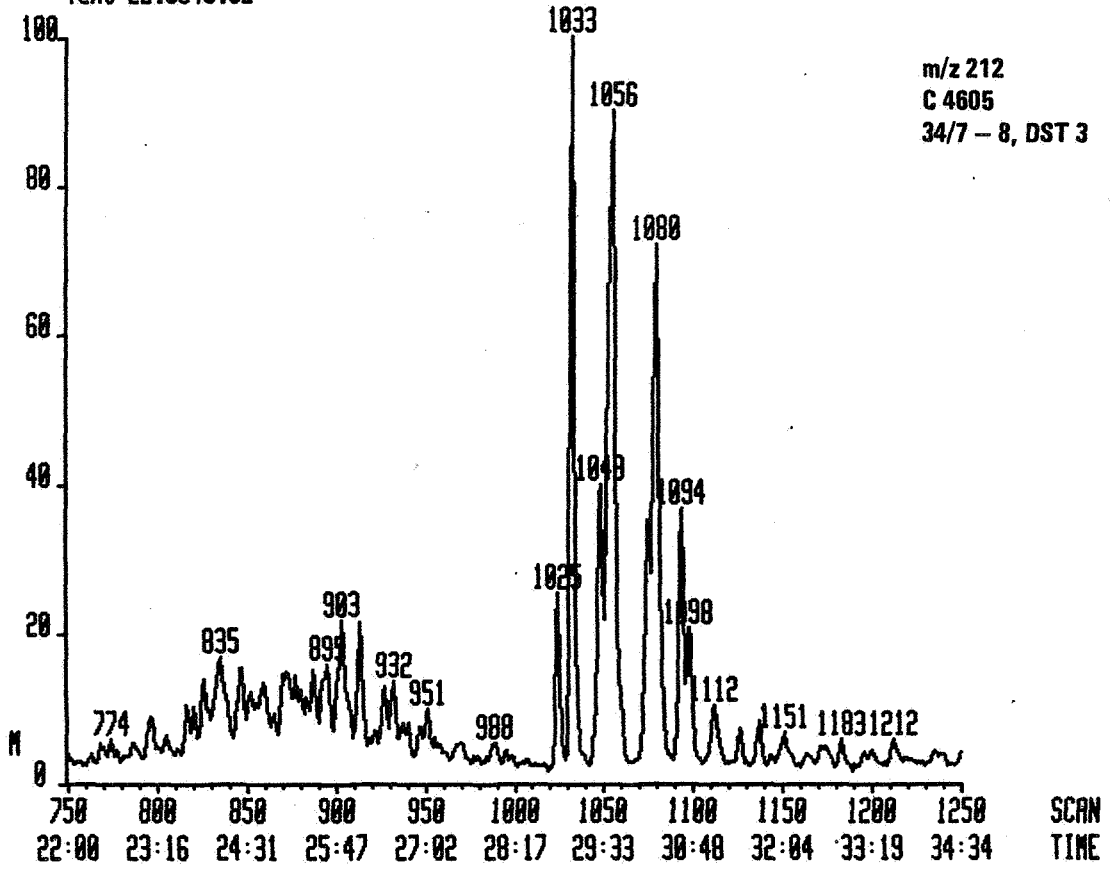
IKU SINTEF-GRUPPEN

C4604ARO #750-1250 1-JUL-86 10:52 12250 acnt:IKU Syst&MPAROMATICS
Chromatogram Identifiers : M1:212 M: 107000
Text:22.8043.82



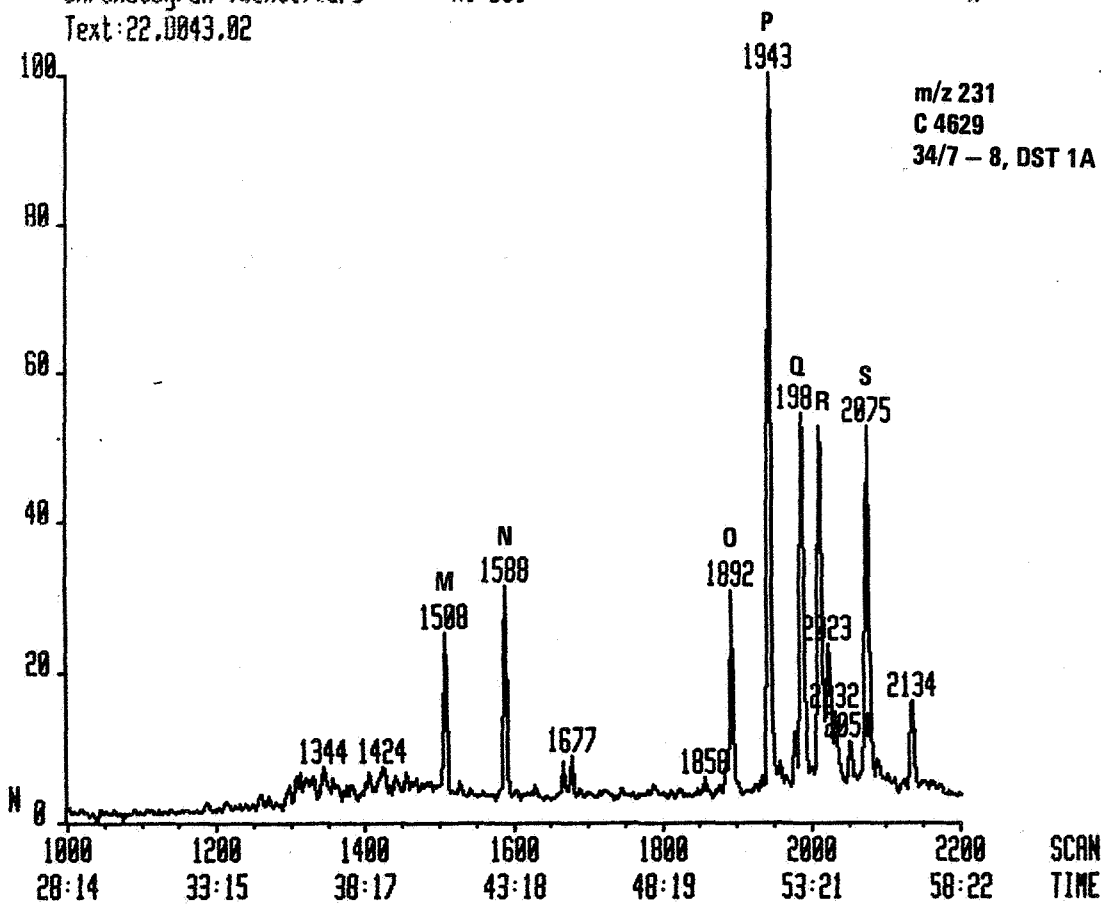
IKU
SINTEF-GRUPPEN

C4605ARO #750-1250 1-JUL-86 14:41 12250 acnt:IKU SystemAROMATICS
Chromatogram Identifiers : M1:212 M: 377000
Text:22.8043.02

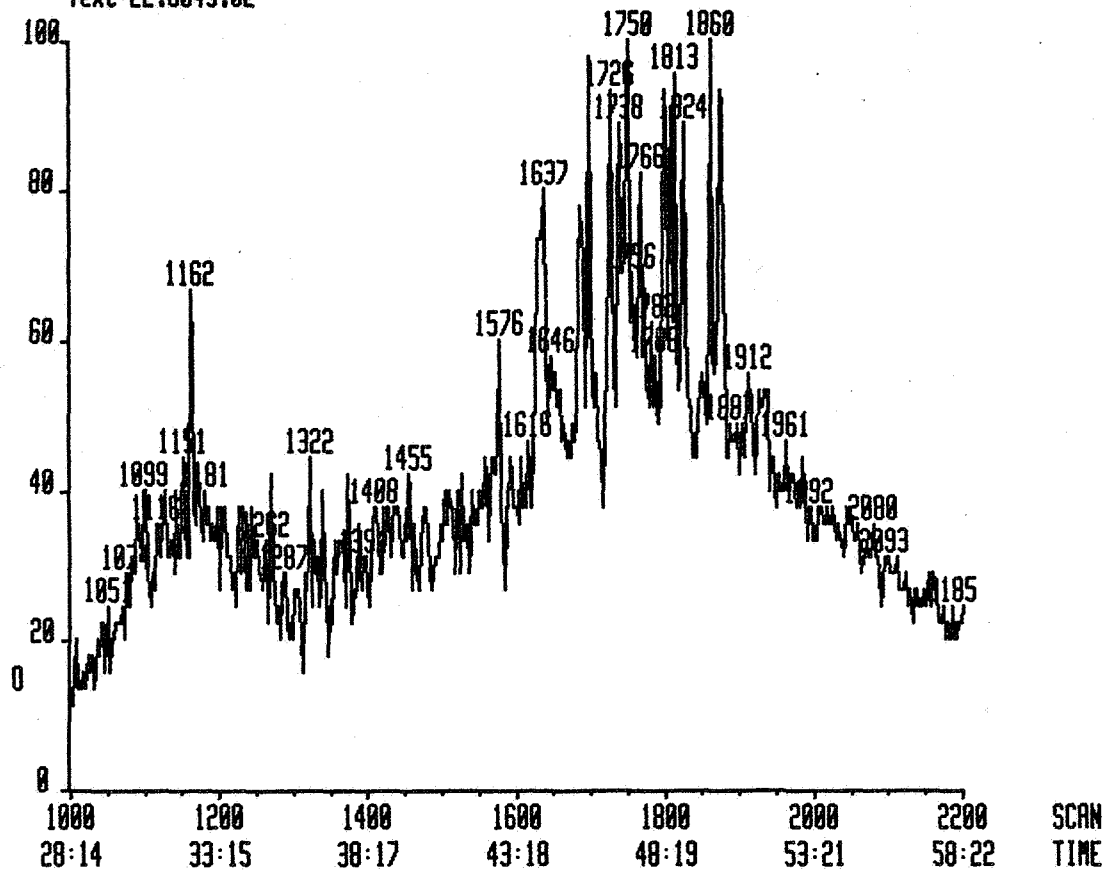


IKU
SINTEF-GRUPPEN

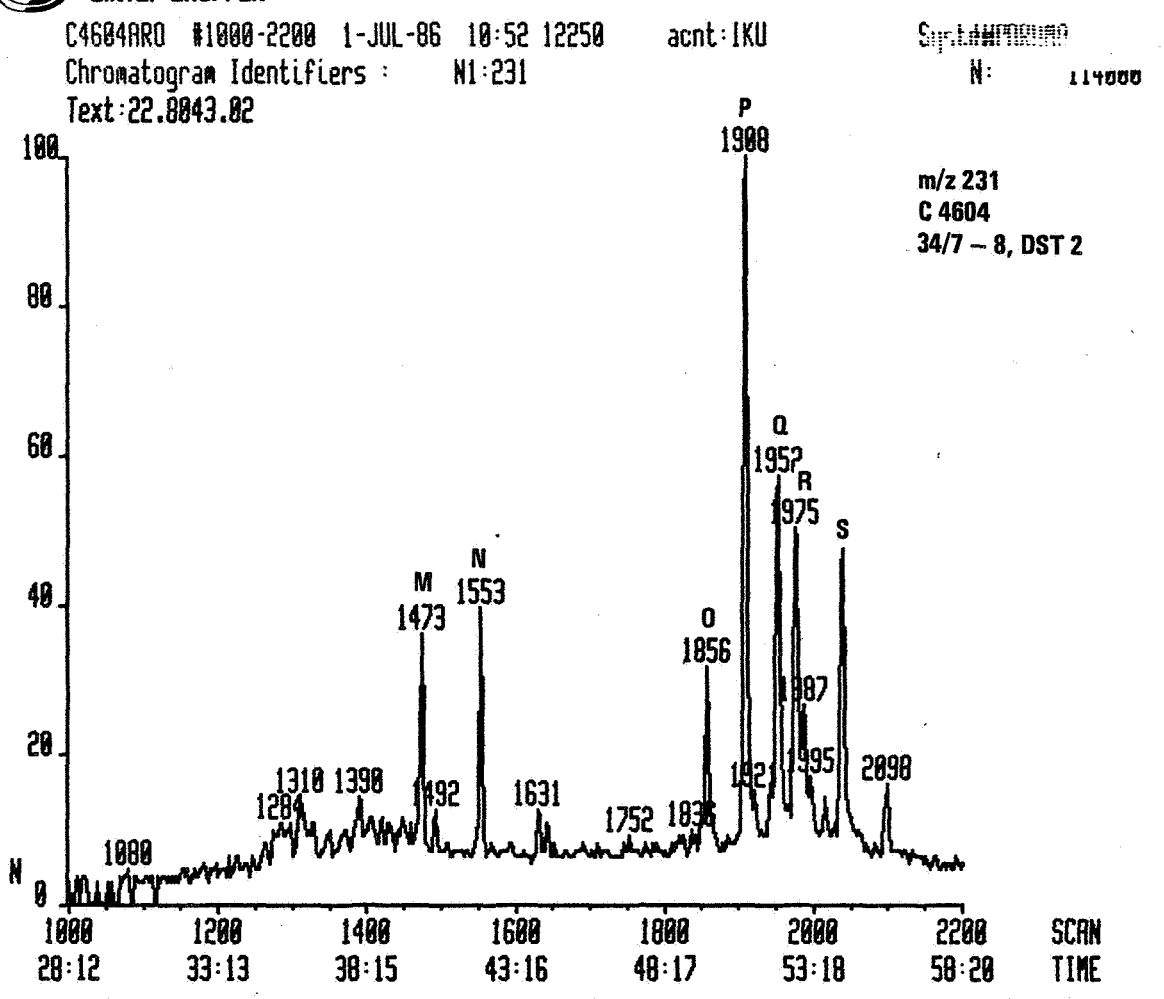
C4629ARO #1000-2200 2-JUL-86 09:51 12250 acnt:IKU Syst#AROMA
Chromatogram Identifiers : N1:231 N:
Text:22.0043.02

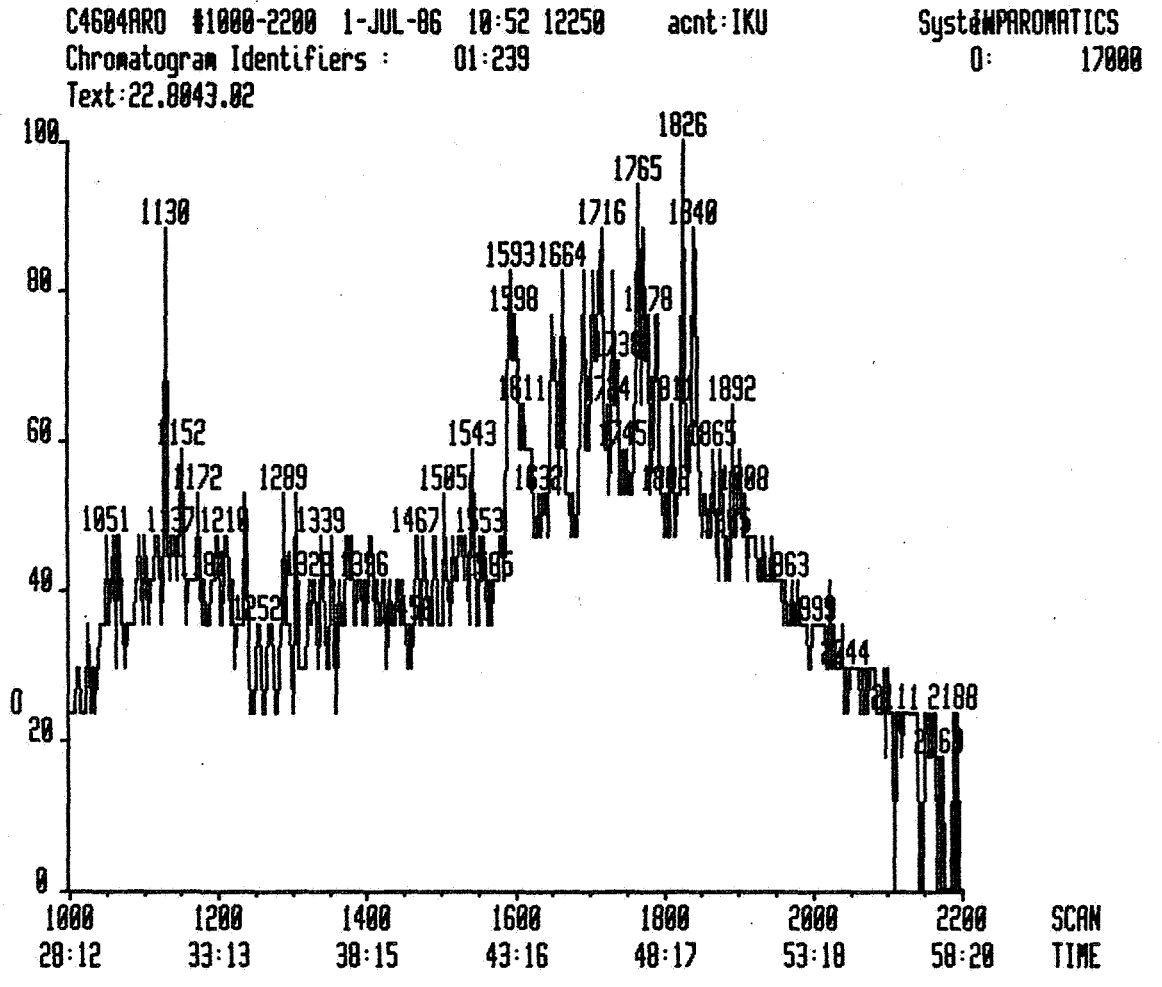


C4629ARO #1000-2200 2-JUL-86 09:51 12250 acnt:IKU Syst#AROMATICS
Chromatogram Identifiers : 01:239 0: 45000
Text:22.0043.02

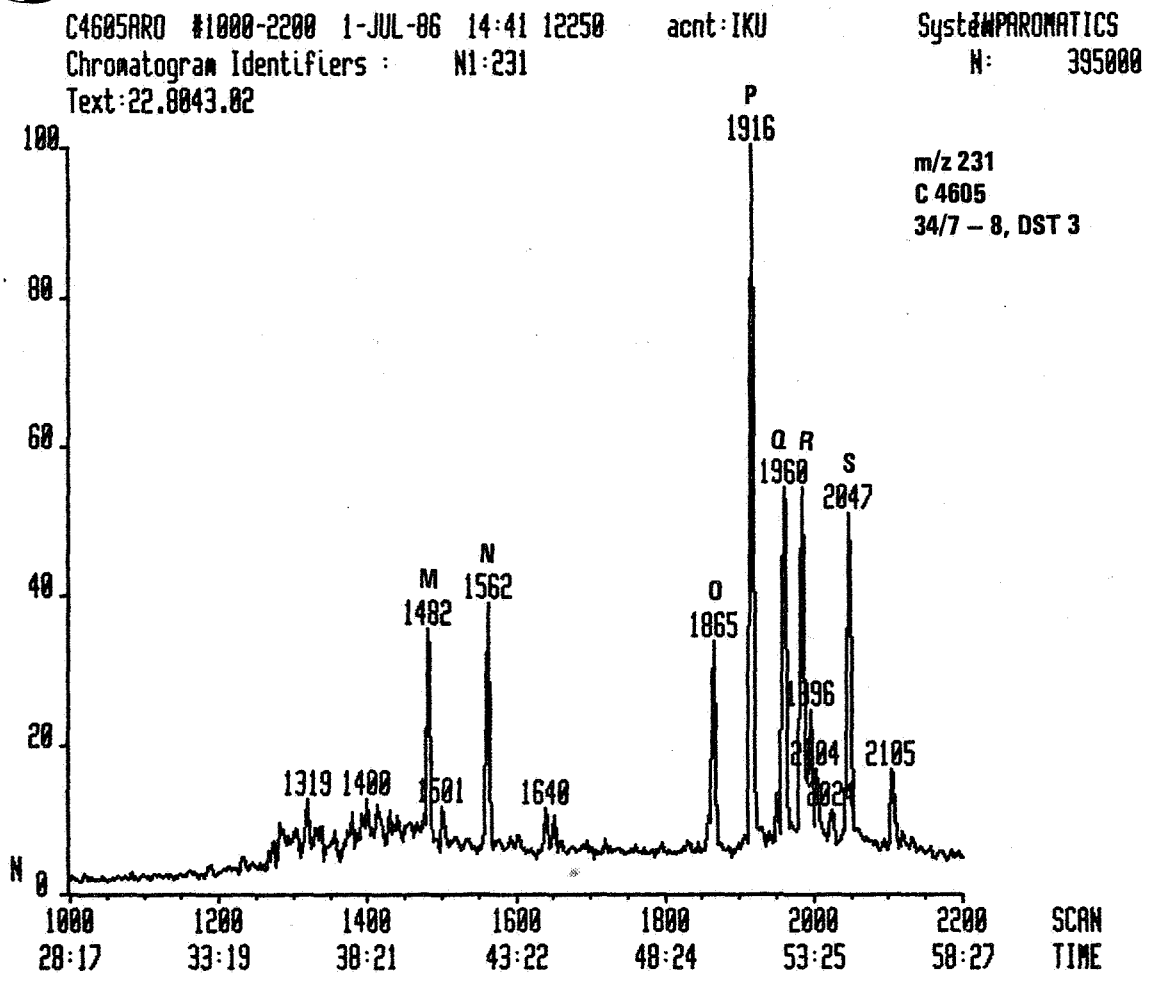


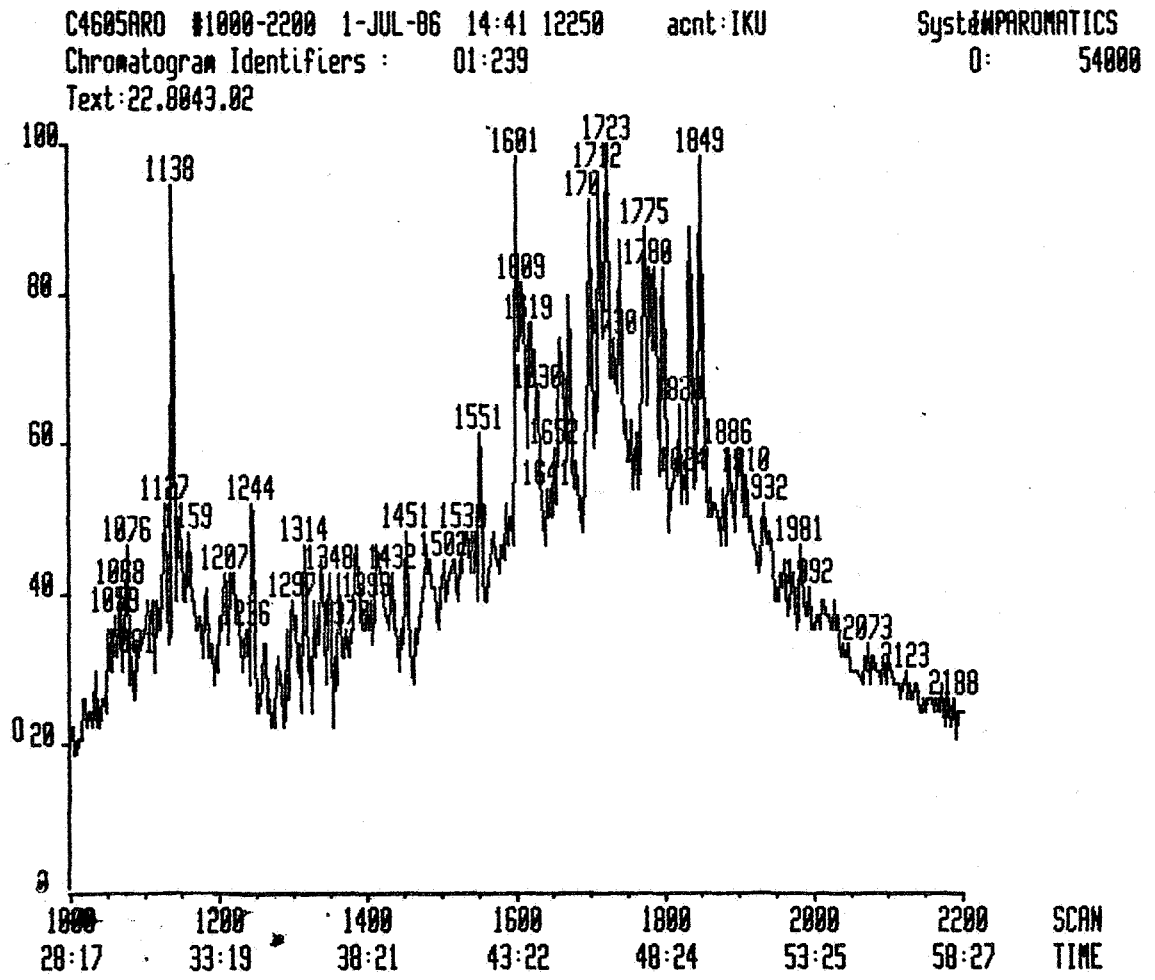
IKU
SINTEF-GRUPPEN





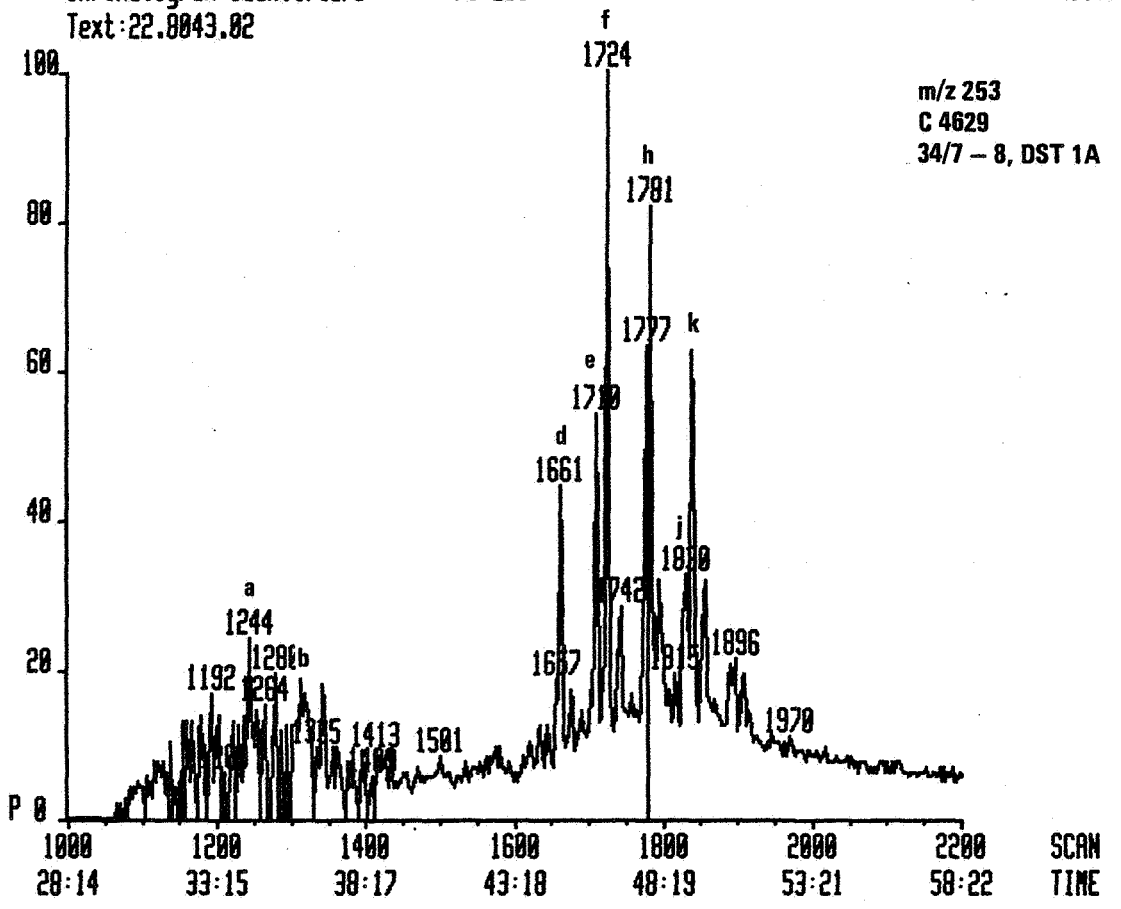
IKU
SINTEF-GRUPPEN



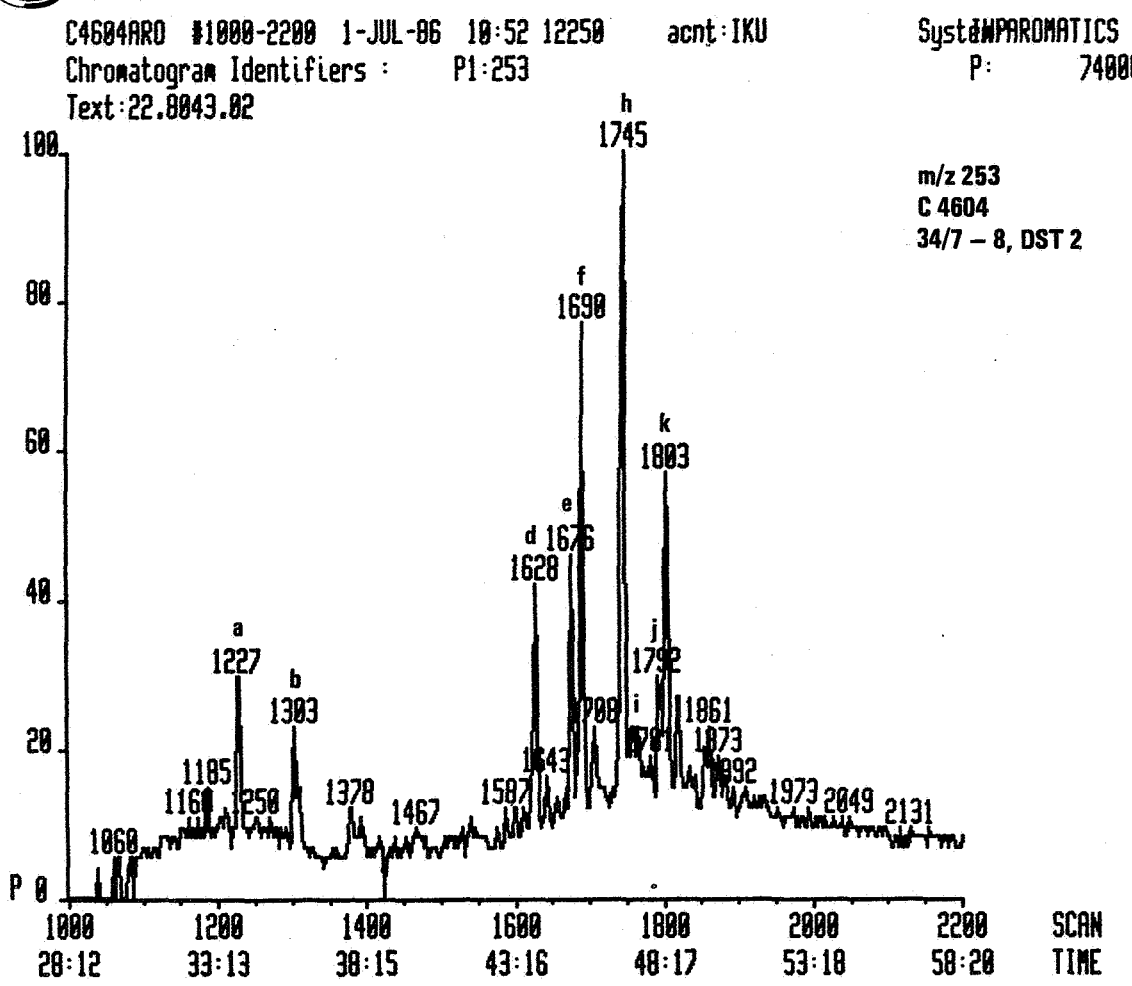


IKU
SINTEF-GRUPPEN

C4629ARO #1000-2200 2-JUL-86 09:51 12250 acnt:IKU Syst&WPAROMATICS
Chromatogram Identifiers : P1:253 P: 144000
Text:22.8043.82

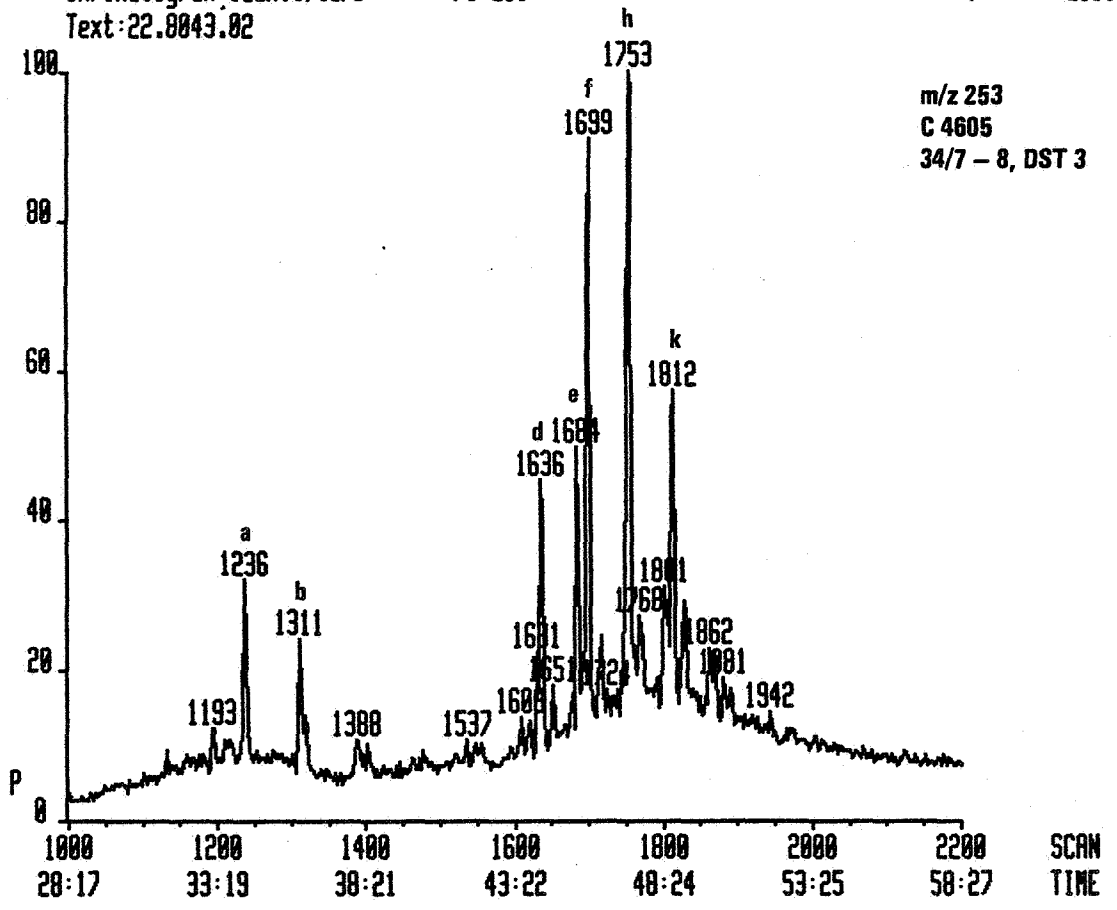


IKU
SINTEF-GRUPPEN



IKU
SINTEF-GRUPPEN

C4605ARO #1000-2200 1-JUL-86 14:41 12250 acnt:IKU Syst#MPAROMATICS
Chromatogram Identifiers : P1:253 P: 200000
Text:22.8043.02



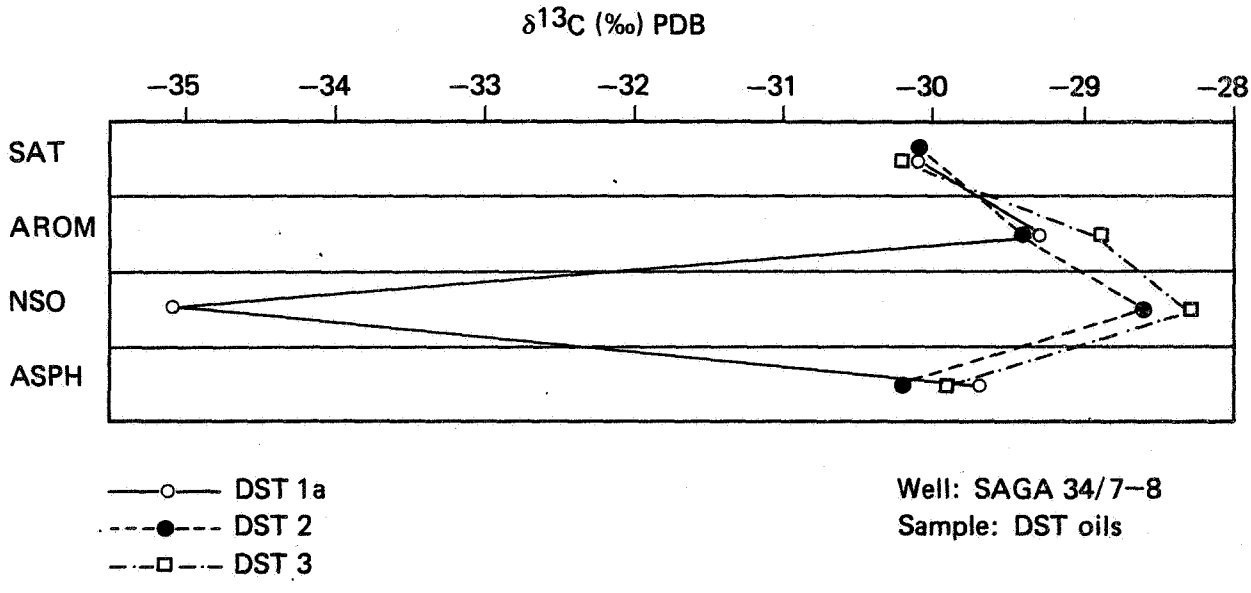


Figure 12: Plot of $\delta^{13}C$ values for various oil fractions.(After Stahl, 1977).

APPENDIX 1.

Molecular ratios from terpane and sterane mass chromatograms applied as maturity and source characteristic parameters

Geochemical fossil/biological marker compounds are characteristic of the type of organic matter present at the time the sediments were deposited. The biological isomers of these compounds are converted to the geochemical isomers with increasing maturity until a stable mixture of the isomers is attained. Migration and weathering processes also alter the distribution of biomarker compounds in a sample.

Hopanes, moretanes and tricyclic terpanes are the most common compounds in the m/z 191 mass chromatograms of most extracts and oils. Of the hopanes, the C_{27} and C_{29}-C_{35} homologs are ubiquitous, while 28,30-bisnorhopane is believed to be typical of certain types of source rocks. This is also thought to be true for a component, probably gammacerane, which sometimes coelutes with the 22S isomer of the C_{31} 17α(H)-hopanes. The relative distribution of the C_{27} trisnorhopanes is thought to be both source- and maturity-dependant.

In the m/z 217 and 218 sterane mass chromatograms, the molecular weight distribution of the C_{27}-C_{30} regular steranes is thought to be representative of the original organic matter input. The C_{29} steranes are generally indicative of input from higher land plants, but, more recently, similar compounds have been reported from marine micro-organisms. Moldowan (1984) has also recently published data on C_{30} steranes that are thought to be characteristic of input from marine organisms. This is one of the few marine markers reported, and previously the indication of marine origin for mature geolipids was assessed on the basis of absence of nonmarine marker compounds.

The biological hopane isomers, the 17β(H),21β(H)-hopanes, undergo structural changes during maturation. These isomerisation reactions are believed to proceed through the 17β(H),21α(H)-hopane structure (moretanes) to the stable 17α(H),21βα(H)-hopane structure. With thermal maturity, 17α(H)-hopanes account for 90-100% of the hopanes present. The ratio αβ/αβ+βα is used to describe this reaction. In the extended hopanes ($\geq C_{31}$), the thermally stable S configurations at C-22 become increasingly more abundant compared to the biologically preferred R configu-

rations with increased maturity. The ratio of the 22S:22R isomers stabilises at about 60:40 at thermal maturity. The Tm/Ts C_{27} hopane ratio (Seifert et al, 1978) also varies with thermal maturity such that, with increasing maturity, 17α(H)-trisnorhopane (Tm) is reduced in intensity relative to the more stable 18α(H)-trisnorhopane (Ts), causing the Tm/Ts ratio to decrease. However, this ratio is also thought to be source-dependant, and this should be allowed for when using the ratio as a maturation indicator. The tricylic terpanes vary in abundance with maturity (Schou et al., 1984a), as does 28,30-bisnorhopane (Cornford et al.,1983; Schou et al., 1984b).

Two sterane isomerisation reactions are commonly used for maturity determination based on data from the m/z 217 mass chromatogram. The biologically preferred 14α(H),17α(H) regular sterane isomers are gradually replaced by the more thermally stable 14β(H),17β(H)-sterane isomers. At thermal maturity, ββ isomers may account for 75-85% of the αα/ββ mixture. Mackenzie et al (1980) have observed a change from a dominance of the biological sterane epimer in recent sediments to the more stable S-configuration at C_{20}, such that this configuration accounts for 50% of the epimers at thermal maturity. The abundance of rearranged steranes relative to regular steranes has also been reported to increase with thermal maturity.

One of the reactions taking place at an early stage of diagenesis is the aromatisation of steranes, leading to the formation of mono- and triaromatic analogs. This process is measured by the abundance of triaromatic compounds relative to mono-aromatic compounds (% tri/tri+mono) from the m/z 231 and 253 mass chromatograms, respectively. Cracking processes also take place during early diagenesis, and may be used for maturity determination together with the %tri/tri+mono ratio (Mackenzie et al., 1980; 1981; 1982).

The effect of migration and weathering on the distribution of biological markers is less well understood than maturity-induced changes. Migration may be observed to cause an increase in the relative amounts of rearranged and 14β(H),17β(H) regular steranes (Seifert and Moldowan, 1978). Severe biological alteration leads to the formation of desmethyl-hopanes (Seifert and Moldowan, 1979).