

## **Incorporating Gas Chromatography and CHN Elemental Analysis into the Undergraduate Science Laboratory Curricula**

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### **GC Labs: An Overview**

After completion of the series of GC pre- and mini-labs students are now challenged to apply what they learned to GC labs that emphasize the qualitative and semi-quantitative chromatographic data analysis of more complex liquid mixtures such as gasoline, charcoal lighter, gas and fuel injector treatment liquids, etc.

### **Listing of GC Activities (Pre-Labs, Mini-Labs, and Labs)**

The list below summarizes the gas chromatography (GC) lab activities carried out by students in either General Chemistry 2 (CHM 154), Organic Chemistry 1 & 2 (CHM 235 and 236 respectively), and Analytical Methods in Environmental Science (ENV 280). GC activities marked with a single asterisk (\*) are preceded by a GC pre-lab activity. GC activities marked with a pound sign (#) indicate a take-home assignment. Brief descriptions of the GC labs listed below begin on page 3. Typical GC operating conditions for the labs begin on page 8.

<b><u>GC Activity</u></b>	<b><u>CHM 154</u></b>	<b><u>CHM 235</u></b>	<b><u>CHM 236</u></b>	<b><u>ENV 280</u></b>
*Relationship Between Molecular Weight & Retention Time, $R_t$ ?	X	X		X
*Relationship Between Boiling Point & $R_t$ ?	X	X		X
*Relationship Between GC Oven Temperature, $T_{\text{oven}}$ , & $R_t$ ?	X	X		X
*Relationship Between GC Injector Temperature, $T_{\text{inj}}$ , & $R_t$ ?		X		
*, # Capillary Column Thickness, $d_f$ : Influence on $R_t$ ?		X		

<b><u>GC Activity</u></b>	<b><u>CHM 154</u></b>	<b><u>CHM 235</u></b>	<b><u>CHM 236</u></b>	<b><u>ENV 280</u></b>
Distillation: Separation and Purification of Organic Compounds (Hexane & Toluene)		X		
Stereoisomerism: Principles Illustrated with Models & Experiments		X		
Steam Distillation of Spices: GC Analysis of Volatile Components		X		
Comparison of Fractional Distillation Columns		X		
Dehydration of Cyclohexanol		X		
Dehydration of 2-Methyl-2-Butanol		X		
S <sub>N</sub> 2 & S <sub>N</sub> 1: Structure & Reactivity in Nucleophilic Substitution Reactions		X		
#Quantitative GC: Triangulation & Height Times the Width at Half-Height Methods		X		
#GC Analysis of Hexane Purity		X		
#Detector Response: To What is the FID Responding?		X		
Influence of GC Oven Temperature Ramping on Peak Resolution		X		
Carrier Gas Flow Rate: Influence on R <sub>t</sub> ?		X		
Does the Split Ratio Influence R <sub>t</sub> ? Detector Response?		X		

<u>GC Activity</u>	<u>CHM 154</u>	<u>CHM 235</u>	<u>CHM 236</u>	<u>ENV 280</u>
GC Analysis of Street-Grade Gasolines: Octane Ratings & Suppliers	X		X	X
GC Analysis of STP <sup>®</sup> & Super Tech Gas Treatment & Fuel Injector Products	X		X	X
GC Analysis of “Heavy” Fuels & Paint Thinner	X			X
GC Monitoring of Vehicle Exhaust	X			
GC Monitoring of Soil Off-Gassing (Respiration)	X			
GC Monitoring of Microbial Activity in River Mud				

### **Summary Description of GC Mini-Labs and More Advanced Labs**

Unless noted otherwise in the summary description GC analysis was performed on a Perkin Elmer Elite-5 (Crossbond 5% diphenyl-95% dimethyl polysiloxane) capillary column (30m, 0.25mm i.d., 0.25 $\mu$ m df, Part # N9316076). All GC analyses were carried out under constant carrier gas flow (0.8mL/min) using Ultra High Purity (99.995 mole %) helium. Volume of liquid sample injected ranged from 0.1 to 0.4 $\mu$ L. Injector split ratio settings typically ranged from 50:1 to 150:1 depending on volume injected and chromatographic signals produced. Injector temperatures varied with volatility of liquids injected. All GC analyses used a flame ionization detector (FID) and injections were done manually. GC mini-labs marked with an asterisk (\*) are preceded by an appropriate GC pre-lab activity.

#### ***\*Relationship Between Molecular Weight & Retention Time, $R_t$ ?***

In this mini-lab students inject functional group related compounds with different molecular weights (2-propanol, 2-butanol, 2-pentanol, and/or 2-octanol) to determine whether MW influences retention time ( $R_t$ ) and if so is the relationship direct or indirect (inverse).

#### ***\*Relationship Between Boiling Point & $R_t$ ?***

In this mini-lab students inject two isomeric (equal MWs) alcohols (1- and 2-propanol, or 1- and 2-pentanol) or di-substituted aromatics ( $\sigma$ -,  $m$ -, and  $p$ -xylenes) with different BPs to determine whether BP influences  $R_t$  and if so is the relationship direct or indirect (inverse).

***\*Relationship Between GC Oven Temperature,  $T_{oven}$ , &  $R_t$ ?***

In this mini-lab students inject two compounds (1- and 2-propanol, or 2-propanol and 2-butanol) separately and as a mixture (1:1 v:v) at two different GC oven temperatures ( $T_{oven}$ ) to determine whether  $T_{oven}$  influences  $R_t$  and if so is the relationship direct or indirect (inverse). In addition, the relationship between  $T_{oven}$  and peak resolution is addressed.

***\*Relationship Between GC Injector Temperature,  $T_{inj}$ , &  $R_t$ ?***

In this mini-lab students inject 2-octanol at two different GC injector temperatures ( $T_{inj}$ ) to determine whether  $T_{inj}$  influences  $R_t$  and if so is the relationship direct or indirect (inverse). In addition, the influence of  $T_{inj}$  on peak shape is addressed.

***\*#Capillary Column Thickness,  $d_f$ : Influence on  $R_t$ ?***

In this activity 1-pentanol (or another compound) is injected onto separate columns (30m, 0.25mm i.d., Crossbond 5% diphenyl-95% dimethylpolysiloxane) with differing stationary phase thicknesses of 0.25 $\mu$ m and 0.1 $\mu$ m. From the two chromatograms students determine if column thickness influences  $R_t$  (and hence resolution) and if so is the relationship direct or indirect.

***Distillation: Separation and Purification of Organic Compounds (Hexane & Toluene)***

In this lab students carry out both simple and fractional distillations of a two component miscible liquid mixture containing hexane (bp = 70 $^{\circ}$ C) and toluene (bp = 111 $^{\circ}$ C). Students interpret chromatograms to determine which distillation technique is better (more efficient) at separating the two liquids whose difference in boiling temperatures is ~40 $^{\circ}$ C.

***Stereoisomerism: Principles Illustrated with Models & Experiments***

In this lab students inject separately and under identical GC operating conditions pure samples of two enantiomers, (+)-carvone and (-)-carvone. From interpretation of the chromatograms students determine if enantiomers have different or identical BPs.

***Steam Distillation of Spices: GC Analysis of Volatile Components***

In this lab groups of students carry out steam distillation on a number of fragrant spices, flowers, and/or citrus products. Examples include orange peels, roses, cloves, garlic, onion, and cinnamon. Condensate is collected, the organics extracted with methylene chloride from the water, the methylene chloride distilled off, and the resulting organic product mixture is injected into the GC.

***Comparison of Fractional Distillation Columns***

Students carry out fractional distillation of a two component miscible liquid mixture using three different unjacketed fractionating columns- Hempel, Snyder (three-section), and Vigreux. Comparison of chromatograms allows for determining which column has the greater separation efficiency. Chromatogram interpretation is also done on a three component liquid mixture fractional distilled using the three columns.

### ***Dehydration of Cyclohexanol***

Students use the GC to monitor the extent of the dehydration of the symmetrical cyclic secondary alcohol cyclohexanol to cyclohexene. Chromatograms of the product mixture and starting material (cyclohexanol) are compared to determine if the reaction went to completion, *i.e.* all the cyclohexanol is converted to cyclohexene. From the singular peak in the GC analysis of the product mixture students conclude that dehydration of cyclohexanol yields only one product, thereby illustrating regioselectivity.

### ***Dehydration of 2-Methyl-2-Butanol***

Students use the GC to monitor the extent of the dehydration of 2-methyl-2-butanol, an acyclic tertiary alcohol. From interpretation of the chromatograms students determine the relative ratios of the major (2-methyl-2-butene, bp = ~36-38<sup>o</sup>C) and minor (2-methyl-1-butene, ~30-31<sup>o</sup>C) isomeric products. As with the dehydration of cyclohexanol, students monitor the extent of the reaction by comparing the chromatogram of the product mixture with that of 2-methyl-2-butanol alone. Two peaks of unequal height and shorter retention times than starting material indicate that MWs and BPs of the products are less than starting material, 2-methyl-2-butanol. Literature values for the predicted products confirm this.

### ***#Quantitative GC: Triangulation & Height Times the Width at Half-Height Methods***

In this handout students learn how to quantify chromatographic peaks based on the two methods mentioned in the title. Students inject different volumes (0.1, 0.3, and 0.5 $\mu$ L) of 2-propanol in 2-octanol (~1:5 v:v) separately under isothermal conditions and the interpret the chromatograms to determine if the volume injected is directly or indirectly related to detector response, and also if volume injected influences  $R_t$  and if so is the relationship direct or indirect.

### ***#GC Analysis of Hexane Purity***

In this activity students determine the accuracy of the percent purity of a hexane bottle labeled as 95+% hexane. Students inject a sample into the GC and the areas of each peak determined via either the *triangulation* or *height times the width at half-height* quantitative methods. Percent purity of hexane is found by comparing the area of hexane to the total peak area.

### ***#Detector Response: To What is the FID Responding?***

In this activity students determine if the flame ionization detector (FID) responds to moles or mass of compound. Two separate equivolume injections of 1-pentanol ( $d = 0.8110\text{g/mL}$ ) and 1-butanol ( $d = 0.810\text{g/mL}$ ) are carried out under identical GC operating conditions. Equivolume injections of equidensity compounds translate into equal masses but since the molecular weights are different the numbers of moles injected are different. From the chromatograms and series of calculations students determine if the FID responds to mass or moles.

### ***Influence of GC Oven Temperature Ramping on Peak Resolution***

In this activity STP<sup>®</sup> Octane Booster is injected under isothermal and temperature ramping conditions to illustrate the increase in resolution with  $T_{\text{oven}}$  programming.

### ***Carrier Gas Flow Rate: Influence on $R_t$ ?***

In this activity 2-propanol is injected separately under isothermal conditions on the same column but at different carrier gas flow rates. From the two chromatograms students determine if carrier gas flow rate influences  $R_t$  (and hence resolution) and if so is the relationship direct or indirect.

### ***Does the Split Ratio Influence $R_t$ ?***

In this activity 0.4 $\mu$ L of 2-propanol in 2-octanol (~1:5 v:v) are injected separately under three different injector split ratios 50:1, 100:1, and 150:1. From the chromatograms students determine if the injector split ratio influences not only  $R_t$  but also the detector response.

### ***GC Analysis of Street-Grade Gasolines: Octane Ratings & Suppliers***

In this activity students qualitatively interpret chromatograms of street-grade gasoline: 1) with the same octane rating but taken from different sources (Chevron Octane 87 vs. Express Stop Octane 87), and 2) from the same source but with different octane ratings (Chevron Octane 87 vs. Chevron Octane 91).

### ***GC Analysis of STP<sup>®</sup> & Super Tech Gas Treatment & Fuel Injector Products***

In this activity students qualitatively interpret and compare chromatograms of a number of STP<sup>®</sup> and Super Tech<sup>®</sup> gasoline and fuel injector treatment products.

### ***Monitoring of Soil Off-Gassing (Respiration)***

In this activity plastic gas collection cylindrical tubes (~3-4" in length, 1" diameter)-made from a 100mL graduated cylinder and serrated rubber septum (see photo below)-are inserted into soil with different types of vegetative cover (grass vs. no grass) and solar exposure (shade vs. no shade). GC analysis of the accumulated gas in the tube's headspace (distance between top of soil and bottom of rubber septum) occurs once a week. An alumina column was used since the headspace gas was not dried prior to injection. Monitoring for one month showed no discernable chromatographic results different from the initial baseline chromatographic analysis.



**Soil Off-Gassing Collection Tubes**

### ***GC Monitoring of Microbe Activity in River Mud***

This activity was conceived and beta-tested in spring 2006, giving promising results,

namely a temporal reduction in oxygen gas ( $O_2$ ) by aerobic microbes and an increase in carbon dioxide ( $CO_2$ ) from (presumably) microbial respiration. This activity will replace the unsuccessful *GC Monitoring of Soil Off-Gassing (Respiration)* activity described previously.

In this activity gas chromatography is used to monitor the temporal consumption of  $O_2$  by aerobic microbes and the production of  $CO_2$  from microbial respiration in either river or lake mud. Mud is collected and plant detritus and pebbles are removed. About 10grams (g = grams) calcium carbonate ( $CaCO_3$ , a source of inorganic carbon) and about a half of a boiled egg yolk (a source of sulfur) are added to the mud and mixed thoroughly. Approximately one inch of either paper or hay (a source of cellulose) is placed at the bottom of a transparent, colorless glass 100mL graduated cylinder (maximum volume = ~120mL). Taking into account the water in the mud slurry, about 90-100mL of the mud slurry is added to the cylinder and air bubbles removed with a glass stirring rod. A serrated rubber septum is tightly inserted into the cylinder mouth (see photos below) and sealed off with parafilm to create a self-contained microbial community.

The microbial mud communities can be exposed to a number of environmental conditions such as different types of light exposure (fluorescent vs. incandescent, vs. no light), different light-exposure regimes (for example, continuous 24 hours vs. diurnal (12 hrs light/12 hrs dark)), or different temperatures (room temperature vs. temperatures above or below room temperature). GC analysis of the headspace gas, *i.e.* gas found in the volume between top of water level and bottom of septum, was done approximately every week for six weeks. Typical GC operating conditions for chromatographic separation and identification of headspace gases at ambient room temperature ( $\sim 25^\circ C$ ) was carried out on a Perkin Elmer Elite- GC GC MOLESIEVE molecular sieve column (30m, 0.53mm i.d., Part # N9316361) with constant carrier gas flow (0.8mL/min) using Ultra High Purity (99.995 mole %) helium. Volume of manual "wet" headspace gas sample injections was 300 $\mu$ L. Identification of oxygen ( $O_2$ ), nitrogen ( $N_2$ ), and carbon dioxide ( $CO_2$ ) gases was done with a thermal conductivity detector.



**Gas Collection Cylinders**

## GC Operating Conditions

Instrument: Perkin Elmer Clarus 500 GC  
Method: MW & R<sub>t</sub>  
Sample: 1-propanol, 1-butanol, & 1-pentanol  
Solvent:  
Sample volume: ~0.2μL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250μm  
Injector temp.: 150°C (isothermal)  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 100°C  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: BP & R<sub>t</sub>  
Sample: 1-propanol and 2-propanol  
Solvent:  
Sample volume: ~0.2μL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250μm  
Injector temp.: 150°C (isothermal)  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 75°C  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: T<sub>oven</sub> & R<sub>t</sub>  
Sample: 1-propanol and 2-propanol  
Solvent:  
Sample volume: ~0.2μL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250μm  
Injector temp.: 150°C (isothermal)  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 150°C, 100°C, and 75°C  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: T<sub>inj</sub> & R<sub>t</sub>  
Sample: 2-octanol  
Solvent:  
Sample volume: ~0.2μL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250μm

Injector temp.: 150°C and 75°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 150°C  
Detector: FID  
Detector temp.: 190°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Simple Distillation of Hexane/Toluene  
Sample: hexane, toluene  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250µm  
Injector temp.: 150°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 70°C  
Detector: FID  
Detector temp.: 180°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: (+)-Carvone and (-)-Carvone & GC  
Sample: (+)-Carvone and (-)-Carvone  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250µm  
Injector temp.: 235°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 150°C  
Detector: FID  
Detector temp.: 250°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Steam Distillation & GC  
Sample: Cloves, Orange peels  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250µm  
Injector temp.: 200°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 100°C hold for 1 min, 10°C/min to 200°C, hold for 1 min  
Detector: FID  
Detector temp.: 225°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Fractional Distillation Column Comparison  
Sample: 2-propanol, 2-butanol, & 2-pentanol  
Solvent:  
Sample volume: ~0.2 $\mu$ L direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250 $\mu$ m  
Injector temp.: 150 $^{\circ}$ C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 70 $^{\circ}$ C (isothermal)  
Detector: FID  
Detector temp.: 175 $^{\circ}$ C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Dehydration of Cyclohexanol  
Sample: cyclohexanol & product mixture  
Solvent:  
Sample volume: ~0.2 $\mu$ L direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250 $\mu$ m  
Injector temp.:  $^{\circ}$ C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.:  $^{\circ}$ C (isothermal)  
Detector: FID  
Detector temp.:  $^{\circ}$ C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Dehydration of 2-methyl-2-butanol  
Sample: 2-methyl-2-butanol & product mixture  
Solvent:  
Sample volume: ~0.2 $\mu$ L direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250 $\mu$ m  
Injector temp.: 80 $^{\circ}$ C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 40 $^{\circ}$ C (isothermal)  
Detector: FID  
Detector temp.: 120 $^{\circ}$ C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Volume Injected & R<sub>t</sub>  
Sample: 2-propanol in 2-octanol  
Solvent:  
Sample volume: ~0.2 $\mu$ L direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250 $\mu$ m  
Injector temp.: 150 $^{\circ}$ C

Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 125°C (isothermal)  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Detector Response  
Sample: 1-pentanol and 1-butanol  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.250mm ID, 0.250µm  
Injector temp.: 170°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 100°C (isothermal)  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Column thickness & R<sub>t</sub>  
Sample: 1-pentanol  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm & PE-5HT, 30m, 0.25mm ID, 0.1µm  
Injector temp.: 150°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 75°C (isothermal)  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: T<sub>oven</sub> Ramping, Peak Resolution, & R<sub>t</sub>  
Sample: STP<sup>®</sup> Octane Booster  
Solvent:  
Sample volume: ~0.2µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm  
Injector temp.: 225°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 75°C hold for 1 min, 10°C/min to 250°C hold 1 min  
Detector: FID  
Detector temp.: 235°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC

Method: Carrier Flow Rate & R<sub>t</sub>  
Sample: 2-propanol  
Solvent:  
Sample volume: ~0.3µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm  
Injector temp.: 175°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 1.2mL/min, 0.9mL/min, and 0.7mL/min  
Oven temp.: 75°C  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Split Ratio & R<sub>t</sub> & Detector Response  
Sample: 2-propanol in 2-octanol  
Solvent:  
Sample volume: ~0.4µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm  
Injector temp.: 150°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Split Ratio: 50:1, 100:1, and 150:1  
Oven temp.: 125°C  
Detector: FID  
Detector temp.: 150°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: Gasoline Analysis  
Sample: Octane 87 & 91 gasolines  
Solvent:  
Sample volume: ~0.3µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm  
Injector temp.: 175°C  
Carrier gas: UHP Helium (constant flow rate)  
Flow rate: 0.8mL/min  
Oven temp.: 100°C  
Detector: FID  
Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC  
Method: STP<sup>®</sup> products  
Sample: STP<sup>®</sup> Fuel Treatment products  
Solvent:  
Sample volume: ~0.3µL direct injection  
Column: Elite-5, 30m, 0.25mm ID, 0.25µm  
Injector temp.: 175°C

Carrier gas: UHP Helium (constant flow rate)

Flow rate: 0.8mL/min

Oven temp.: 100°C

Detector: FID

Detector temp.: 175°C (isothermal)

Instrument: Perkin Elmer Clarus 500 GC

Method: "Heavy" Fuels

Sample: Lamp oil, kerosene, Kingsford lighter fluid

Solvent:

Sample volume: ~0.3µL direct injection

Column: Elite-5, 30m, 0.25mm ID, 0.25µm

Injector temp.: 250°C

Carrier gas: UHP Helium (constant flow rate)

Flow rate: 0.8mL/min

Oven temp.: 75°C hold 1 min, 10°C/min to 250°C hold 1 min

Detector: FID

Detector temp.: 250°C (isothermal)