



Designation: ~~D8144 – 18~~^{ε1} D8144 – 22

Standard Test Method for Separation and Determination of Aromatics, Nonaromatics, and FAME Fractions in Middle Distillates by Solid-Phase Extraction and Gas Chromatography¹

This standard is issued under the fixed designation D8144; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—Footnote 4 was updated editorially in June 2019.

1. Scope—Scope*

1.1 This test method covers the separation and determination of representative aromatics, nonaromatics, and fatty acid methyl ester (FAME) fractions in middle distillates that boil between 170 °C and 400 °C, including biodiesel blends with up to 20 % by volume of FAME, by solid phase extraction and gas chromatography.

1.2 This test method provides two procedures, A and B. Procedure A is applicable to the petroleum-based middle distillates fuel, and Procedure B is applicable to the biodiesel blends with up to 20 % by volume of FAME.

1.3 This test method is applicable to middle distillates samples with aromatics content ranging from 5 % to 50 % by mass and biodiesel blends with FAME content in the range of 0.5 % to 20 % by volume. This test method may apply to concentrations outside these ranges, but the precision has not been determined.

1.4 For Procedure B, biodiesels in the form of fatty acid ethyl ester (FAEE) can also fully elute into the FAME fraction, and they have the similar FID (flame ionization detector) relative response factors with that of FAME. The determined content of FAME fractions are the sum of concentrations of FAME and FAEE by this test method (see [3.1.53.2.5](#)).

1.5 From the investigation results obtained for FAME determination, the low concentrations of monoglycerides (usually less than 0.5 % by mass in biodiesel blends) are not detectable under the gas chromatographic (GC) condition of this test method and will not interfere with the determination of FAME by Procedure B. As a result, biodiesel blends, conforming to the requirements of Specification [D7467](#), containing up to 20 % by volume of biodiesel blendstock meeting the requirements in Specification [D6751](#), typically contain concentrations of monoglycerides of less than 0.1 % by mass. The diglycerides and triglycerides, if present, are not detected under the GC condition of this test method due to their higher boiling points.

NOTE 1—If a sample is suspected of containing an abnormal FAME biodiesel feedstock than specified in Specification [D6751](#), for example, a sample contaminated with vegetable oil with a high level of total triglycerides, the content of mono-, di-, or tri-glycerides in the isolated FAME fraction may be determined using Test Method [D6584](#). Samples containing biodiesels with a high amount of glycerides than specified in Specification [D6751](#) may contaminate the GC column and not recommended for this test method.

1.6 The values stated in acceptable SI units are to be regarded as the standard. No other units of measurement are included in this standard

¹ This test method is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.04.0L](#) on Gas Chromatography Methods.

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*A Summary of Changes section appears at the end of this standard

1.7 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.

1.8 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:²

[D2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry](#)

[D2549 Test Method for Separation of Representative Aromatics and Nonaromatics Fractions of High-Boiling Oils by Elution Chromatography](#)

[D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography](#)

[D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter](#)

[D4057 Practice for Manual Sampling of Petroleum and Petroleum Products](#)

[D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants](#)

[D4177 Practice for Automatic Sampling of Petroleum and Petroleum Products](#)

[D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance](#)

[D6584 Test Method for Determination of Total Monoglycerides, Total Diglycerides, Total Triglycerides, and Free and Total Glycerin in B-100 Biodiesel Methyl Esters by Gas Chromatography](#)

[D6751 Specification for Biodiesel Fuel Blend Stock \(B100\) for Middle Distillate Fuels](#)

[D7467 Specification for Diesel Fuel Oil, Biodiesel Blend \(B6 to B20\)](#)

2.2 Other Standards:³

[EN 14103 Fat and oil derivatives—Fatty Acid Methyl Esters \(FAME\)—Determination of ester and linolenic acid methyl ester contents](#)

[EN 14214 Automotive fuels—Fatty acid methyl esters \(FAME\) for diesel engines—Requirements and test methods](#)

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology [D4175](#).

3.2 Definitions of Terms Specific to This Standard: [ASTM D8144-22](#)

<https://standards.iteh.ai/catalog/standards/sist/252f3b9a-27b7-40bb-9a80-1269f5ff49dd/astm-d8144-22>

3.2.1 *aromatics fraction, n*—the portion of the sample desorbed with the dichloromethane-ethyl alcohol mixture eluants (Procedure A) and dichloromethane-n-hexane eluants (Procedure B); the aromatics fraction may contain aromatics, condensed naphthenic-aromatics, aromatic olefins, and compounds containing sulfur, nitrogen, and oxygen atoms.

3.2.2 *biodiesel, n*—a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, designated B100.

3.2.3 *biodiesel blend, n*—a blend of biodiesel fuel with petroleum-based diesel fuel.

3.2.4 *diesel fuel, n*—petroleum-based middle distillate fuel.

3.2.5 *fatty acid methyl ester fraction, n*—the portion of the diesel fuels blends with fatty acid methyl ester (FAME) eluted with dichloromethane-ethyl alcohol; the FAME fraction may contain FAEE and compounds containing nitrogen and oxygen atoms.

3.2.6 *nonaromatics fraction, n*—the portion of the sample eluted with n-hexane.

3.2.6.1 Discussion—

The nonaromatics fraction is a mixture of paraffinic and naphthenic hydrocarbons if the sample is a straight-run material. If the sample is a cracked stock, the nonaromatics fraction will also contain aliphatic and cyclic olefins.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from British Standards Institution (BSI), 389 Chiswick High Rd., London W4 4AL, U.K., <http://www.bsigroup.com>.

3.2.7 *solid phase extraction separating system, n*—a solid-phase extraction cartridge packed with stationary phase material to effectively separate the aromatics, nonaromatics, and other compounds (such as FAME) fractions in middle distillates based on the mechanism of solid phase extraction (SPE).

4. Summary of Test Method

4.1 *Procedure A*—The sample is charged to the top of a SPE column and separated into aromatics and nonaromatics fractions by eluants with different polarities. Two aliquots of internal standards are added to these two fractions and both fractions are analyzed by the gas chromatograph equipped with hydrogen flame ionization detector (GC-FID). The content of the aromatics and nonaromatics are calculated based on the peak areas of the aromatics, nonaromatics, and internal standards.

4.2 *Procedure B*—The sample is charged to the top of a SPE column and separated into aromatics, nonaromatics, and FAME fractions by eluants with different polarities. Three aliquots of internal standards are added to these three fractions. All of these fractions are analyzed by the gas chromatograph equipped with hydrogen flame ionization detector (GC-FID). The content of the aromatics, nonaromatics, and FAME fractions are calculated based on the peak areas of the aromatics, nonaromatics, FAME, and internal standards. The volume percent of FAME is calculated based on the density of sample and mass percent of FAME.

5. Significance and Use

5.1 For the middle distillates whose boiling range is between 170 °C and 400 °C by such distillation methods like Test Method **D2887**, Procedure A can separate and determine the content of total aromatics and total nonaromatics by SPE and GC analysis of the resulting fractions. The determination of the total content of saturates and aromatics in petroleum middle distillates is useful to investigate the effects of petroleum processes on production of various finished fuels.

5.2 The total aromatics content and polycyclic aromatics content are important to characterize the quality of diesel fuels. This test method is demonstrated to be time-saving and eco-friendly by reducing the amount of reagent consumption and avoiding the necessity of solvent evaporation step as required, for example, in such Test Method **D2549**.

5.3 The determination of detailed hydrocarbon composition by mass spectrometry requires a preliminary separation of the sample into representative aromatics and nonaromatics, as in Test Method **D2425**, where Test Method **D2549** is used to separate the distillate fuel. The SPE fractionation procedure described herein may provide a suitable fractionation alternative approach for these mass spectrometric types of methods.

<https://standards.iteh.ai/catalog/standards/sist/252f3b9a-27b7-40bb-9a80-1269f5ff49dd/astm-d8144-22>

5.4 Biodiesel is a blendstock commodity primarily used as a value-added blending component with diesel fuel. Procedure B can provide a separation and determination technique to monitor the FAME content for FAME biodiesel blends.

6. Apparatus

6.1 Solid Phase Extraction Separating System:

6.1.1 *Solid Phase Extraction (SPE) Column*,⁴ as shown in Fig. 1. The SPE column used in Section 11 is 3 mL column packed with 1.5 g stationary phase particles. The stationary phase is a mixture 90:10 by mass of 75 µm to 150 µm silica gel and 75 µm to 150 µm neutral aluminum oxide. Appropriate separation efficiency and activity are required for the SPE column to obtain a satisfactory separation and quantification results. The detailed verification procedure and criteria for SPE column separation efficiency are described in 10.1.

NOTE 2—Any automated solid phase extraction instrument that can perform this separation procedure with the satisfied separation efficiency can also be used.

NOTE 3—The SPE column may be stored in a dry atmosphere as long as its performance meets the specifications; the SPE column is disposable and is used only once.

6.1.2 *Erlenmeyer flask*, 10 mL.

6.1.3 *Syringe*, 2 mL and 0.25 mL.

6.1.4 *Pipette*, 1 mL.

6.1.5 *Analytical Balance*, capable of weighing to the nearest 0.0001 g.

6.2 *Gas Chromatographic (GC) System*—The gas chromatographic system shall be equipped with sample inlet system, capillary column, column temperature programmer, FID detector and data acquisition system. Recommended GC operating conditions are

- | | |
|---|----------------------------------|
| 1 | Sample Inlet |
| 2 | Adapter |
| 3 | Solid Phase Extraction Cartridge |
| 4 | Sieve-plate |
| 5 | Stationary Phase Particles |
| 6 | Sample Outlet |

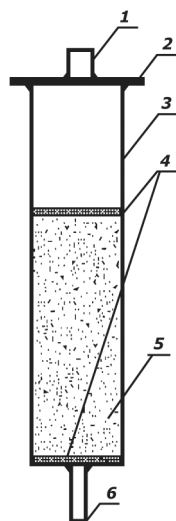


FIG. 1 Solid Phase Extraction Column

⁴ The sole source of supply of the apparatus (Solid Phase Extraction (SPE) Column that meets the requirements for this test method) known to the committee at this time is Research Institute of Petroleum Processing, China Petroleum and Chemical Corporation, 18 Xueyuan Road, Beijing 100083, P. R. China. North American distribution is through Dikma Technologies Inc. 255 Shields Court, Unit A&B, Markham, ON L3R 8V2, Canada, Toll-Free: 1-866-889-9072 or <http://www.dikmatech.com>. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,¹ which you may attend.

given in **Table 1**. The GC system and operating conditions shall ensure baseline separation of the solvent, sample and internal standard as shown in **Fig. 2** and **Fig. 3**. Any other gas chromatograph instrument and operating conditions capable of yielding equivalent results may be used.

6.2.1 Sample Introduction System—Manual or recommended automated liquid syringe injection into a splitting inlet may be employed. The sample amount reaching the column (combination of injection volume and split ratio) should meet the requirement of separation efficiency and linear response calibration range.

6.2.2 Capillary Column—This test method is limited to the use of non-polar silica capillary columns. The column and conditions shall provide separation of typical petroleum hydrocarbons in order of increasing boiling point. See **Fig. 2** and **Fig. 3** for examples of acceptable separation.

6.2.3 Detector—This test method requires a flame ionization detector (FID). The detector shall have enough sensitivity, linearity, and stability to meet performance requirements.

6.2.4 Data Acquisition System—A computerized data acquisition and reporting system is required to acquire, display, and process GC data. The areas of chromatographic peaks can be determined through either manual or automated peak integration.

7. Reagents and Materials

7.1 Purity of Reagents—Reagent grade chemicals shall be used in this test. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society,⁵ where

TABLE 1 Recommended Operating Conditions of GC^A

Column	Fused silica WCOT capillary column
Size	30 m × 0.25 mm ID, film thickness 0.25 μm
Stationary phase	Non-polar, such as 100 % dimethyl polysiloxane or 5 % phenyl-methyl polysiloxane
Column Temperature Program	Initial oven temperature 60 °C, initial hold 2 min, program rate 40 °C/min, final oven temperature 300 °C, final hold 5 min
Inlet Temperature	300 °C
Split ratio	20:1
Sample size	0.5 μL
Carrier gas Type	Helium, Nitrogen, or Hydrogen
Constant Flow Mode	1 mL/min
Detector Type	Flame ionization detector (FID)
Detector Temperature	350 °C
Fuel gas	Hydrogen (~30 mL/min)
Oxidizing gas	Air (~300 mL/min)
Make-up gas	~25 mL/min

^A The operating conditions given in this table are typical and may vary. The length of the WCOT column can be 15 m to 30 m; the inner diameter can be 0.15 mm to 0.32 mm. The suitable oven program can be selected to ensure baseline separation of the solvent, sample, and internal standard. See **Fig. 2** and **Fig. 3** for examples of suitable resolution.

⁵ ACS Reagent Chemicals, Specifications and Procedures for Reagents and Standard-Grade Reference Materials, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

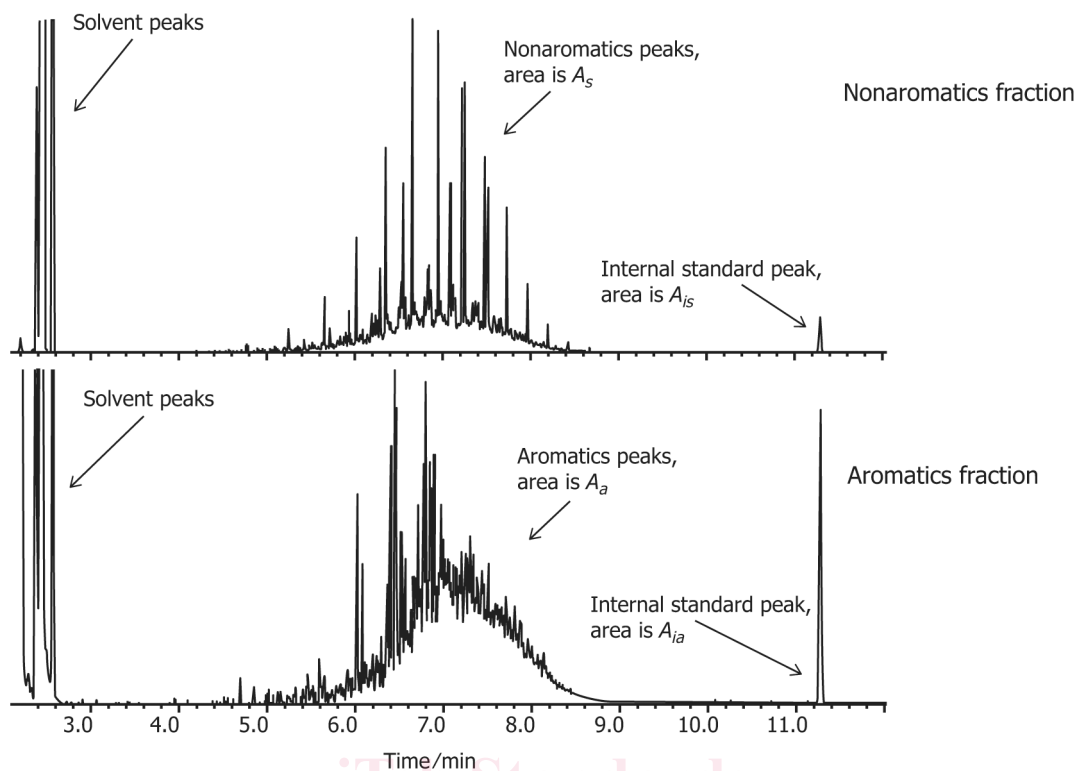


FIG. 2 Chromatograms of Nonaromatics and Aromatics Fractions in Petroleum-based Middle Distillate Fuel

such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

7.2 Ethyl Alcohol, anhydrous, reagent grade. (**Warning**—Flammable.)

7.3 Dichloromethane, reagent grade. (**Warning**—Toxic. Harmful if inhaled or skin contact.)

7.4 n-hexane, reagent grade. (**Warning**—Flammable.)

7.5 n-hexadecane, reagent grade.

7.6 n-triacontane, reagent grade.

7.7 n-dotriacontane, reagent grade.

7.8 Methyl oleate, >99 %.

7.9 Internal Standard Solution, n-triacontane or n-dotriacontane dissolved in n-hexane solvent to obtain the mass concentrations of 0.001 g/mL to 0.005 g/mL.

7.10 Silica Gel, 75 μm to 150 μm .

7.11 Aluminum oxide (neutral), 75 μm to 150 μm .

7.12 Carrier gas, Nitrogen, Helium, or Hydrogen, 99.99 % pure. (**Warning**—Compressed gas under high pressure.)

7.13 Hydrogen, 99.9 % pure. (**Warning**—Extremely flammable gas under high pressure.)

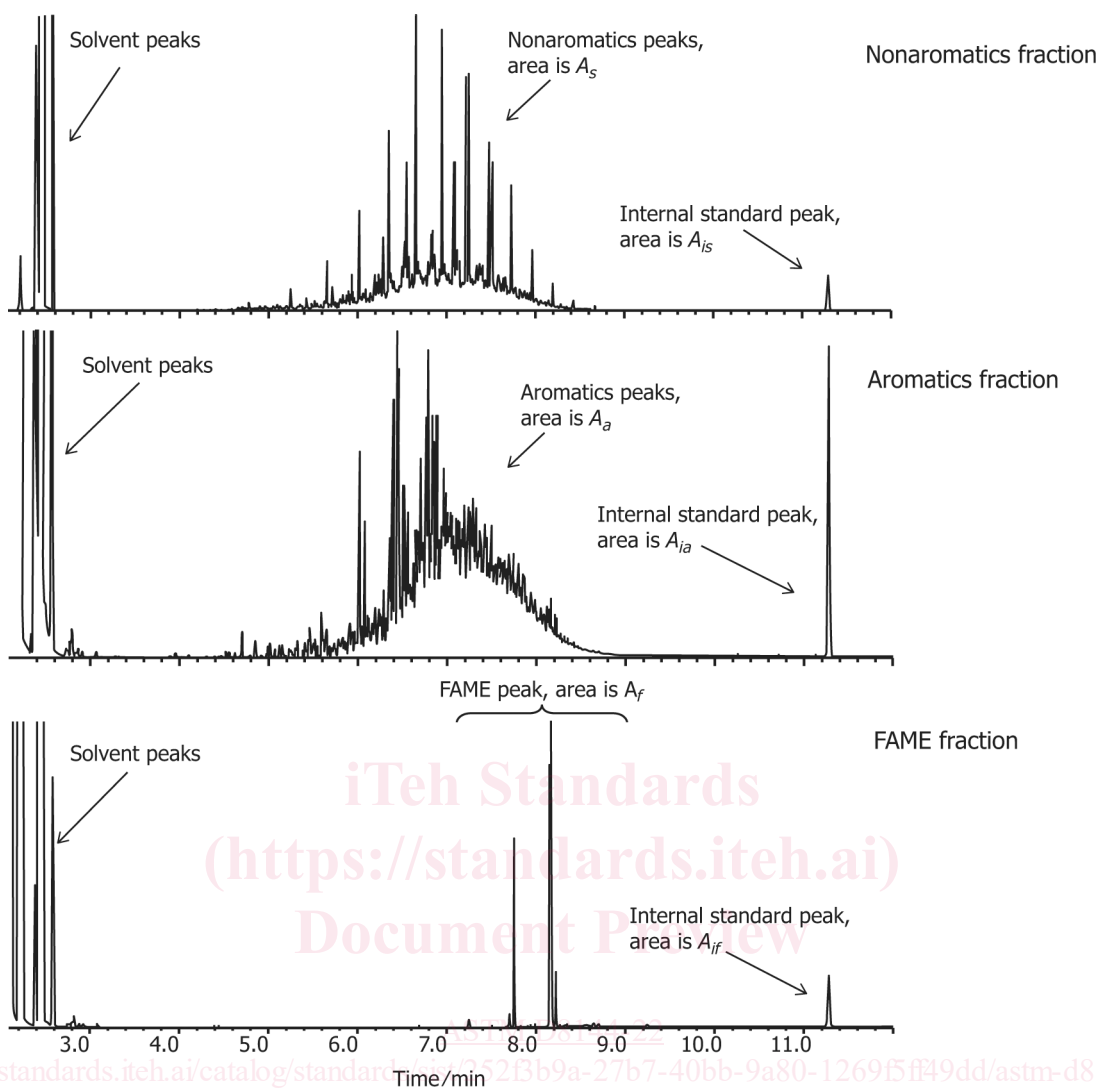


FIG. 3 Chromatograms of Nonaromatics, Aromatics, and FAME Fractions in FAME Biodiesel Blends

7.14 Air, compressed, 99.9% pure. (**Warning**—Compressed gas under high pressure that supports combustion.)

7.15 *Column Fractionation Efficiency Evaluation Mixture (Procedure A)*, used to evaluate the separation efficiency of SPE column in Procedure A. The mixture can be prepared by pure saturates in the range of 50 % to 95 % by mass and pure aromatics in the range of 5 % to 50 % by mass. The pure saturates can be a qualitative mixture of at least three paraffins from n-C₁₀ to n-C₂₀. The pure aromatics can be a qualitative mixture of at least three alkylbenzenes, such as C₄ to C₁₂-benzene, naphthalene, and phenanthrene. It is recommended that the concentrations of alkylbenzene and polycyclic aromatics are similar with that in a diesel fuel sample. The representative compositions and concentrations for the evaluation mixtures are listed in [Table A1.1](#) in [Annex A1](#).

7.16 *Column Fractionation Efficiency Evaluation Mixture (Procedure B)*, used to evaluate the separation efficiency of SPE column in Procedure B. The mixture can be prepared by pure saturates in the range of 30 % to 95 % by mass, pure aromatics in the range of 5 % to 50 % by mass and FAME in the range of 0.5 % to 20 % by volume. The pure saturates can be a qualitative mixture of at least three paraffins from n-C₁₀ to n-C₂₀. The pure aromatics can be a qualitative mixture of at least three alkylbenzenes, such as C₄ to C₁₂-benzene, naphthalene, and phenanthrene. It is recommended that the concentrations of alkylbenzene and polycyclic aromatics are similar with that in a diesel fuel sample. Any FAME standard or a mixture of FAME standards can be used to prepare this mixture. The representative composition and concentrations for the evaluation mixtures are listed in [Table A1.2](#) in [Annex A1](#).

7.17 *Relative Response Factor Mixture*, used to calculate the relative response factor of FAME (relative to n-hexadecane). Prepare