Designation: ~~D3238 – 22~~ D3238 – 22a

Standard Test Method for Calculation of Carbon Distribution and Structural Group Analysis of Petroleum Oils by the n-d-M Method[1]

This standard is issued under the fixed designation D3238; 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.

1. Scope*

1.1 This test method covers the calculation of the carbon distribution and ring content (Note 1) of olefin-free petroleum oils from measurements of refractive index, density, and molecular weight (n-d-M).[2] This test method should not be applied to oils whose compositions are outside the following ranges:

1.1.1 *In terms of carbon distribution*—up to 75 % carbon atoms in ring structure; percentage in aromatic rings not larger than 1.5 times the percentage in naphthenic rings.

1.1.2 *In terms of ring content*—up to four rings per molecule with not more than half of them aromatic. A correction must be applied for oils containing significant quantities of sulfur.

NOTE 1—The composition of complex petroleum fractions is often expressed in terms of the proportions of aromatic rings (R_A), naphthene rings (R_N), and paraffin chains (C_P) that would comprise a hypothetical mean molecule. Alternatively, the composition may be expressed in terms of a carbon distribution, that is, the percentage of the total number of carbon atoms that are present in aromatic ring structures (% C_A), naphthene ring structures (% C_N), and paraffin chains (% C_p).

1.2 The values stated in SI units are to be regarded as the standard.

1.2.1 *Exception*—The values in parentheses are for information only.

1.3 *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.*

1.4 *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:*[3]

D1218 Test Method for Refractive Index and Refractive Dispersion of Hydrocarbon Liquids

[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 D02.04.0K on Correlative Methods.

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[2] Van Nes, K., and van Westen, H. A., *Aspects of the Constitution of Mineral Oils*, Elsevier, New York, 1951.

[3] 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.

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

D1480 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Bingham Pycnometer
D1481 Test Method for Density and Relative Density (Specific Gravity) of Viscous Materials by Lipkin Bicapillary Pycnometer
D1552 Test Method for Sulfur in Petroleum Products by High Temperature Combustion and Infrared (IR) Detection or Thermal Conductivity Detection (TCD)
D2502 Test Method for Estimation of Mean Relative Molecular Mass of Petroleum Oils from Viscosity Measurements
~~D2503 Test Method for Relative Molecular Mass (Molecular Weight) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure (Withdrawn 2022)[4]~~
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry

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:*

~~3.2.1 *base stock, n*—a hydrocarbon lubricant component, other than an additive, that is produced by a single manufacturer to the same specifications (independent of feed source or manufacturer's location), and that is identified by a unique formula number or product identification number, or both.~~

~~3.2.2 *density, n*—mass per unit volume at a given temperature.~~

~~3.2.2.1 *Discussion*—~~

~~Standard units of density are kg/m³ (SI unit) or mg/cm³. Less preferred units, for example, kg/L or g/mL, are still in use.~~

~~3.2.3 *dynamic viscosity (η), n*—the ratio of applied shear stress and the resulting rate of shear of a liquid.~~

~~3.2.3.1 *Discussion*—~~

~~It is also sometimes called absolute viscosity. Dynamic viscosity is a measure of the resistance to flow of the liquid at a given temperature. In SI, the unit of dynamic viscosity is the Pascal·second (Pa·s), often conveniently expressed as milliPascal·second (mPa·s), which has the cgs system equivalent of the centipoise (cP).~~

~~3.2.4 *refractive index, n*—the ratio of the velocity of light (of specified wavelength) in air, to its velocity in the substance under examination.~~

~~3.2.4.1 *Discussion*—~~

~~The relative index of refraction is defined as the sine of the angle of incidence divided by the sine of the angle of refraction, as light passes from air into the substance. If absolute refractive index (that is, referred to vacuum) is desired, this value should be multiplied by the factor 1.00027, the absolute refractive index of air. The numerical value of refractive index of liquids varies inversely with both wavelength and temperature.~~

3.2.1 *solvent refining, n*—~~*term*~~ *in lubricant manufacture,* a manufacturing process for the removal of most of the ring structures and aromatics ~~(weak, undesirable components) of oil~~ from heavy distillates by liquid extraction.

3.2.1.1 *Discussion*—

Common and suitable solvents for extraction are phenol, ~~furfural,~~furfural and ~~sulphur dioxide.~~sulfur disoxide. Furfural is used ~~extensively~~ as the extractant for the ~~refining~~manufacture of paraffinic oils.

4. Summary of Test Method

4.1 The refractive index and density of the oil are determined at 20 °C. The molecular weight is determined experimentally or estimated from measurements of ~~dynamic~~kinematic viscosity at 37.8 °C and 98.89 °C (100 °F and 210 °F). These data are then used to calculate the carbon distribution (% C_A, % C_N, % C_P) or the ring analysis (R_A, R_N) using the appropriate set of equations.

5. Significance and Use

5.1 The carbon distribution and ring content serve to express the gross composition of the heavier fractions of petroleum. These data can be used as an adjunct to the bulk properties in monitoring the manufacture of lubricating oil base stocks by distillation, solvent refining or hydrogenation, or both, and in comparing the composition of stocks from different crude sources. Furthermore, the data can often be correlated with critical product performance properties.

6. Measurement of Physical Properties

6.1 Determine the refractive index of the oil at 20 °C using Test Method D1218.

6.2 Determine the density at 20 °C using Test Method D1480, Test Method D1481, or Test Method D4052.

6.3 Determine the average molecular weight using Test Method D2502 ~~or Test Method D2503~~.

7. Determination of Sulfur Content

7.1 Determine the percentage of sulfur in the oil using Test Methods D1552, D2622, or D4294.

8. Calculation of Carbon Distribution and Ring Content

8.1 Calculate the factors *v* and *w* from the observed density (*d*) and the observed refractive index (*n*) using the following equations:

$$v = 2.51(n_D^{20} - 1.4750) - (d_4^{20} - 0.8510) \quad (1)$$

$$w = (d_4^{20} - 0.8510) - 1.11(n_D^{20} - 1.4750) \quad (2)$$

8.2 Calculate the percentage of aromatic carbon ($\% C_A$) from *v* and the molecular weight (*M*) using one of the following equations:

$$\text{if } v \text{ is positive:} \% C_A = 430\,v + 3660/M \quad (3)$$

$$\text{if } v \text{ is negative:} \% C_A = 670\,v + 3660/M \quad (4)$$

8.3 Calculate the percentage of carbon in total (aromatic and naphthenic) ring structures ($\% C_R$) from *w* and the molecular weight.

$$\text{if } w \text{ is positive:} \% C_R = 820\,w - 3\,S + 10000/M \quad (5)$$

$$\text{if } w \text{ is negative:} \% C_R = 1440\,w - 3\,S + 10600/M \quad (6)$$

where:

S = mass % sulfur.

8.4 Calculate the percentage of naphthenic carbon ($\% C_N$) and the percentage of paraffinic carbon ($\% C_P$) as follows:

$$\% C_N = \% C_R - \% C_A \quad (7)$$

$$\% C_P = 100 - \% C_R \quad (8)$$

8.5 Calculate the average number of aromatic rings per molecule (R_A) from *v* and the molecular weight:

$$\text{if } v \text{ is positive:} R_A = 0.44 + 0.055\,Mv \quad (9)$$

$$\text{if } v \text{ is negative:} R_A = 0.44 + 0.080\,Mv \quad (10)$$

8.6 Calculate the average total number of rings per molecule (R_T) from *w* and the molecular weight:

$$\text{if } w \text{ is positive:} R_T = 1.33 + 0.146\,M\,(w - 0.005\,S) \quad (11)$$

$$\text{if } w \text{ is negative:} R_T = 1.33 + 0.180\,M\,(w - 0.005\,S) \quad (12)$$

where:

S = mass % sulfur.

8.7 Calculate the average number of naphthene rings per molecule (R_N) by difference:

$$R_N = R_T - R_A \quad (13)$$