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Characterization of Some Local Petroleum Residues by Spectroscopic Techniques

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Abstract *Two vacuum residues were delivered from two different petroleum refineries, one from Suez Petroleum Company and the second from Alexandria Petroleum Company. Two heavy residues were subjected to solvent extraction using n-pentane, n-heptane, and ethyl acetate. The studied residues were fractionated into their components. Infrared spectroscopy was applied to study the distribution of functional groups contained in samples and their components. Some ratios calculated from the peak heights of selected infrared bands allow for a better comparison. The UV-Vis spectroscopic technique was applied to the aromatic fraction to determine how much mono-, di-, and polyaromatics are present in the aromatic fraction. The monoaromatics represent the lowest constituent among the aromatics present, whereas the polyaromatics and diaromatics are predominantly present and form the major constituent.*

Keywords infrared, UV-Vis spectra, vacuum residue

1. Introduction

Several research groups have applied Fourier transform electron-ionization cyclotron resonance mass spectrometry (FT-ICR MS) to analyze constituents in petroleum distillates, diesel fuel, or heavy crude oil (Ohashi et al., 1983; Hsu et al., 1994; Guan et al., 1996; Rodgers et al., 1998; Ancgeyta-Juarez et al., 2000; Miyabayashi, Naito, et al., 2000; Miyabayashi, Suzuki, et al., 2000).

Fourier transform infrared spectroscopy (FT-IR) is one of the available analytical methods for interpreting the structure of asphaltenes and it has been used to characterize functional groups in these compounds.

Yuan et al. (2006) indicated that there are only a few examples of mid-infrared (MIR) technology used in the determination of physical and chemical properties of heavy petrochemical products. They focused on the simultaneous determination of multi-properties; for example, saturate, aromatic, resin, asphaltenen (SARA), density, viscosity, carbon residue, hydrogen, sulfur, nitrogen, and element contents of three types of residual oils (atmospheric residue, vacuum residue, and hydro cracked residue) using mid infrared-

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attenuated total reflection (MIR ATR)-cell coupled with multivariate quantitative and qualitative calibration methods.

Chung and Ku (2000) have determined American Petroleum Inistitute (API) gravity of atmospheric residue by the use of an MIR spectrometer with an ATR probe and partial least squares (PLS) methods. Wilt et al. (1998) have studied the determination of asphaltene content in crude oils by MIR spectroscopy. Aske et al. (2001) have also used MIR ATR-cell to determine SARA components of crude oils. Some of the local vacuum residues delivered from two different areas were evaluated.

2. Experimental

Two vacuum residues (VR_S) were delivered, one from Alexandria Petroleum Company and the second Suez Petroleum Company. Three solvents, *n*-pentene, *n*-heptane, and ethyl acetate, were used for studying the composition of the two residues. The solvents used are analytical grade from Fluka Chemical Company.

2.1. Fractionation of the Residues into Their Constituents

The studied residues were fractionated into their asphaltenes, maltenes, resins, aromatics, mono-, di-, and polyaromatics and saturates (Altgelt and Gauw, 1979). This is shown in Figure 1.

Asphaltenes and maltenes were separated from the two vacuum residues under studied according to the standard test method IP-143 (IP, 1991).

Maltenes that resulted from deasphalting of the residues were further separated into saturates, aromatics, and resins using alumina column chromatography.

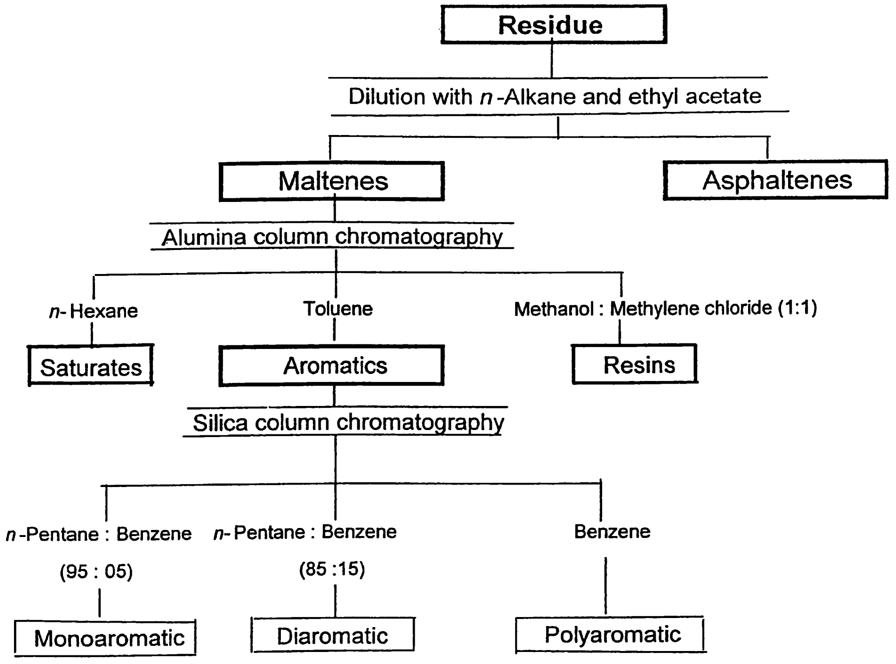


Figure 1. Scheme of separation of the residue into saturates, aromatics, resins, and asphaltenes.

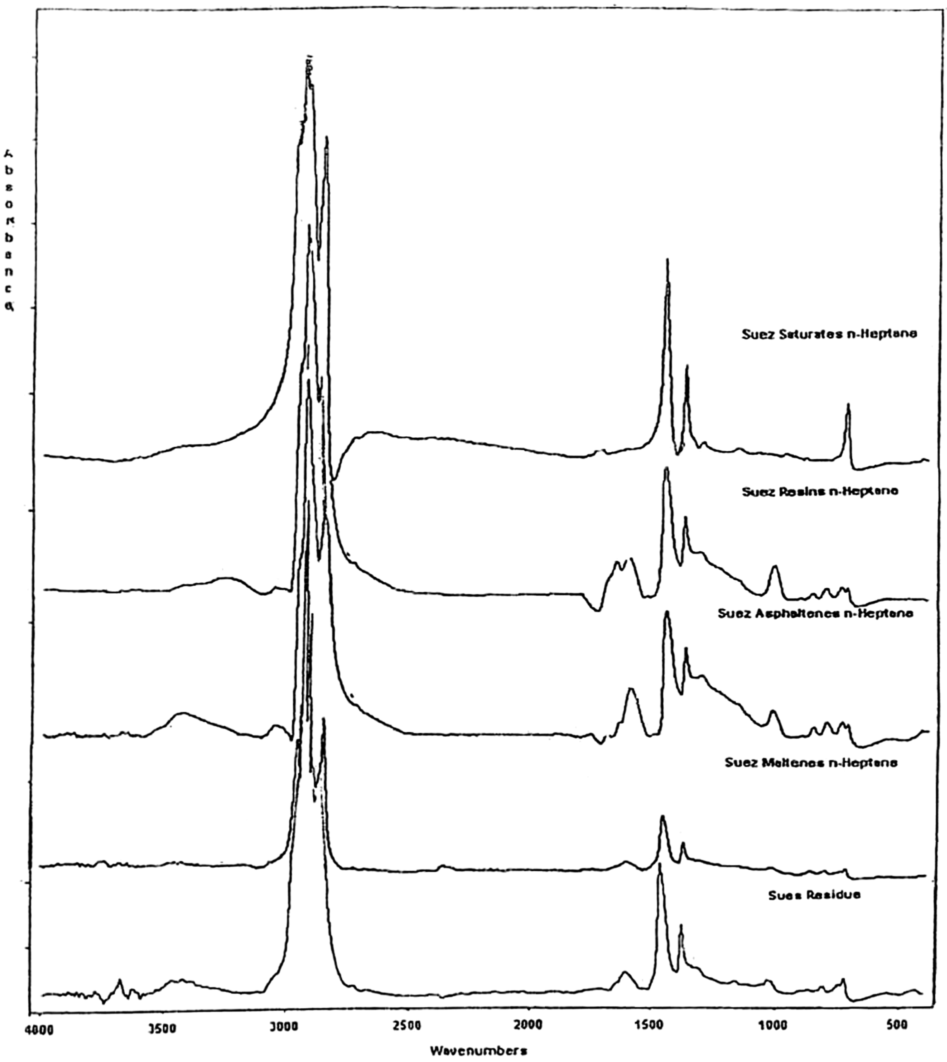


Figure 2. Infrared spectra of Suez vacuum residue and its fractions separated by *n*-heptane and ethyl acetate. (*continued*)

A glass column (150 cm × 4 cm i.d.) was packed with 800 g alumina (neutral; 70–230 mesh, Merck) activated overnight at 300°C in a muffle furnace. The column was wetted with *n*-hexane, and 40 g of the maltenes dissolved in the least amount of *n*-hexane was charged onto the column. The saturates, aromatics, and resins were eluted by *n*-hexane, toluene, and methanol–methylene chloride mixtures (1:1), respectively. The solvents were distilled off and the separated saturates, aromatics, and resins were dried in an oven to constant weight.

Aromatics were further separated into mono-, di-, and polyaromatics using silica gel column chromatography. A glass column (150 cm × 2 cm i.d.) was packed with 200 g silica gel (100–200 mesh, Merck) activated at 180°C in an oven for 4 hr. The column was wetted with *n*-pentane, and 10 g of the sample dissolved in the least amount of *n*-

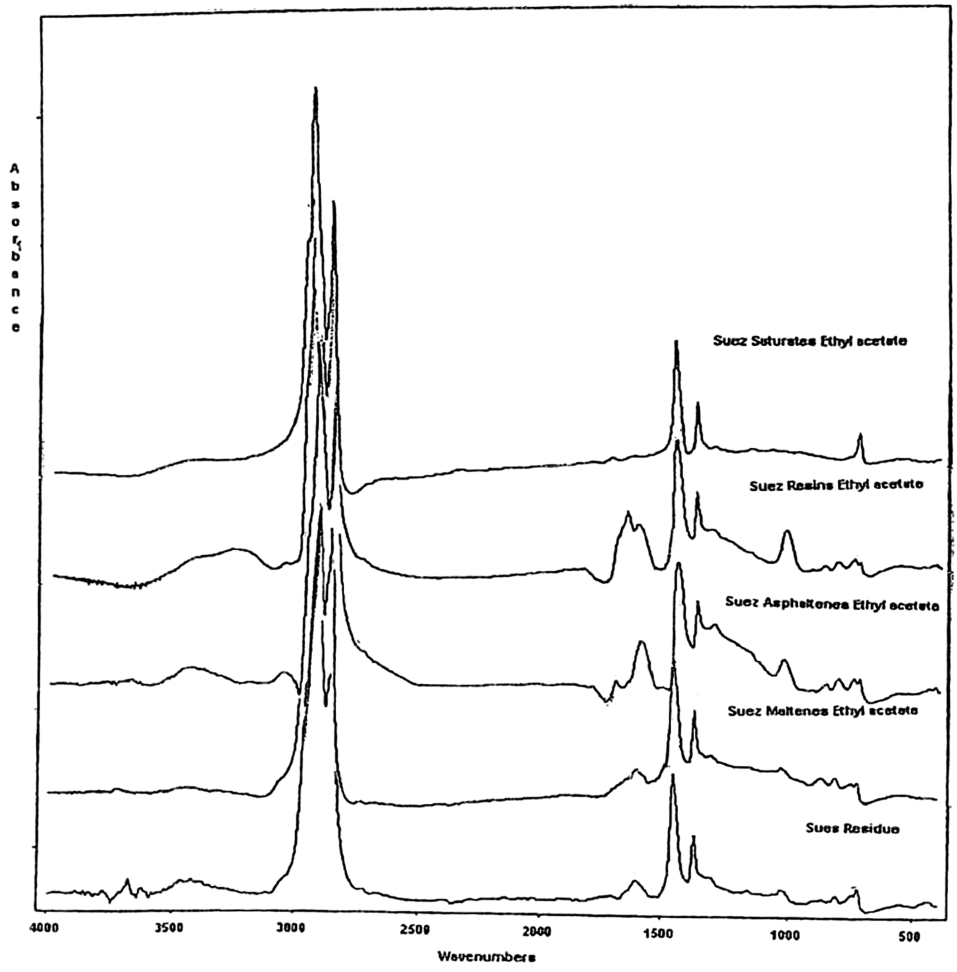


Figure 2. (*Continued*).

pentane was charged onto the column. Monoaromatics were eluted from the column by an *n*-pentane–benzene mixture (95:5). After collection the first 100 mL, each 25 mL of the eluted fraction was collected in a weighed flask and the solvent was distilled off, and the separated fraction was dried in an oven to constant weight. The refractive index of each fraction was measured. Monoaromatics were collected from the fractions having refractive index up to 1.53 at 20°C. Polyaromatics were finally eluted from the column by benzene.

2.2. Instrumental Analysis

2.2.1. Infrared Spectroscopy. The infrared spectra of the two vacuum residues, asphaltenes and maltenes, separated by different solvents, as well as resins, aromatics, and saturates that separated from maltenes, were measured using KBr disk technique and the aromatic and saturates were measured in the pure state. The measured infrared spectra are in the range 4,000 to 400 cm^{-1}. IR spectra were recorded on an FT-IR spectrometer (model 960 MOOO9, ATI Mattson Infinity series).

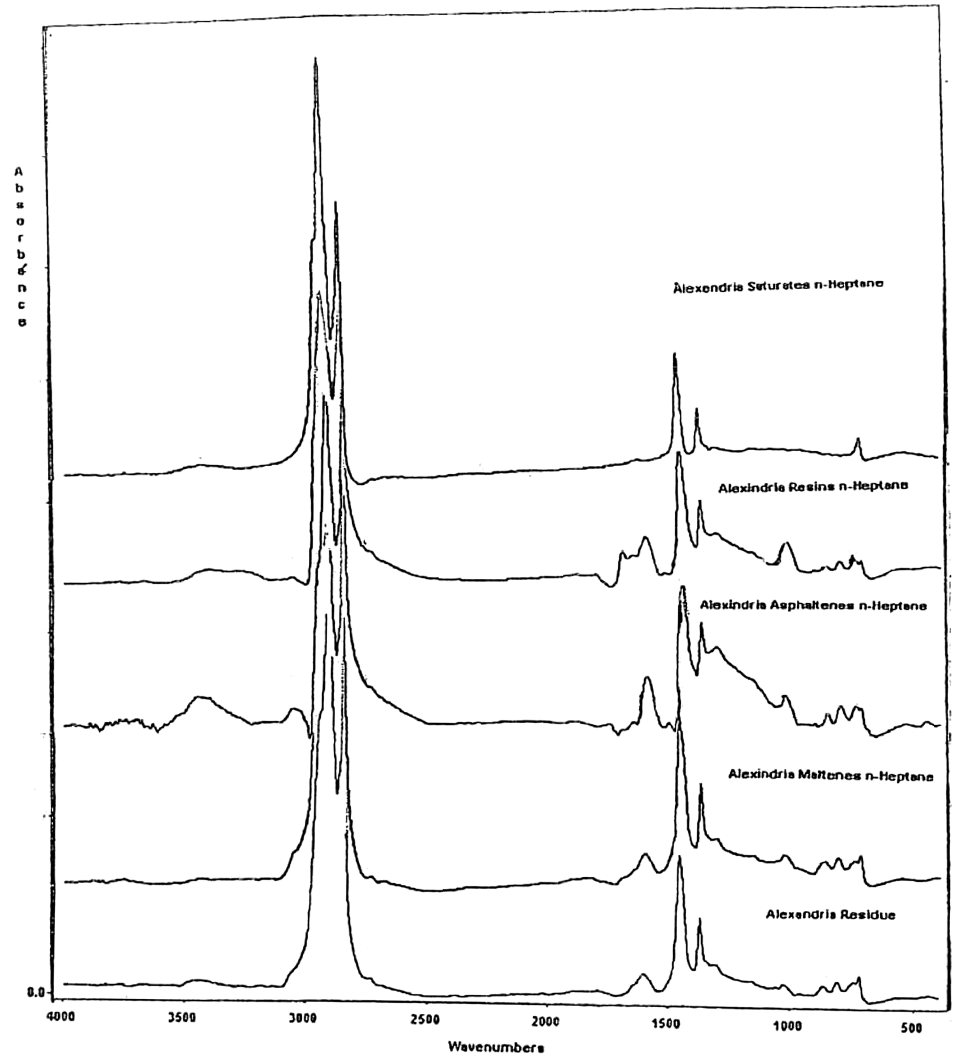


Figure 3. Infrared spectra of Alexandria vacuum residue and its fractions separated by *n*-heptane and ethyl acetate. (*continued*)

2.2.2. Ultraviolet Spectra. The two understudied vacuum residues and their constituents were subjected to ultraviolet/visible study. The measured UV spectra were in the range $\lambda = 200$–400 nm. Ultraviolet spectra were carried out using a UV-Vis/NIR spectrometer, model V-570/UV.

3. Results and Discussion

3.1. Infrared Studies

Infrared absorption spectroscopy can be applied for the investigation of the structure of petroleum and its fractions, including their functional groups (Ludwig, 1965; Whittle

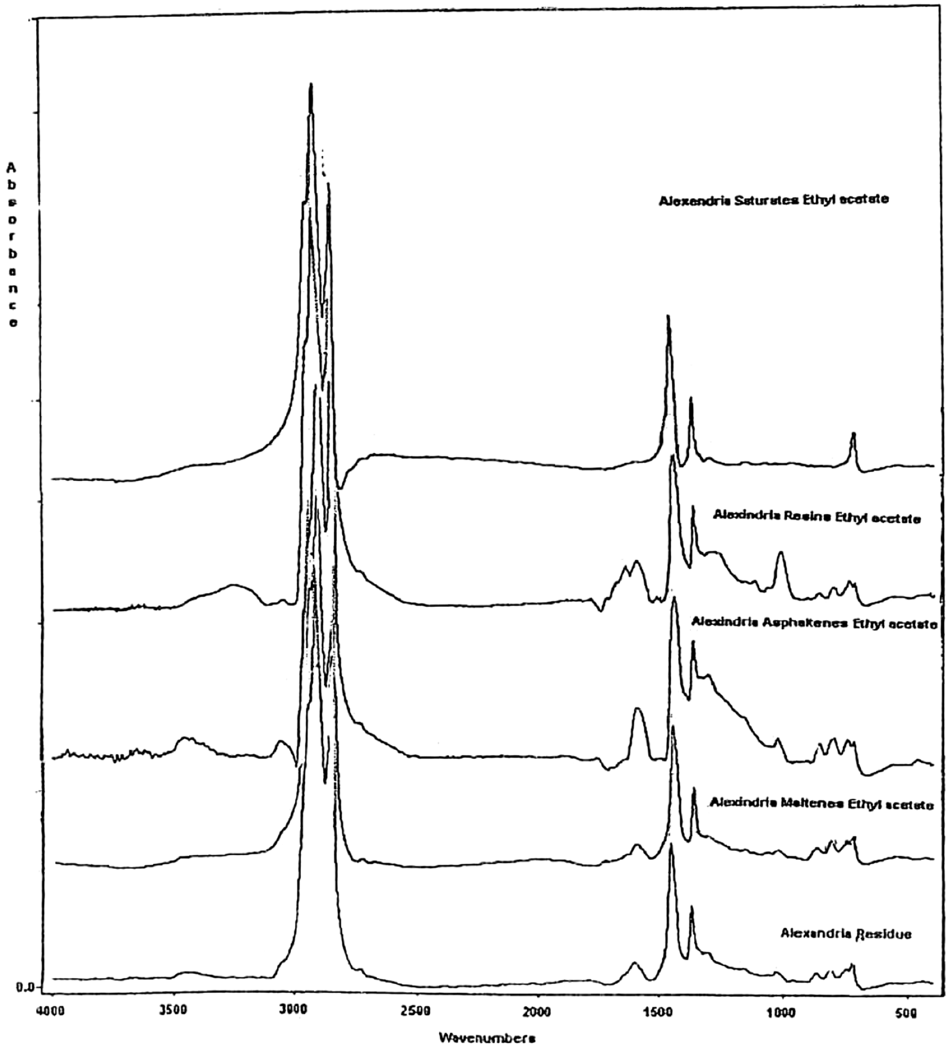


Figure 3. (*Continued*).

et al., 1980; Daghbouche et al., 1996). The assignments of the vibration of the function groups are summarized in Table 1.

In this work, the infrared spectra of the two vacuum residues, asphaltenes and maltenes, separated by different solvents, as will as the resins, aromatics, and saturates that separated from maltenes by alumina column chromatography, were measured using FT-IR spectroscopic techniques. The residues, maltenes, asphaltenes, and resins were measured using the KBr disk technique and the aromatics and saturates were measured in the pure state. The measured infrared spectra in the range 4,000 to 400 cm^{-1} are shown in Figures 2–5. The infrared spectra of the *n*-heptane and ethyl acetate asphaltenes separated from Suez and Alexandria vacuum residues are shown in Figures 2 and 3. It is clear that low-intensity bands appear in the region 3,500–3,300 cm^{-1}, with maxima at 3,446–3,421 cm^{-1} as in the spectra of the Suez vacuum residue, whereas a maxima appeared at

Table 1

Assignment of the vibrations of the functional groups in the infrared spectra of the petroleum products

Wave numbers, cm^{-1}	Assignment of the vibrations of the functional groups
3,600–3,200	OH stretching, NH stretching,
3,100–3,000	CH stretching in aromatic rings
2,955–2,945	CH_3 asymmetric stretching
2,930–2,945	CH_2 asymmetric stretching
2,900–2,880	CH stretching in CH_3, CH_2, and CH
2,875–2,850	CH_3 symmetric stretching
2,860–2,845	CH_2 symmetric stretching
2,730–2,725	CH stretching in aldehyde groups
2,000–1,800	Overtones of polycondensed aromatics
1,760–1,640	C=O stretching in carbonyl groups
1,610–1,590	C=C stretching in aromatic rings
1,485–1,445	CH_2 and CH_3 asymmetric deformation (scissoring)
1,380–1,365	CH_3 symmetric deformation (scissoring)
1,315–1,300	CH_2 wagging in long-chain paraffins
1,165–1,155	$(CH_3)_2$-C
1,035–1,020	C-O stretching, C-N stretching, S=O stretching
970–950	CH in naphthenic rings
945–910	OH out-of-plane deformation
890–860	CH aromatic out-of-plane deformation (one free hydrogen)
815–805	CH aromatic out-of-plane deformation (two or three adjacent free hydrogen atoms)
760–740	CH aromatic out-of-plane deformation (four adjacent free hydrogen atoms)
730–720	CH_2 rocking in chains, $(CH_2)_n$, $n \geq 4$

3,451–3,419 cm^{-1} in the spectra of Alexandria vacuum residue. These two bands indicate a very low concentration of OH and NH groups, which are responsible for asphaltenes aggregation through hydrogen bonding (Moschopedis and Speight, 1976). The very weak bands around 3,050 and 3,040 cm^{-1} result from C-H stretching in aromatic rings. The spectra also reveal strong bands in the region around 3,000 and 2,800 cm^{-1}, particularly two distinct bands at about 2,920 cm^{-1}. These two bands result from the CH_2 asymmetric and symmetric stretching, respectively. A small peak at about 1693 cm^{-1} in the spectra of asphaltenes may indicate the presence of the carbonyl group (C=O) stretching. All infrared spectra also show an intense, fairly sharp, band at about 1,600–1,500 cm^{-1}, which is characteristic of the C=C in aromatic rings (Figures 4 and 5). Another strong band was also observed around 1,461–1,451 cm^{-1}, which is due to asymmetric deformation of methyl and methylene groups. A small band observed at about 1,375 cm^{-1} might be attributed to methyl symmetric deformation. The band at about 1,315–1,305 cm^{-1} is due to CH_2 wagging in long-chain paraffins. The appearance of a weak band at 1,035–1,020 cm^{-1} results from the C-O, C-N, and/or S=O stretching. A very weak band at about 935–906 cm^{-1} may be due to the OH out-of-plane deformation. Three bands at

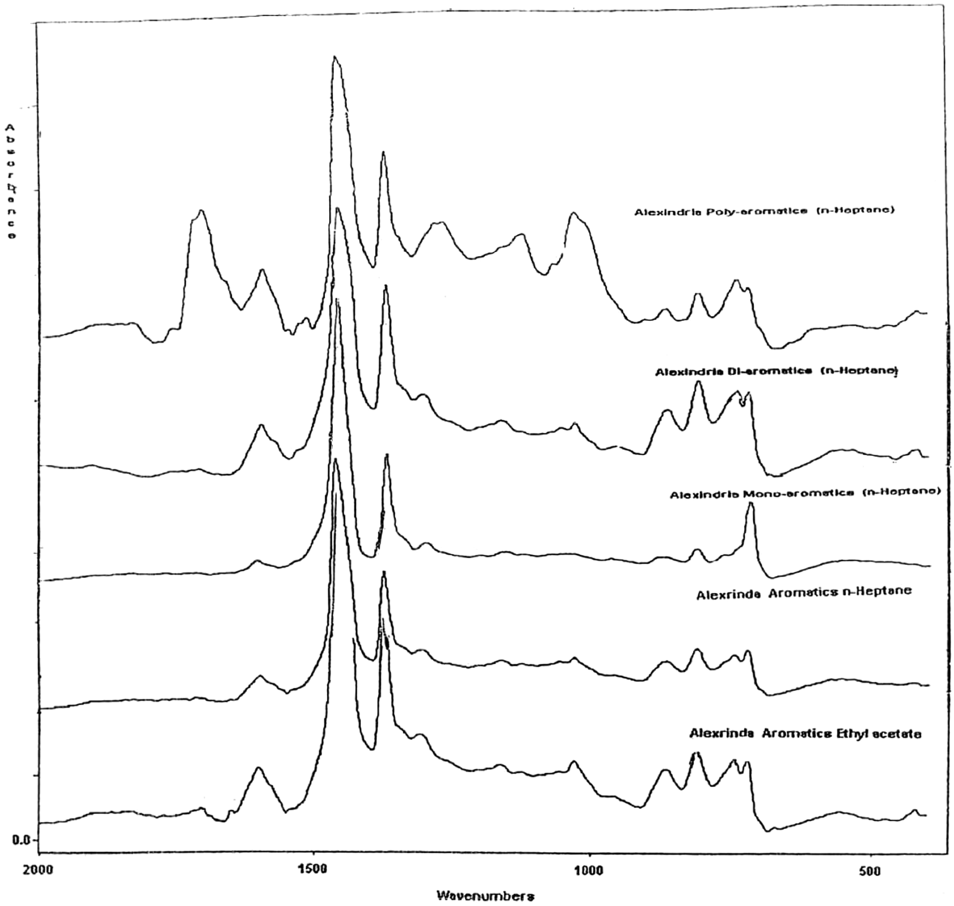


Figure 4. Infrared spectra of the Alexandria aromatics as separated by *n*-heptane and ethyl acetate solvents.

865–855, 810, and 740 cm^{-1} are weak and broad and probably result from the out-of-plane deformation of CH in aromatic rings. A weak band at about 720 cm^{-1}, due to CH_2 rocking in long chains [-$(CH_2)_n$-] where $n \geq 4$, is also present.

The infrared spectra of *n*-heptane and ethyl acetate resins, illustrated in Figures 2 and 3, indicate that these resins have nearly the same functional groups as present in asphaltenes. The spectra show broad bands of OH and NH in the region 3,600–3,200 cm^{-1} with maxima at about 3,419 cm^{-1} in Suez *n*-heptane resin and Alexandria *n*-heptane resin 3,415 or 3,370 cm^{-1}. A weak band appeared at 3,051–3,018 cm^{-1} of CH stretching in aromatic rings and two strong bands at about 2,921 and 2,851 cm^{-1} of the CH_2 asymmetric and symmetric stretching, respectively. A weak band is assigned to the stretching in the carbonyl group at 1,685–1,648 cm^{-1} (Alexandria resins ethyl acetate) or 1,693–1,650 cm^{-1} (Alexandria resins *n*-heptane) and 1,649 cm^{-1} in case of ethyl acetate Suez resins, whereas the band at about 1,609–1,545 cm^{-1} is due to the stretching virbration of C=C aromatic rings. Bands at 1,452, 1,375–1,365, and 1,313–1,311 cm^{-1} are due to $CH_2 + CH_3$ asymmetric deformation, CH_3 symmetric deformation, and CH_2 wagging in long-chain paraffins, respectively. The band of C-O, C-N, and/or

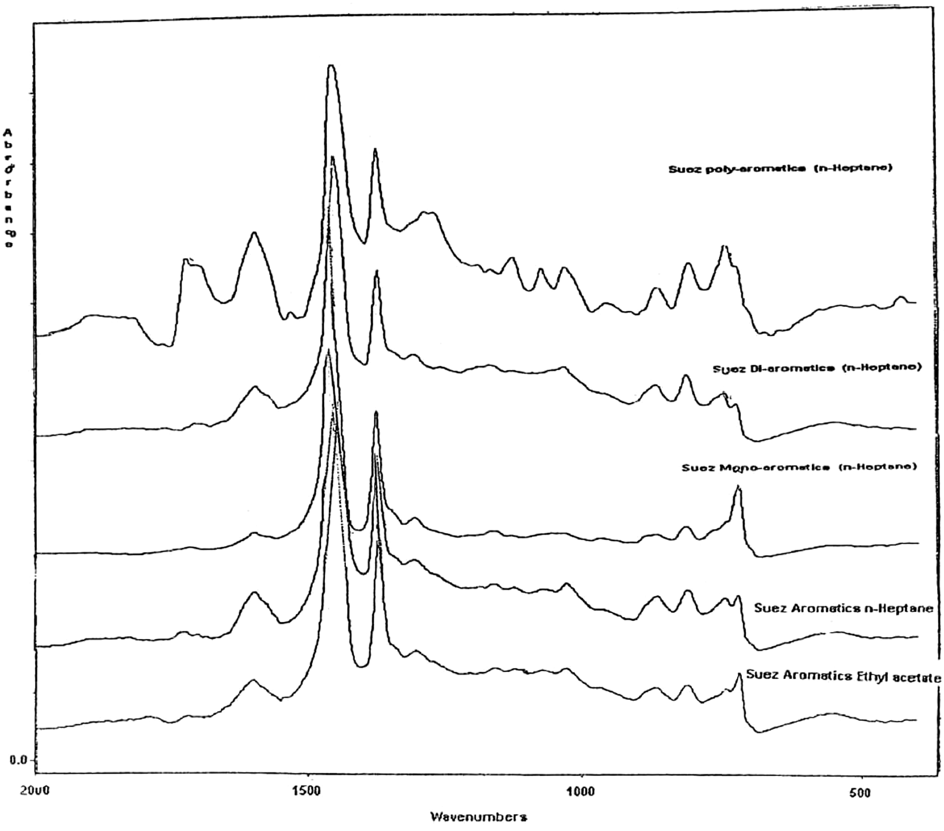


Figure 5. Infrared spectra of the Suez aromatics as separated by *n*-heptane and ethyl acetate solvents.

S=O stretching is present at about 1,020 cm^{-1}, whereas that of the OH out-of-plane deformation bands is at about 912–914 cm^{-1}. The CH aromatic out-of-plane deformation bands are at about 863–840, 811–808, and 745 cm^{-1}. The band of CH_2 rocking in long chains is also present at about 722 cm^{-1}.

Infrared spectra of the *n*-heptane and ethyl acetate aromatics, mono-aromatics, di-aromatics, and polyaromatics are shown in Figures 4 and 5. The OH and NH stretching are very weak above 3,200 cm^{-1} with a maxima at 3,556–3,455 cm^{-1}. The CH stretching in aromatic rings appears at about 3,050–3,040 and 3,020–3,015 cm^{-1}. There are very strong two bands at 2,927 and 2,851 cm^{-1}, which are probably due to CH_2 asymmetric and CH_3 symmetric stretching, respectively. Two very weak bands appear only in the spectra of aromatics at about 2,727 and 1,889 cm^{-1}; the first may represent CH stretching in aldehydes groups, whereas the second may be due to the overtones of polycondensed aromatics. The C=O stretching in carbonyl groups is very weak and appears at 1,700–1,654 cm^{-1}. The C=C stretching in aromatic rings is present as a weak band at about 1,600 cm^{-1} in both Alexandria and Suez. The CH_2 plus CH_3 symmetric and CH_3 symmetric deformation bands are at about 1,462 and 1,376 cm^{-1}, respectively. These two bands are sharp and very strong and followed by a weak band at 1,311–1,305 cm^{-1} due to the CH_2 wagging in long-chain paraffins. The very weak band at about 1,206–

1,088 cm^{-1} is attributed to the [-$(CH_3)_2$–C], whereas that at 1,032–1,030 cm^{-1} may be due to C-O, C-N, and/or S=O stretching. The CH in naphthenic rings is present as a very weak band at 960–950 cm^{-1}. Three bands at 880, 865, and 750 cm^{-1} represent the CH aromatic out-of-plane deformation. The CH_2 rocking in long chains [-$(CH_2)_n$-] where $n \geq 4$ is present at about 720 cm^{-1}.

The infrared spectra of the saturate, which were separated from the maltenes by alumina column chromatography, are shown in Figures 2 and 3. The spectra show very weak broad bands of the OH and NH stretching at about 3,100 cm^{-1}. The CH_3 asymmetric, CH_3 symmetric, and CH_2 symmetric stretching virbrations in aliphatic appear as three very strong bands at 2,958–2,854, 2,927–2,917, and 2,854 cm^{-1}, respectively. The C=C stretching in aromatics is present as a weak band at 1,606–1,503 cm^{-1}, indicating that the saturates contain very small amounts of aromatics. Strong bands at nearly 1,460 and 1,375 cm^{-1} may be attributed to methyl symmetric deformation (scissoring). A very weak band at 1,305 cm^{-1} was assigned to symmetric wagging of methylene groups in long-chain paraffins. The 1,038 cm^{-1} very weak band may be due to C-O, C-N, and S=O stretching vibrations. The presence of two very weak bands at about 890–793 cm^{-1} may be assigned to the out-of-plane deformation of C-H in aromatics. These bands, as well as the band of C=C stretching in aromatics at about 1,600 cm^{-1} indicate the presence of very small amounts of aromatic in the separated saturates. The two strong bands at about 730 cm^{-1} may be due to the rocking of methylene groups in long-chain paraffins that have four [CH_2] groups or more.

Some ratios calculated from peak heights of selected infrared bands allow for better comparison of the spectra. The ratio of absorbance of CH_3 symmetric deformation at 1,375 cm^{-1} to that of CH_2 + CH_3 symmetric deformation at 1,460 cm^{-1}; that is, A_{1375}/A_{1460} is a measure of the degree of branching and the ratio of CH_2 rocking at 720 cm^{-1} to CH_2 + CH_3 or CH_3 symmetric deformation; that is, A_{720}/A_{1460} or A_{720}/A_{1375} is a measure of the chain length (Landias et al., 1993). The degree of substitution in aromatic structures is measured from the ratio of absorbance of CH aromatic out-of-plane deformation two, three, or four adjacent hydrogen atoms, at 810 or 750 cm^{-1}, respectively, to that of one free hydrogen atom at 870 cm^{-1} (Blanco et al., 1996); i.e., A_{810}/A_{870} or A_{750}/A_{870}. The degree of branching, chain length, and the substitution degree in aromatic structures have been determined for asphaltenes, resins, and aromatics. The results are given in Table 2. The results show that the degree of branching in asphaltenes separated by *n*-heptane solvents from both Alexandria and Suez residues is more than that separated by ethyl acetate, and the chain length of *n*-heptane asphaltenes is less than that of ethyl acetate asphaltenes. The degree of branching of the resins and aromatics separated by *n*-heptane is less than that of those separated by ethyl acetate and the chain length of *n*-heptane resin and aromatic is more longer than that of ethyl acetate resin and aromatics. The results also reveal that the ratios of A_{810}/A_{870} or A_{750}/A_{870} in the asphaltenes separated by *n*-heptane are higher than that of asphaltenes separated by ethyl acetate. This indicates that the degree of substitution in the aromatics system of the *n*-heptane asphaltenes is less than that of ethyl acetate asphaltenes. On the other hand, the degree of substitution in the aromatics system of *n*-heptane resins and aromatics is higher than of ethyl acetate resins and aromatics.

3.2. Ultraviolet Studies

Ultraviolet spectroscopy is generally employed to study the presence of total, mono-, di-, and polyaromatics in crude petroleum and its fractions.

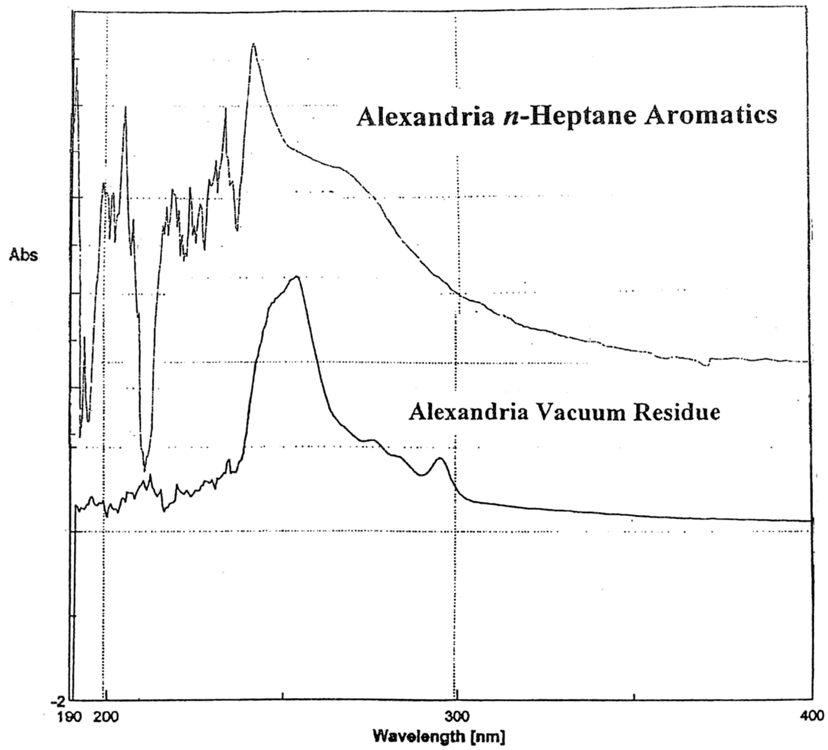
Table 2

Chain length, degree of branching, and substitution degree in the aromatics structures of the asphaltenes, resins, and aromatics determined by the infrared spectrometry

Fraction	Chain length		Degree of branching	Substitution degree	
	A_{720}/A_{1375}	A_{720}/A_{1460}	A_{1375}/A_{1460}	A_{810}/A_{870}	A_{750}/A_{870}
Asphaltenes: Alexandria:					
n-Pentane	0.252	0.189	0.747	1.260	1.305
n-Heptane	0.246	0.188	0.767	1.333	1.382
Ethyl acetate	0.253	0.192	0.759	1.217	1.135
Suez:					
n-Heptane	0.230	0.169	0.735	1.233	1.267
Ethyl acetate	0.301	0.221	0.734	1.114	1.083
Resins: Alexandria:					
n-Pentane	0.231	0.162	0.701	1.268	1.548
n-Heptane	0.251	0.164	0.653	1.237	1.406
Ethyl acetate	0.231	0.154	0.665	1.343	1.760
Suez:					
n-Heptane	0.281	0.181	0.664	1.181	1.304
Ethyl acetate	0.238	0.155	0.649	1.497	1.681
Aromatics: Alexandria:					
n-Pentane	0.365	0.211	0.578	1.271	1.135
n-Heptane	0.378	0.217	0.572	1.249	1.110
Ethyl acetate	0.338	0.201	0.573	1.267	1.138
Suez:					
n-Heptane	0.310	0.186	0.600	1.102	0.979
Ethyl acetate	0.295	0.176	0.595	1.138	0.985

It is well known that saturates have no significant absorption bands in the ultraviolet or visible spectroscopy. Therefore, the ultraviolet-visible spectroscopy is generally employed for the detection of aromatics (Yokota et al., 1986). On addition to the well-defined amounts of energy to increase its vibrational and rotational energy, a molecule can also absorb some energy to increase the energy of its electrons. The energy changes involved are considerably greater than those involved in vibrational and rotational energy changes and correspond to radiation in the ultraviolet (γ = 200–400 nm) and visible (λ = 400–750 nm) region.

In our study, the two understudied vacuum residues and their constituents were subjected to ultraviolet/visible study. The data are given in Tables 3 and 4, and the spectra are shown in Figure 6. From these tables, one can see the presence of two prominent bands, one sharp band at the range between about 230 to 235 nm, which mainly corresponds to the diaromatics, and the other band, which is strong, appears at about 255 nm, which generally shifted toward higher wavelengths, 256–257.5 nm, as shown by Suez vacuum residue (Table 3), and 254.5–257.5 nm, as shown by Alexandria vacuum residue (Table 4). A third band was reported at about 191 nm. This band sometimes shifted to higher wavelength, 191–198 nm, in the case of the two vacuum residues.



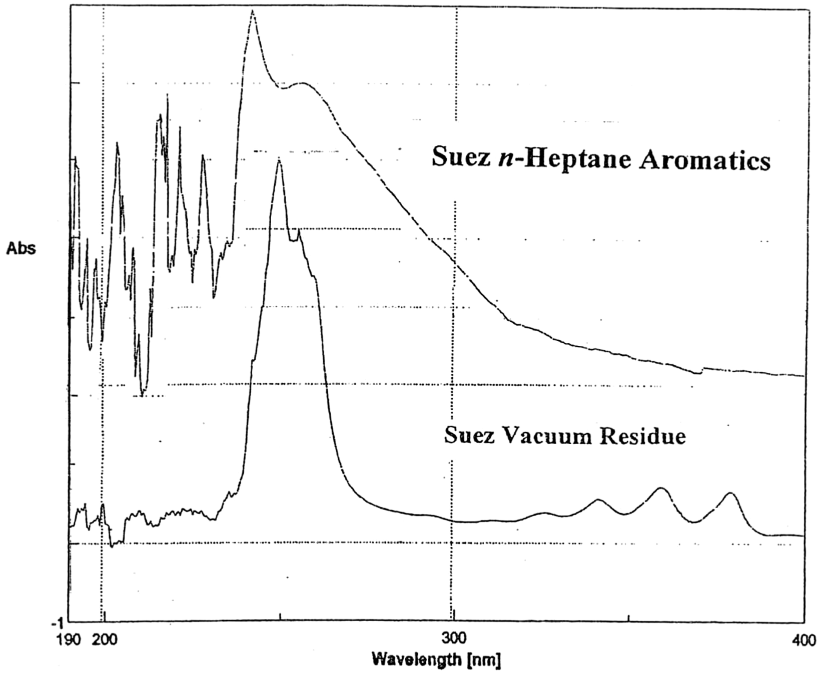


Figure 6. Ultraviolet spectra of the *n*-heptane aromatics separated from Suez and Alexandria vacuum residues.

Table 3
Ultraviolet spectra of Suez vacuum residue and its constituents as separated by different solvents

	Mono-aromatics		Di-aromatics		Polyaromatics	
Fraction	γ_1	α_1	γ_2	α_2	γ_3	α_3
Residue	194.5@	64.29	235	108.15	254.5	160.92
Maltenes extracted by:						
n-Heptane	194.5	60.06	231.5	111.18	257.5	133.16
Ethyl acetate	193.0	55.78	230.5	102.03	254.5	110.09
Asphaltene extracted by:						
n-Heptane	191.5	78.06	234.0	138.92	251.0	446.57
Ethyl acetate	198.5	75.03	234.0	139.63	255.0	390.59
Aromatics extracted by:						
n-Heptane	195.0	43.93	227.0	78.03	257.0	86.61
Ethyl acetate	193.5	39.72	227.5	61.77	257.5	78.96
Resin extracted by:						
n-Heptane	198.0	123.82	233.0	262.16	257.0	373.54
Ethyl acetate	192.0	104.36	234.0	193.72	251.0	305.04
Mono-aromatics (+)	195.0	57.59	232.0	43.95	257.5	40.13
Di-aromatics (+)	191.0	36.19	231.0	103.00	256.0	98.16
Polyaromatics (+)	197.5	29.79	229.5	76.49	256.5	109.76

$\alpha = \text{L g}^{-1}, \text{cm}^{-1}$, (+): As separated by column chromatography.

Generally the absorption coefficient (α) is higher at γ_2 and γ_3, corresponding to di-aromatics and polyaromatics, respectively, but it is lower in the case of γ_1, which corresponds to the mono-aromatics. As shown from Tables 3 and 4, mono-aromatics, which were separated by asilica gel column chromatography, reveal three wavelengths at 195 (intensity coefficient 57.59), 232 (intensity coefficient 43.95), and 257 nm (intensity coefficient 40.13) in the case of Suez vacuum residue, but in the case of the Alexandria vacuum residue, these three bands are shown at 194 (intensity coefficient 130.68), 231 (intensity coefficient 68.92), and 256 nm (intensity coefficient 51.78), respectively. The intensities of these bands indicate that mono-aromatics separated by column chromatography still contain some traces of both di-aromatics and polyaromatics.

The same is observed in the case of di-aromatics and polyaromatics. The di-aromatics reveal three bands at 191 (intensity coefficient 36.19), 231 (intensity coefficient 103.0), and 256 nm (intensity coefficient 98.16) in the case of Suez vacuum residue. On the other hand, Alexandria vacuum residue reveals corresponding three bands at 194 (intensity coefficient 48.41), 229.5 (intensity coefficient 175.18), and 257.5 nm (intensity coefficient 96.81).

The polyaromatics also reveal three absorption bands at 197.5 (intensity coefficient 29.79), 229.5 (intensity coefficient 76.49), and 256.5 nm (intensity coefficient 109.76), as shown by Suez vacuum residue. Bands were revealed by Alexandria vacuum residue at

Table 4
Ultraviolet spectra of Alexandria vacuum residue and its constituents as separated by different solvents

	Mono-aromatics		Di-aromatics		Polyaromatics	
Fraction	γ_1	α_1	γ_2	α_2	γ_3	α_3
Residue	193	54.14	229.5	103.76	253.50	139.48
Maltenes extracted by:						
n-Heptane	194.5	54.64	234.0	100.35	257.5	117.88
Ethyl acetate	192.5	59.04	232.5	108.11	257.5	127.94
n-Pentane	192.0	57.45	228.5	90.42	257.0	121.17
Asphaltene extracted by:						
n-Heptane	194.5	44.32	230.5	127.60	244	324.31
Ethyl acetate	195.5	40.01	230.5	101.21	258	210.64
n-Pentane	198	60.29	232.00	96.38	259	111.47
Aromatics extracted by:						
n-Heptane	191	64.17	230.50	105.43	251	99.39
Ethyl acetate	192	57.19	235.00	134.14	258	133.97
n-Pentane	198	60.29	232.00	96.38	259	111.47
Resin extracted by:						
n-Heptane	192.0	64.11	232.5	116.25	257.5	193.49
Ethyl acetate	196.5	80.34	232.0	115.61	257.5	195.15
n-Pentane	194.0	85.47	232.5	113.36	245.0	190.32
Mono-aromatics (+)	194.0	130.68	231.0	68.92	256.0	51.78
Di-aromatics (+)	194.0	48.41	229.5	175.18	257.5	96.81
Polyaromatics (+)	193.5	49.43	231.0	72.42	256.0	125.72

$\alpha = \text{L g}^{-1}, \text{cm}^{-1}$, (+): As separated by column chromatography.

193.5 (intensity coefficient 49.43), 231 (intensity coefficient 72.42), and 256 nm (intensity coefficient 125.72).

The above results indicate that the aromatic constituents of the petroleum vacuum residue contain a complex mixture of mono-, di-, and polyaromatics that affect the efficiency of silica gel column chromatography and therefore the separated mono-aromatics, di-aromatics, and polyaromatics each contain a trace amount of the other two.

4. Conclusion

Infrared absorption spectroscopy was used for the analysis of our studied residues and their solvent extracts. Infrared spectroscopic techniques were applied to study the distribution of functional groups contained in samples and their components. The data of the ultraviolet studies of the separated aromatics and their constituent of mono-, di-, and polyaromatics show that the mono-aromatics represent the lowest constituent among the aromatics present, whereas the polyaromatic and di-aromatics are predominantly present and form the major constituent. Therefore, some of the di-aromatics and polyaromatics usually contaminate the mono-aromatics fraction. The efficiency of silica gel column chromatography is affected by the aromatic constituents.

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