FTIR Analysis of the Whole Asphalt and Some Crackates

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(Received 14th September 2006, revised 13th December 2006)

Summary: The present paper demonstrates the Fourier-Transform Infrared (FTIR) analysis of the virgin asphalt and some crackates obtained thermally as well as catalytically in a micro autoclave under nitrogen atmosphere. Existence of pronounced bands in the spectrum of virgin asphalt confirms that the sample under study is enriched with complex aromatic hydrocarbons in addition to aliphatic, olefinic and naphthenic configurations. The presence of bands correspond to aromatic configurations in most of the spectra of the crackate obtained with catalysts like HZSM-5, silica, phospho-tungstic acid, and $AlCl_3$ as evidenced from their poor catalytic activities. The appearance of some bands correspond to polar compounds in some of the spectra of crackates obtained with catalysts like nickel oxide and ammonium heptamolybdate have confirmed their effectiveness in the conversion of the asphalt in to oxygenated compounds. The disappearance of some bands corresponding to aromatic configurations in some crackates obtained with catalysts like UTIMAC (Utmanzai Clay) and sodium silicate, has confirmed their effectiveness in the conversion of asphalt under study in to useful products. Amongst the modifiers used, the effect of coal was beneficial.

Introduction

Many techniques have been developed for the analysis of petroleum and petroleum based oils, which fostered a renewed interest into finding the exact organic chemistry of these compounds. The development of FTIR has unfolded the complex picture of the chemical analysis of a variety of organic compounds. This technique is helpful to detect distribution of a variety of functional groups like CH_2, CH_3, aromatic and aliphatic carbons and carbonyl/ carboxyl configurations as well as mineral mater in carbonaceous material. In addition, this technique is also helpful to determine physical properties like penetration value of viscous petroleum resides *i.e.* bitumen [1]. FTIR spectroscopy has been used to study the distribution of functional groups contained in the crude oil samples and has provided valuable information about its aromaticity and diverse functionalities, factors which define the thermal history of the crude oil samples [2].

Understanding chemistry has been the driving force behind research in petroleum. Akrami *et al.*, [3] have studied the chemical changes due to the different processes in crudes and pitches detected by FTIR spectroscopy. They have reported that distillation under vacuum has promoted dehydrogenation and aromatization through significant reduction of aliphatic structures and the H/ C atomic ratio. Christiansen *et al.*, [4] studied various methods for detecting and characterizing asphaltenes instability, highlighting that FTIR is an excellent technique to analyze asphaltenes. Workman *et al.*, [5] used near-infrared (NIR) spectroscopy for the analysis of petroleum products. The method is reported to be faster and avoid the use of toxic or corrosive reagents employed in other traditional methods of analysis. Various physical and chemical properties of hydrocarbons, fuels and other petroleum products have been determined using NIR spectroscopy jointly with multivariate calibration. The application of NIR spectroscopy to gasoline analyses, including octane index [6], PIONA constituents (paraffins, isoparaffins, olefins, naphthenes and aromatics) [7], the percentage weight of oxygen [8], the methyl tert-butyl ether (MTBE) content [9] or the major hydrocarbons content [10], is well established.

In the present work, asphalt was subjected to catalytic cracking. The whole asphalt and crackates fractions were analyzed using FTIR spectroscopy in order to view their chemical nature *i.e.* aliphatic, naphthenic, aromatic, polar, etc.

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Results and Discussion

The Whole Asphalt

Pentane Soluble Fraction (PS)

Petroleum residues are generally considered as aromatic rich materials. In order to know the chemical configurations present in pentane soluble fraction of the asphalt under study, FTIR study was performed. The information collected is summarized in Table-1. The FTIR spectrum of PS sample is displayed in Fig. 1. Intensities of aromatic C-H usually appear at 3048 cm^{-1} and that of aliphatic C-H appear at 2850- 2960 cm^{-1} [11]. Bands in the profile can be observed at 2800 cm^{-1}, which indicates that the sample contains aliphatic configurations. The spectrum also featured a medium band at 2609 cm^{-1}. The band in this region was previously assigned to carbon-carbon double bond in conjugated systems [12]. This band evidenced the presence of olefinic as well as naphthenic configurations. No pronounced band could be seen in the wave number range 1500 cm^{-1} - 2000 cm^{-1}, depicting that the sample under trial has no polar or oxidized compounds. The bands can be seen in the wave number range 1000 cm^{-1} -1600 cm^{-1} mostly centered at 1560 cm^{-1}, 1377 cm^{-1}, 1340 cm^{-1}, 1169.7 cm^{-1} and 1033 cm^{-1}. The band appearing at 1560 cm^{-1} could be assigned to the aromatic C = C bond. A strong absorption band at 1377 cm^{-1} showed CH_2 bending vibration. The band near 1340 cm^{-1} showed C-N stretching (aromatic amines); two peaks at 1169.7 cm^{-1} and 1033 cm^{-1} showed alkyl R-O and Ar-O stretching (alkyl-aryl aromatic ethers). A medium peak at 742.4 cm^{-1} could be seen which showed carbon hydrogen out-of-plane bending. Three consecutive peaks observed at 813 cm^{-1}, 876 cm^{-1} and 746 cm^{-1} showed an aromatic C-H out-of-plane bending vibration. Existence of pronounced bands in the wave number range 1200 cm^{-1} -1600 cm^{-1} as well as 700 cm^{-1} - 900 cm^{-1} confirmed that the sample under study was enriched with complex aromatic hydrocarbons in addition to aliphatic, olefinic and naphthenic configurations as was confirmed from the existence of the bands at 2800 cm^{-1} and 2609 cm^{-1}.

Pentane Insoluble Fraction (PI)

FTIR spectrum of PI fraction is also displayed in Fig. 1. The configurations assigned to the respective bands are provided in Table-1. The spectrum showed a broad band at 2800 cm^{-1}, which showed C-H mostly in aliphatic structures. The spectrum also exhibited a medium weak band centered at 1653 cm^{-1}, showing C = C for conjugated double bond compounds. The band at 1500 cm^{-1} could be observed, which showed aromatic C = C bonds. Existence of several pronounced bands centered at 745 cm^{-1}, 801 cm^{-1} and 877 cm^{-1}

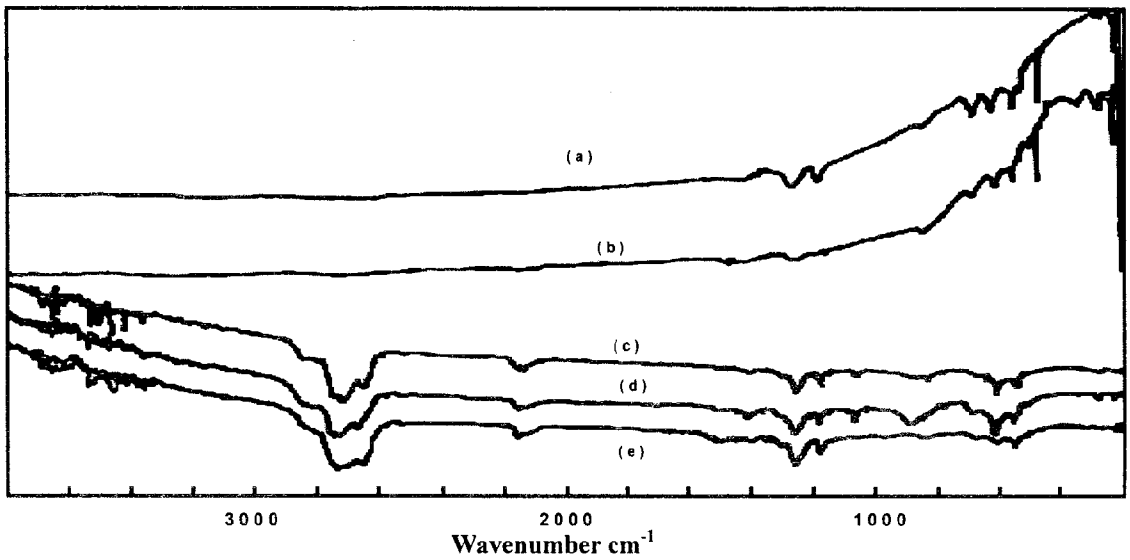

Fig. 1: FTIR Spectra of Virgin and Thermally Cracked Asphalt Samples
(a) Pentane Soluble Fraction (virgin); (b) Pentane Insoluble Fraction (virgin); (c) Asphalt cracked at 300 °C (PS); (d) Asphalt cracked at 350 °C (PS); (e) Asphalt cracked at 400 °C (PS)

Table-1: FTIR Cumulative Data and Groups Assigned to Virgin Asphalt and Variously Obtained Crackates

Sample	Fraction	Band (cm^{-1})	Intensity	Origin	Group Assigned
Asphalt1 Virgin		2800	High	C-H_2	Saturated Hydrocarbons
		1600	Medium	C = C (Ar)	Aromatic Hydrocarbons
	PS	1500	Weak	C = C (Ar)	Aromatic Hydrocarbons
		1340	Medium	C-N (Str)	Aromatic amines
		1169	Weak	R-O-Ar	Alkyl Aryl ether
		1030	Weak	R-O-Ar	Alkyl Aryl ether
		3000	Broad-Medium	C-H (Ar)	Aromatic Hydrocarbons
	PI	1653	Medium	C = C	Conjugated Hydrocarbons
		1500	Medium	C = C (Ar)	Aromatic Hydrocarbons
No Catalyst		2923.9	High	C-H	Saturated Hydrocarbons
300 °C		2856.4	High	C-H_2	Saturated Hydrocarbons
Contact Time		2343.4	Med-weak	S-H	Mercaptans
1hr	PS	1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons
		1375.2	Weak	C-H_2 (bend)	Saturated Hydrocarbons
		1022.2	Weak	R-O-Ar	Alkyl Aryl ether
		812	Weak	C-H	Aromatic Hydrocarbons
		744	Medium	C-H_2 (bend)	Saturated Hydrocarbons
UTIMAC		2854.5	High	C-H_2	Saturated Hydrocarbons
300 °C	PS	1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons
Contact Time		1377.1	medium	CH_2 (bend)	Saturated Hydrocarbons
1hr		744.5	Medium	CH_2 (bend)	Saturated Hydrocarbons
HZSM-5		2927.7	High	C-H	Saturated Hydrocarbons
300 °C		2854.5	High	C-H_2	Saturated Hydrocarbons
Contact Time		2341.4	Med-weak	S-H	Mercaptans
1hr		2360.7	Med-weak	S-H	Mercaptans
		1604.7	Medium	C-H	Aromatic hydrocarbons
	PS	1456	Weak	C-H (CH_n)	Saturated Hydrocarbons
		1159.1	Weak	R-O-Ar	Alkyl Aryl ether
		1033.8	Weak	R-O-Ar	Alkyl Aryl ether
		812	Weak	C-H	Aromatic Hydrocarbons
		746.4	Medium	C-H_2 (bend)	Saturated Hydrocarbons
		698.2	Weak	C-H	Aromatic Hydrocarbons
Silica		2923.9	High	C-H	Saturated Hydrocarbons
300 °C		2854.5	High	C-H_2	Saturated Hydrocarbons
Contact Time	PS	1602.7	Medium	C = C	Aromatic Hydrocarbons
1hr		1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons
		746.4	Medium	C-H_2 (bend)	Saturated Hydrocarbons
Sodium-		2850.6	High	C-H_2	Saturated Hydrocarbons
Silicate		2358.8	Med-weak	S-H	Mercaptans
300 °C		1604.7	Medium	C = C	Aromatic Hydrocarbons
Contact Time	PS	1452.3	Weak	C-H (CH_n)	Saturated Hydrocarbons
1hr		1031.8	Weak	R-O-Ar	Alkyl Aryl ether
		812	Weak	-	-
		746.4	Medium	C-H_2 (bend)	Saturated Hydrocarbons
Phospho		2920	High	C-H	Saturated Hydrocarbons
tungstic		2856.4	High	C-H_2	Saturated Hydrocarbons
acid		2331.8	Med-weak	S-H	Mercaptans
300 °C	PS	1602.7	Medium	C = C	Aromatic Hydrocarbons
Contact Time		1259.4	Weak	R-O-Ar	Alkyl Aryl ether
1hr		1035.7	Weak	R-O-Ar	Alkyl Aryl ether
		810	Weak	C-H	Aromatic Hydrocarbons
		744.5	Medium	C-H_2 (bend)	Saturated Hydrocarbons
$AlCl_3$		2854.5	High	C-H_2	Saturated Hydrocarbons
300°C		2331.8	Med-weak	S-H	Mercaptans
Contact Time	PS	1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons
1hr		812	Weak	C-H	Aromatic Hydrocarbons
		746.4	Medium	CH_2(bend)	Saturated Hydrocarbons
Nickel-		2922	High	C-H	Saturated Hydrocarbons
Oxide		2854.5	High	C-H_2	Saturated Hydrocarbons
300 °C		2358.8	Med-weak	S-H	Mercaptans
Contact Time 1hr		1699.2	High	C = O	Carbonyl (ketones)
	PS	1602.7	Medium	C = C	Aromatic hydrocarbons
		1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons

Table-1: continued.

Sample	Fraction	Band (cm^{-1})	Intensity	Origin	Group Assigned
		1259	Weak	R-O-Ar	Alkyl Aryl ether
		1022.2	Weak	R-O-Ar	Alkyl Aryl ether
		812	Weak	C-H	Aromatic Hydrocarbons
		746.4	Medium	$C-H_2$ (bend)	Saturated Hydrocarbons
Ammonium-		2927.7	High	C-H	Saturated Hydrocarbons
Hepta-		2866	High	$C-H_2$	Saturated Hydrocarbons
Molybdate		1602.7	Medium	C = C	Aromatic Hydrocarbons
300 °C	PS	1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons
Contact Time 1hr		1259.2	Weak	R-O-Ar	Alkyl Aryl ether
		1035.7	Weak	R-O-Ar	Alkyl Aryl ether
		810	Weak	-	-
		746.4	Medium	$C-H_2$ (bend)	Saturated Hydrocarbons
Methyl-		2925.8	High	C-H	Saturated Hydrocarbons
Iodide		2854.5	High	$C-H_2$	-
300 °C	PS	2341.4	Med-weak	S-H	Mercaptans
Contact Time 1hr		1602.7	Medium	C = C	Aromatic hydrocarbons
		1456	Weak	C-H (CH_n)	Saturated Hydrocarbons
		744	Medium	$C-H_2$ (bend)	Saturated Hydrocarbons
Hangu Coal		2925.8	High	C-H	Saturated Hydrocarbons
300 °C	PS	2856.4	High	$C-H_2$	Saturated Hydrocarbons
Contact Time 1hr		2331.8	Med-weak	S-H	Mercaptans
		1456.2	Weak	C-H (CH_n)	Saturated Hydrocarbons

confirmed the presence of condensed aromatic structures in the sample under study. A weak peak at 1378 cm^{-1} showed CH_2 bending, while at 720 cm^{-1} presented aromatic character. The study confirmed that sample under study contained condensed aromatic ring compounds.

Crackates Obtained Using No Catalysts

The FTIR of liquid fraction (Fig. 2) displays a strong and broad band at 2923.9 cm^{-1} which shows CH_2, C-H stretching vibration. The other C-H bonds were masked over this band nearby at 2856.4 cm^{-1}. These bands exhibited the aliphatic configurations of the sample. Mercaptans (S-H) stretching was indicated by a broad double band at 2343.4 cm^{-1}. A sharp peak centered at 1456.2 cm^{-1} showed C = C aromatic stretching. A peak at 1375.2 cm^{-1} represented CH_2 bending vibrations, while another peak at 1022.2 cm^{-1} showed CH-alkenes out-of-plane vibration. The band originated at 812 cm^{-1} as well as centered at 744 cm^{-1} showed aromatic CH out-of-plane defused vibration, thereby suggesting orientation of aromatic rings.

The results show that the sample (crackates) was a mixture of alkanes, alkenes, aromatics and mercaptans. The presence of sulfur and nitrogen may be in the rings or in alkyl chains.

Crackates Obtained with Some Clay Type Catalysts

Crackates Obtained with UTIMAC

The FTIR spectrum of the liquid fraction (PS) obtained with UTIMAC (Utmanzai Clay) as catalyst is displayed in Fig. 2 and the information collected is summarized in Table-1. The profile showed medium peaks centered at 3361.7 cm^{-1}, 3396.4 cm^{-1}, 2920 cm^{-1} and 2854.5 cm^{-1}. The existence of these bands was due to CH_3-CH and CH_2-CH stretching, which established the presence of aromatic C-H bonds. A few very weak and ill-developed bands could be seen in the region 700 cm^{-1} 1000 cm^{-1} .Comparing the profile with that of the virgin asphalt, the absence of numerous bands in this region confirmed the cracking of polyaromatic configurations in to mono ring aromatics.

Crackates Obtained with HZSM-5

The FTIR spectrum of the liquid fraction (PS) obtained with HZSM-5 (Fig. 2) features several signals in the region 2800 cm^{-1} to 3000 cm^{-1} with an intense well-developed band centered at 2927.7 cm^{-1}. As aforementioned, these bands were due to CH_3-CH_2, C-H stretching in aliphatic structures. The band could also be seen at 2854.5 cm^{-1}. The presence of these bands evidenced the presence of aliphatic moieties. The bands could also be seen at 2341.4 cm^{-1} and 2360.4 cm^{-1} which showed the presence of conjugated configurations. In the classical mechanism of catalytic cracking, the end products obtained from hydride ion abstraction (facilitated by the catalyst) followed by β-scission were mainly olefins. A medium less intense peak at 1604.7 cm^{-1} showed C = C stretching bond. A band at 1456 cm^{-1} showed aromatic C = C bond, which was confirmed by several other peaks appearing at 875.6 cm^{-1}, 812 cm^{-1} and 746.4 cm^{-1} and could be ascribed to

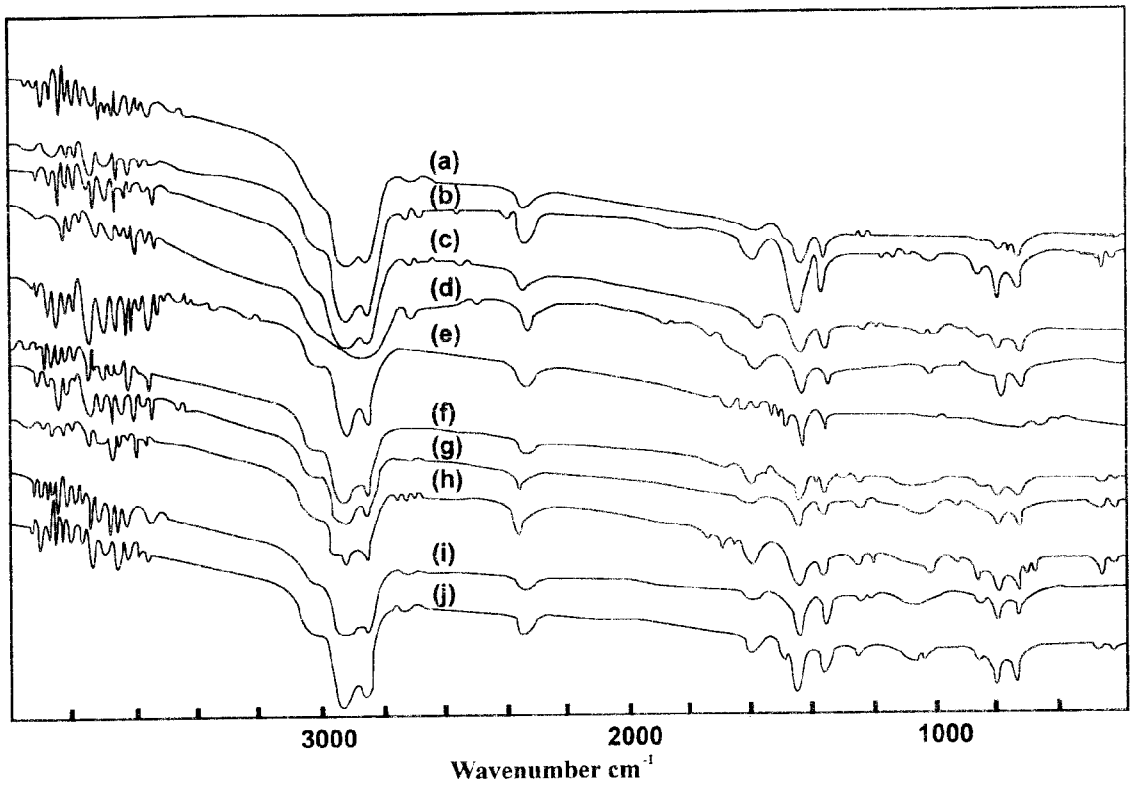

Fig. 2: FTIR Spectra of Various Crackates (PS Fractions)
(a) UTIMAC-assisted charge; (b) HZSM-5-assisted charge; (c) Silica-assisted charge; (d) Sodium Silicate-assisted charge; (e) Phosphotungstic acid-assisted charge; (f) $AlCl_3$-assisted charge; (g) NiO_2-assisted charge ; (h) Ammonium heptamolybdate-assisted charge; (i) Methyl Iodide-assisted charge;(J) Hangu Coal-assisted charge

aromatic C-H out-of-plane bending. A less intense band at 1159.1 cm^{-1} and 1033 cm^{-1} showed C-N stretching in aromatic and aliphatic amines. A band at 698.2 cm^{-1} could be seen, which may have originated due to some impurity. Comparing the profile with the whole asphalt and crackates of UTIMAC, the existence of some bands assigned to aromatics suggested some activity of this catalyst for the sample under study.

Crackates Obtained with Silica

The FTIR spectrum of the crackates (PS) obtained with silica is displayed in Fig. 2. The spectrum exhibits a strong peak centered at 2923 cm^{-1} which showed the presence of CH_3-CH, C-H stretching. A band at 2854 cm^{-1} showed sp^2 C-H stretching. The presence of a band at 1602 cm^{-1} showed the formation of some polar compounds. A peak at 1456 cm^{-1} also showed the presence of unsaturated C-H configurations. A band centered at 746 cm^{-1} mostly originated due to the out-of-plane bending of sp^2 C-H of mono-substituted aromatics.

The sample under study was a mixture of polar saturated and unsaturated compounds along with aromatic hydrocarbons. Comparing the profile with the aforementioned profiles suggested the poor catalytic activity of this catalyst for the sample under study.

Crackates Obtained with Sodium Silicate

The FTIR spectrum of crackates (PS) obtained with sodium silicate is provided in Fig. 2. The presence of peaks at 2928.4 cm^{-1}, 2854 cm^{-1} and 2337 cm^{-1} indicated the presence of aliphatic and naphthenic configurations. The bands at 1456 cm^{-1}

and 1377 cm^{-1} confirmed the C-H of methyl group in aromatic configuration. An absence of bands in the region below 1000 cm^{-1} suggested the conversion of polyaromatic to mono-ring or straight chain configurations. The cracking of this catalyst was observed to be satisfactory in the case of the asphalt.

Crackates Obtained with Some Acid Type Catalysts

Crackates Obtained with Phosphotungstic Acid

The FTIR spectrum showed a similarity with the aforementioned spectrum. A broad intense band at 2920 cm^{-1} and another at 2856.4 cm^{-1} suggested the presence of aliphatics. Band at 2331.8 cm^{-1} showed mercaptans S-H stretching. A broad band centered at 1602.7 cm^{-1} represented polar configuration. A strong peak at 1259.4 cm^{-1} depicted ethereal Ar-O bond, while a broad medium peak at 1035 cm^{-1} represented ethereal R-O linkage, and strong intense peaks at 810 cm^{-1} and 744.5 cm^{-1} highlighted the presence of poly aromatics.

The results conclude that the sample was a mixture containing aromatic ether and aliphatic linkage, in addition to unsaturated alkenes, mercaptans and aromatic substituted compounds. This conclusion infers the least efficiency of this catalyst.

Crackates Obtained with $AlCl_3$

FTIR of crackates (PS) obtained with $AlCl_3$ is provided in Fig. 2. The profile displayed several bands appearing at 2854.5 cm^{-1}, 2331.8 cm^{-1} 1456 cm^{-1} and 1377 cm^{-1}. Some bands could also be seen in the wave number region below 1000 cm^{-1}. A peak centered at 812 cm^{-1} and another at 746 cm^{-1} showed the aromatic character. It can be inferred from the results that the sample contained unsaturated hydrocarbons, containing C = C bands as well as some aromatic configurations.

Crackates Obtained with Some Oxide Catalysts

Crackates Obtained with NiO_2

The FTIR profile of crackates (PS) obtained with NiO_2 is provided in Fig. 2. The bands in the wave number region 2600 cm^{-1} -3000 cm^{-1} were found to be persistent, whereas the bands at 2341.4 cm^{-1} and 2358.8 cm^{-1} showed mercaptans S-H stretching. A weak band at 1699.2 cm^{-1} showed a β-unsaturated C = O mostly of carboxylic acid. While a less intense (medium) peak at 1602.7 cm^{-1} showed the presence of carbonyls, a peak appearing at 1456.2 cm^{-1} showed aromatic C = C bond.

A medium or less intense peak in the region 1259 cm^{-1} showed aromatic C-O stretching and another medium peak at 1022.2 cm^{-1} showed alkyl C-O stretching vibration, suggesting the presence of alkyl-aryl ethers. Two strong or medium peaks centered at 877.6 cm^{-1} and 812 cm^{-1} showed aromatic C-H, out-of-plane bending vibrations.

The above results showed that the sample is a complex mixture of aliphatic and aromatic hydrocarbons, containing carboxylic aids, mercaptans and aryl-alkyl ethers. The catalyst employed was suggested to be a good catalyst for the conversion of the sample in to oxygenated products.

Crackates Obtained with Ammonium Heptamolybdate

The corresponding profile is displayed in Fig. 2. The band centered at 2923.5 cm^{-1} which could be ascribed to CH_3-CH and C-H stretching mostly in aliphatic structures could be seen. Another band centering at 2856 cm^{-1} indicated CH_2, C-H stretching in aliphatic configuration as mentioned earlier, while bands at 2300 cm^{-1} and 2331 cm^{-1} indicated sulfur as S-H. The band at 1600 cm^{-1} showed the presence of aromatic C = C stretching. A peak at 1259 cm^{-1} showed ethereal linkage like aryl C-O stretching and at 1020 cm^{-1} showed allyl C-O stretching. The band at 742 cm^{-1} showed aromaticity. Hence, it is concluded that sample contained aromatic substituted compounds with short and long alkyl side chains. This catalyst proved to be effective in the conversion of asphalt to desirable products.

Crackates Obtained with Modifiers

Crackates Obtained with Methyl Iodide

The FTIR spectrum showed distinct bands at 2925.5 cm^{-1} and 2854.5 cm^{-1} representing the presence of aliphatics. The band at 2341.4 cm^{-1} showed mercaptans S-H stretching. A medium peak at 1602.7 cm^{-1} indicated C = C aromatic vibration, which was further confirmed by another peak at 1456.2 cm^{-1}. A peak at 1377.1 cm^{-1} supported CH_2 bending vibration and another peak at 744 cm^{-1} confirmed CH_2 out-of-plane bending. The sample contained the aliphatic and aromatic hydrocarbon components with sulfur as substituent (mercaptans).

The cracking activity of this catalyst was found to be poor upon comparison with coal as modifier.

Crackates Obtained with Hangu Coal

The FTIR spectrum of sample (PS) was almost similar to that of crackates obtained with methyl iodide and showed peaks at 2925.6 cm^{-1} and 2856.4 cm^{-1}. The bands appearing at 2331.8 cm^{-1}, 1456.2 cm^{-1} and 1377 cm^{-1} were observed to be repetitive. The spectrum suggested the presence of aliphatic and aromatic hydrocarbons contaminated with mercaptans. The disappearance of bands in the fingerprint region suggested the effectiveness of coal in the conversion of polyaromatics into desired products.

Experimental

Collection of Sample

Asphalt was collected from Morgah, Attock Oil Company Rawalpindi, Pakistan. UTIMAC was collected from Utmanzai, Charsadda, Pakistan. Coal was obtained from Hangu District, N.W.F.P, Pakistan. Properties of asphalt and UTIMAC used have been reported elsewhere [13]. Properties of coal used have been reported in our previous paper [14].

Preparation of Samples

The asphalt sample was kept in a sealed container in order to avoid possible oxidation. The crackates and residues were obtained by subjecting the asphalt to thermal and catalytic cracking in a micro autoclave using the method described elsewhere [15]. The whole as well as each of the crackates fractions were further fractionated into pentane solubles and pentane insolubles [16, 17]. Each of the samples was diluted with n-pentane (30:1 by volume) in Erlenmeyer flasks. The flasks were hand shaken (gently) for 30 minutes to completely dispersing all material. After continuous shaking, the precipitated asphaltenes were removed by vacuum filtration through highly retentive Whatman 542 filter paper. The precipitates were rinsed with another 30-ml aliquot of n-pentane to remove any soluble part. The filtrate as n-pentane oil solution was rotary evaporated under partial vacuum at room temperature to remove n-pentane. The precipitates were collected as asphaltenes (PI) and the residuum from rotary evaporator as oil (PS). All the solvents used were of analytical grade (Merck).

FTIR Analysis

The liquid samples were analyzed by FTIR spectrophotometer Model No. FTIR-8201PC (Schimadzu, Japan). KBr pellet for each of the samples was prepared under load and a thin film of the liquid sample was placed upon the surface of the KBr pellet. The analysis was automatically done using special purpose software HYPER IR (Shimadzu). The wavelength range selected was 400-4000 cm^{-1}.

Conclusion

The existence of pronounced bands in the spectrum of the whole asphalt mostly in the wave number range 1200 cm^{-1} -1600 cm^{-1} as well as 700 cm^{-1} - 900 cm^{-1} confirmed that the sample under study was enriched with complex aromatic hydrocarbons in addition to aliphatic, olefinic and naphthenic configurations as evident from the existence of the bands at 2800 cm^{-1}, and 2609 cm^{-1}. The presence of bands corresponding to aromatic configurations in most of the spectra of crackates obtained with catalysts like HZSM-5, silica, phosphotungstic acid, and $AlCl_3$ showed their poor catalytic activities. The appearance of some bands corresponding to polar compounds in some of the spectra of crackates obtained with catalysts like nickel oxide and ammonium-heptamolybdate, confirmed their effectiveness in the conversion of the asphalt into oxygenated compounds. The disappearance of some bands corresponding to aromatic configurations in some crackates obtained with catalysts like UTIMAC and sodium silicate confirmed their effectiveness in yielding useful products from asphalt. Amongst the modifiers used, the effect of coal was promising compared to methyl iodide.

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