



Revisiting the methodology for asphaltenes precipitation

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ABSTRACT

The world increase in energy demand has directed the petroleum industry to exploit unconventional oil reserves such as the Brazilian Pre-Salt reservoirs. Production conditions verified in those reservoirs enhance the occurrence of asphaltene precipitation as well as the correlated problems. Asphaltenes are well known as a solubility class. Such classification makes tough the determination of consistent chemical properties for these compounds. In this scenario, this study aims to analyze the influence of the standard precipitation methodologies upon the asphaltene characteristics. Three oils were selected, which are hereinafter called BR1, BR2, and BR3. Oil BR1 was produced from a Post-Salt reservoir while oils BR2 and BR3 are originated from a Post-Salt one. The asphaltenes were extracted through precipitation by n-heptane according to the ASTM 2007, ASTM 6560 (IP-143), the so-called ASTM 6560 SOHXLET, and the NUESC methodology. Asphaltene fractions were characterized regarding their chemical composition (FTIR) and thermal stability (DSC). The results showed that endothermic events typically registered for compounds which are strange to the commonly accepted asphaltene composition were verified. Also, the degradation temperature varied according to the precipitation method. In turn, the FTIR spectra detected a peak which is usually associated with naphthenic acids (3500 cm^{-1}). Therefore, the FTIR analysis confirmed what was indicated by the thermograms. In summary, it was concluded that the asphaltene fractions that were extracted through the commonly used ASTM 2007 methodology from the Pre-Salt oils were a precipitated complex composed by asphaltenes and wax of naphthenic acids. Thus, the present work results are suggested as a starting point for the analyses of asphaltene properties and their implications on the crude oil behavior.

1. Introduction

The energy industry has registered an ascendant trend on crude oil production and demand throughout the world, mainly from the deep and ultradeep-water reservoirs like those located in the Brazilian Pre-Salt area. It generates technological challenges to be overcome regarding mainly the high carbon dioxide content in such reservoirs. The corrosivity associated with CO_2 production as well as environmental issues related to its release into the atmosphere has resulted in the carbon dioxide re-injection as the best strategy to deal with such issues. Hence, the reservoir recovery factor can be improved once the pressure depletion will be retarded. On the other hand, the increase in carbon dioxide concentration at the reservoir results in crude oil chemical destabilization. Consequently, solid organic deposition may occur due to asphaltene, naphthenates, and waxes precipitation (Mapolelo et al., 2011; Coto et al., 2010; Coppe, 2009; Melo et al., 2011; Hu et al.,

2004). Therefore, further understanding of the interactions between CO_2 and the crude oil fractions is urgently demanded.

To facilitate the comprehension, crude oil is usually divided into 4 classes of compounds: saturates, aromatics, resins and asphaltenes (Bissada et al., 2016). However, the oversimplification of SARA classification has contributed negatively along years to the fully understanding of some physical-chemical phenomena, such as asphaltene and wax precipitation (Czarnecki, 2009). In this scenario, the stability of organic molecules under variation of thermodynamic conditions during the petroleum production had been considered isolatedly for each SARA class of compound (Japper-Jaafar et al., 2016; Zhao et al., 2015; Bertheussen et al., 2017; Balestrin et al., 2017; Arya et al., 2016). Recently, a paradigm shift occurred (Rudyk, 2018; Sun et al., 2017). Researchers started looking towards the interaction effect among the SARA compounds which can lead to asphaltene-wax-salt coprecipitation, for instance (Sun et al., 2017; Yanes et al., 2018; Lei et al., 2016; Li

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et al., 2016; Ruwoldt et al., 2018; Fatani et al., 2017; Doryani et al., 2018; Ganeeva et al., 2016; Ashoori et al., 2016).

Specifically, asphaltene molecules are the result of bacterial metabolism during crude oil biodegradation (Bailey et al., 1973). Since there are a register of millions of bacteria species throughout geological time around the world, each petroleum reservoir presents a different molecular structure of asphaltenes (Mora et al., 2011). Due to such a molecular diversity, asphaltenes are not a chemically well-defined group but generally identified as a solubility class. Thus, they are classified as the group of compounds from the low volatility portion of petroleum that are soluble in aromatics and not solubilized by n-alkanes. Although this classification is not exact, it is convenient and offers enough chemical restrictions which are chemically and technically useful. Also, the asphaltene molecular structure has been considered to have two configurations: island and archipelago. The island architecture is a core group of condensed aromatic rings with peripheral aliphatic branches. In turn, the archipelago one has aliphatic bonds linking the aromatic groups (Mullins et al., 2012). Recent advances in molecular characterization may contribute to an end of the so far controversial matter regarding asphaltene's molecular architecture. For instance, Schuler et al., 2015 used atomic force microscopy to show that island structures are likely more stable (Schuler et al., 2015). On the other hand, Rüger et al. (2018) suggests the predominance of archipelago-type structure by using mass spectrometry coupled to different thermal analysis (Rüger et al., 2018). Finally, Chacón-Patiño et al. (2017) and Chacón-Patiño et al. (2018) highlighted through FT-CIR MS analysis that both island and archipelago molecular architectures are verified in asphaltene fractions. The dominant structure is sample dependent (Chacón-Patiño et al., 2017; Chacón-Patiño et al., 2018; Chacón-Patiño et al., 2018).

Once asphaltenes have the higher polarizability among the crude oil chemical components, it results in a huge self-aggregation propensity. According to Mullins et al. (Mullins, 2010), the aggregation phenomena is ruled by asphaltene concentration. Thus, the asphaltene molecules originate nanoaggregates of stacked aromatic cores by π - π interactions that become clusters at the so-called critical nanoaggregate concentration. Further, Gray et al. (2011) proposed an alternative paradigm which says that the asphaltene aggregation is explained by the supramolecular assembly theory. Therefore, in addition to π - π interactions between aromatic rings, the hydrogen bonding, acid-base interactions, metal coordination complexes, and hydrophobic pockets composed by alkyl and cycloalkyl groups, all combined, must contribute to the asphaltene instability.

Also, variation of thermodynamic conditions such as temperature, pressure, and composition during petroleum production favors the asphaltene flocculation and consequent precipitation. Despite the current phenomenological debate around the asphaltene issue, it is well established that its aggregation level dictates the potential to generate several problems for the petroleum industry (Durand et al., 2009; Abedini et al., 2011). Among such problems it is worth mentioning the stabilization of emulsions, viscosity increasing, plugging of pipelines and equipments, and wax precipitation. The mitigation strategies applied so far are technical and ecological costly due to high solvent consumption as well as short maintenance time. Therefore, the inhibition of asphaltene precipitation stands as the most advantageous way to deal with the asphaltene issue (Hashmi and Firoozabadi, 2013). In this scenario, the thermodynamic inhibition strategy arises. Thus, to study the flocculation process and the thermodynamic conditions in which it occurs, crude oil model systems are required as a way to overcome the limitations of analyzing asphaltene stability in such a complex system as crude oil.

Thereby, the extraction and purification of asphaltene aggregates becomes a preponderant factor for any relevant conclusion. Garreto et al. (2013) highlighted that longer chain lengths for alkyl flocculant agents precipitate more polarizable and self-aggregating asphaltenes (Gareto et al., 2013). Such variations occur due to the resin washing

extent which is related to the flocculant type. Nevertheless, the ASTM 6560 also known as IP-143 is a standard methodology for determining asphaltene content in crude oil, which is also used to extract them for the studies development with oil model systems. Notwithstanding, authors worldwide have typically precipitated asphaltene through oil dissolution by n-alkane with the n-alkane/oil ratio of 40:1, hereafter referred to as NUESC methodology (Daaou et al., 2015). According to Wang et al. (2010), this methodology results in a maximum asphaltene yield, reason why it is largely reproduced throughout the world. However, it considers the asphaltene stability issue in a simplistic way, since all asphaltene types are then gathered as one similar molecular aggregate. Most recently, some efforts have been made on the development of a precipitation and purification methodology that allows the obtention of asphaltene particles without the co-precipitation of malthenic fractions. For instance, Yarranton et al. (2013) developed a modification of the ASTM 2007 method and reported the size distribution of the obtained asphaltenes. Further, Chacón-Patiño et al. (2016) and Rüger et al. (2018) reported the efficiency of a cleaning/maceration procedure. In turn, this work aims to contribute to the improvement of asphaltene precipitation methods by highlighting what is generally not considered by most of the publications: the compositional difference of asphaltene aggregates precipitated by the very used methodologies such as ASTM 6560, ASTM 2007, and NUESC.

2. Experimental

2.1. Materials

Three Brazilian crude oils were selected for this study, which are hereinafter called BR1, BR2, and BR3. Oil BR1 was originated from a Post-Salt reservoir while oils BR2 and BR3 were produced from Pre-Salt ones. n-Heptane (99%) and toluene (99.9%) were provided by Sigma-Aldrich®. The oil properties are presented in Table 1.

2.2. Experimental procedure

2.2.1. Asphaltene precipitation

The asphaltene fractions were extracted from the selected crude oils through precipitation by n-heptane according to four methodologies: ASTM 6560, ASTM 6560 – SOXHLET, NUESC, and modified ASTM 2007. In summary, as can be seen elsewhere (American society for testing and materials, 2013; Determination of asphalte, 2001), for the ASTM 6560 method a mass portion of crude oil was mixed with a volume of the precipitant agent and kept under hot reflux in a Soxhlet apparatus. The mixture was filtered by using a Whatman® filter paper (grade #2, $\Phi = 25$ mm). Thus, the solid fraction was washed with hot heptane also under reflux to remove any maltenes residue from the asphaltene particles until the solvent got colorless. The asphaltenes was separated from the co-precipitated inorganic material by hot toluene dissolution.

The modified ASTM 2007 method recommends precipitating asphaltenes by solubilizing crude oil with pentane in a pentane/crude oil

Table 1
Crude oil properties.

Properties	Oil			
	BR1	BR2	BR3	
Kinematic viscosity (mm ² /s) (20 °C)	100.20	17.93	36.99	
BSW (%)	0,65	1,40	2,65	
TAN (mgKOH/g)	0,82	3,38	3,83	
SARA composition	Saturates (%)	45.80	52.20	53.80
	Aromatics (%)	32.20	21.10	10.70
	Resins (%)	17.70	22.20	34.70
	Asphaltenes (%)	4.30	1.50	0.80

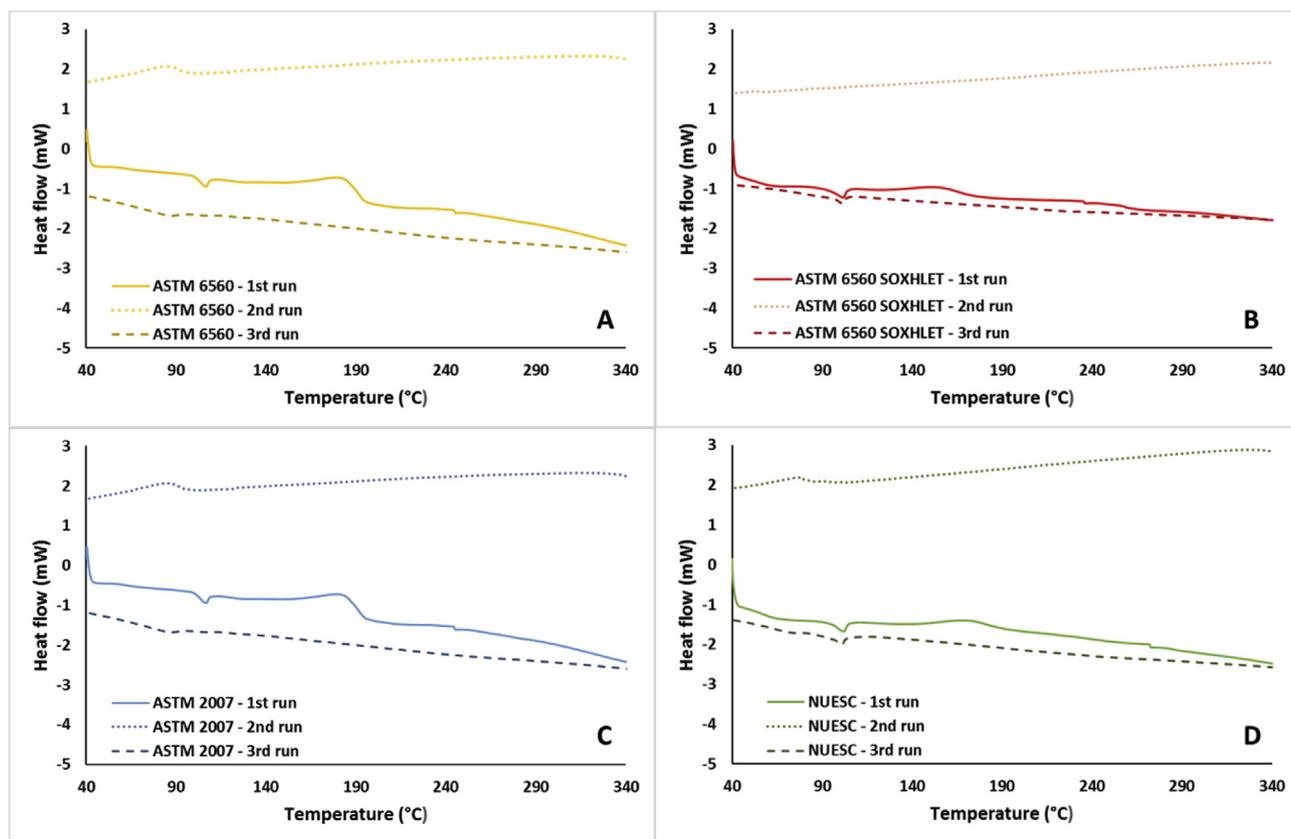


Fig. 1. DSC thermograms for the asphaltene fractions precipitated from oil BR1 through the ASTM 6560 (A), ASTM 6560 – SOXHLET (B), ASTM 2007 (C), and NUESC (D) methodologies.

ratio of 10/2 (v/w), then warming the mixture while stirring it. The solution must be left to stand at room temperature for 30 min and filtered, using the filter with small portions of pentane. However, this work used the modification suggested by Alboudwarej et al. (2002) (Alboudwarej et al., 2002). Such modification replaced pentane by n-heptane as the precipitant solvent in a ratio of 40/1 (v/m). Thus, solutions of crude oil (40 g) and n-heptane (1600 mL) were prepared. Also, by following the proposed modification solutions were sonicated for 60 min or until complete dissolution and then kept under rest at room temperature for 24 h. The filtration was performed in two stages. The same grade #2 filter paper Whatman® was used. Around 1200 mL of the solution was filtered in the first stage. Then, 10% of the initial volume (160 mL) of n-heptane was added to the solution to wash the remained precipitated. It was sonicated for 45 min. After 18 h of resting the second filtration step was performed. The filtered cake was washed with n-heptane for 5 days or until the solvent got colorless. It was made in order to take out the resins trapped into the asphaltene particles. The asphaltene content was registered by gravimetry and the precipitated was purified using toluene. Details of the purification process are explained in Powers et al. (2016)

The NUESC methodology, the simplest one, consists of solubilizing the mixture n-heptane + crude oil in a ratio of 40/1 (v/w) through magnetic stirring for 4 h. The solution is left to stand overnight and then filtered using the same filter paper already mentioned. Then, the filter cake is left to dry out in a fume hood, recuperated and properly stored. In turn, the ASTM 6560 – SOXHLET is a combination of both methodologies: ASTM 6560 and NUESC. In that way, asphaltene were precipitated according to all the NUESC procedure and purified by washing it with hot n-heptane and toluene through a Soxhlet apparatus as suggested by the ASTM 6560 method.

Also, the asphaltene precipitated from the oils BR2 and BR3 through the ASTM 2007 methodology were purified by the herein

called ASF 2017 method based on Chacón-Patiño et al. (2016). In summary, the precipitated asphaltene particles were macerated and washed with hot heptane under reflux through Soxhlet apparatus during 5 h for 4 times. Then, the purified asphaltene fraction was dried in an oven, collected, and analyzed.

2.2.2. Asphaltene characterization

The asphaltene fractions were characterized regarding their chemical composition through FTIR and elemental analysis (CHN) as well as their thermal stability through DSC. A differential scanning calorimeter Q20 coupled with a refrigerated cooling system model 40 from TA Instruments was used for the thermic analysis. The samples were placed in hermetically sealed aluminum pans and heated from 30 to 350 °C with a heat rate of 10 °C/min. In turn, a Fourier-Transform Infrared Spectrophotometer equipped with an attenuated total reflectance probe model CARY 630 (Agilent Technologies®) was used for the analysis of chemical composition. It operated in the transmittance mode at the wavenumber range from 650 cm^{-1} to 4000 cm^{-1} . The elemental analyses were carried out by using a Truspec 630-200-200 through infrared absorption as the detection method for carbon and hydrogen as well as thermic conductivity for the nitrogen detection.

3. Results and discussions

During the development of a parallel study it was observed that the precipitated asphaltene showed different visual aspects according to the precipitation methodology. Thus, further investigations were carried out to identify those differences. Firstly, the comparison of asphaltene thermograms obtained through DSC analysis were performed. Secondly, FTIR spectra were collected for each asphaltene fraction from the studied crude oils and compared.

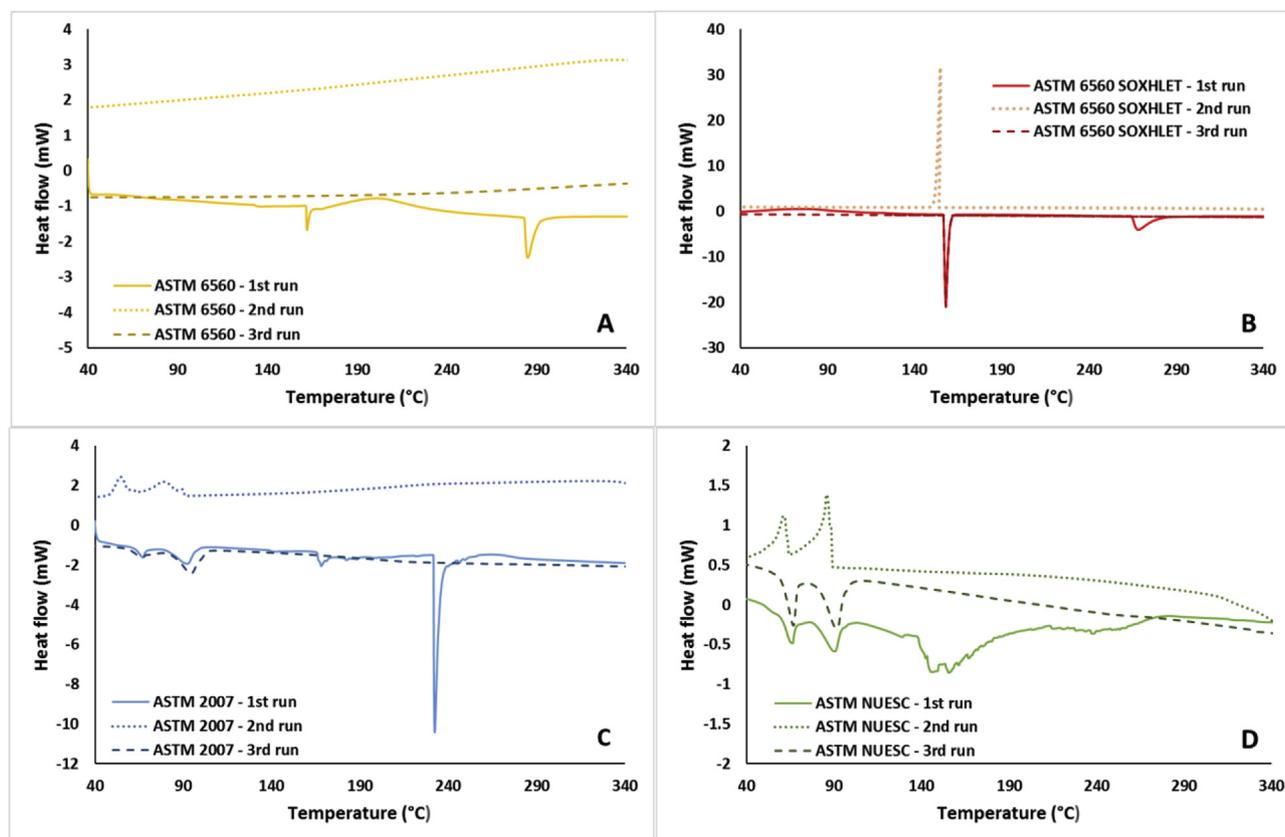


Fig. 2. DSC thermograms for the asphaltene fractions precipitated from oil BR2 through the ASTM 6560 (A), ASTM 6560 – SOXHLET (B), ASTM 2007 (C), and NUESC (D) methodologies.

3.1. DSC analysis

Fig. 1 shows that the asphaltene samples extracted from oil BR1 had the very same thermic stability despite of the used extraction methodology. As one may see, there is an endothermic peak at about 100 °C which could be related to both the evaporation of volatile components or asphaltene glass transition, as suggested by Zhang et al. (2004) (Zhang et al., 2004). Nonetheless, the use of hermetically sealed pans as well as the observed baseline shift reinforces the occurrence of glass transition (Zhang et al., 2003). Further, an endothermic event related to chemical degradation was verified at the temperature around 245 °C in which the asphaltenes become tarlike (see Fig. 1).

On the other hand, when one looks at the thermograms of the asphaltenes obtained from oil BR2, a different behavior can be observed regarding the extraction method. Firstly, a relatively small endothermic peak is verified at 135 °C which is followed by a bigger one at around 160 °C for the ASTM 6560 methodology (Fig. 2A). They result from the morphological reorganization and glass transition phenomena, respectively. It was confirmed by the peak absence in the 2nd and 3rd runs. These events were also detected for all the BR2 asphaltenes with a minimal temperature variation. However, two endothermic peaks are present at temperatures of 65 °C and 90 °C for the asphaltenes precipitated through the ASTM 2007 and NUESC method. It was generated by the melting of micro and macrocrystalline complex waxes that likely co-precipitated with the asphaltenes. The peak shapes which are related to the enthalpy of melting as well as the transition temperatures suggest that those waxes are composed of long-chain molecules such as dotriacontane and cyclohexanonacontane (Drotloff and Möller, 1987; Fleming et al., 2018). Also, the asphaltene degradation temperature was reduced in 30 °C when comparing the methodologies from ASTM 6560 to ASTM 6560 – SOXHLET and further to ASTM 2007. It seems to be caused by the presence of lighter compounds in the asphaltene

fractions that degraded at lower temperatures. For the asphaltenes precipitated through the NUESC method not well-defined peaks were registered at around 150 °C.

The same endothermic events were registered for the BR3 asphaltenes extracted through the ASTM 6560 – SOXHLET (Fig. 3B) and ASTM 2007 (Fig. 3C) methodologies when compared to the BR2 ones. However, the occurrence of an exothermic peak in the 2nd run followed by an endothermic one in the 3rd run at the temperature of 157 °C suggests the melting event of co-precipitated maltenes in the ASTM 6560 SOXHLET asphaltenes. Also, Fig. 3A shows that a unique broad peak was verified for the ASTM 6560 precipitated asphaltenes from the same oil BR3. It is not clear whether a higher enthalpy was demanded by the glass transition or if it was immediately followed by the asphaltene degradation. However and more relevant, such peculiarity highlights the composition variation of such asphaltenes, which is the goal of the present work. Furthermore, the BR3 asphaltenes resulted from the NUESC precipitation methodology showed the presence of co-precipitated complex waxes as verified for the oil BR2. Also, the glass transition for this sample occurred at 120 °C and was followed by a sequence of not well-defined peaks that denotes the presence of impurities in the asphaltene fraction.

Therefore, it becomes clear by the variation in thermic stability that the studied precipitation methods generate asphaltene particles with distinct composition. Hitherto, reports have compared the influence of precipitant solvents on the asphaltene characteristics (Luo et al., 2010; Oliveira et al., 2018). This work, otherwise, highlights the relevance of the precipitation method which has been ignored when studying asphaltene properties and their implications upon crude oil flow assurance issues.

Howsoever, the exhaustive cleaning/maceration procedure suggested by Chacón-Patiño et al. (2016) for purification of asphaltene fractions stands as a promise solution. It was used on the asphaltenes

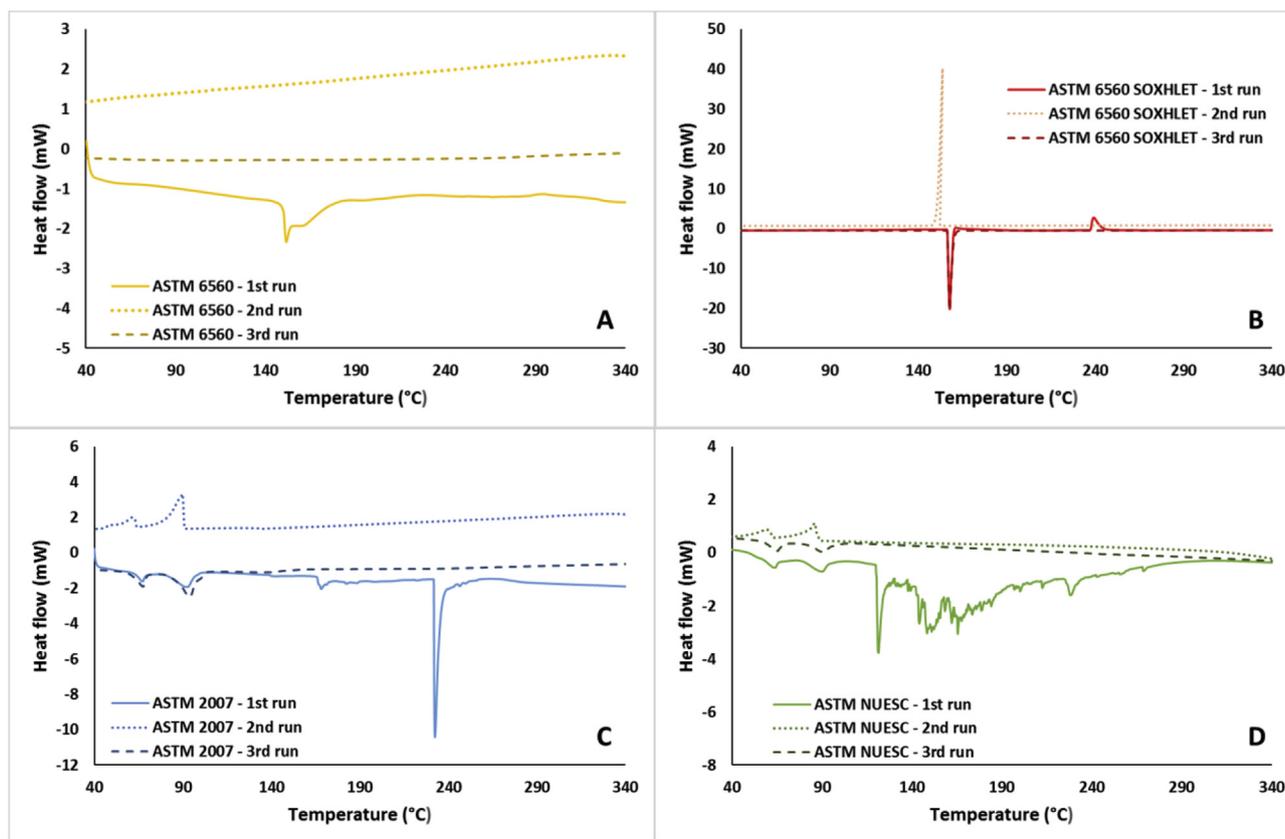


Fig. 3. DSC thermograms for the asphaltene fractions precipitated from oil BR3 through the ASTM 6560 (A), ASTM 6560 – SOXHLET (B), ASTM 2007 (C), and NUESC (D) methodologies.

extracted from oils BR2 and BR3 through the ASTM 2007 method since they showed a larger number of thermic events and the so-correlated impurities. As one may see, Fig. 4(C) and (D) highlights that all the previously verified peaks are missing after the asphaltene purification. Only one broad peak was detected at a temperature of around 80 °C in greater extent for the asphaltenes extracted from oil BR2 (Fig. 4 (D)). Once such event was noticed only in the 1st run and not repeated in the sequent heating step (3rd run), it must be related to the morphological reorganization of asphaltene aggregates or the light compounds still occluded in them. These results are in accordance with was recently reported in the literature. Rürger et al. (2017) related that malthenic species remained trapped in the asphaltene aggregates even after Soxhlet purification of the asphaltenes precipitated through the ASTM 6560 method (Rürger et al., 2017). Afterward, Rürger et al. (2018) analyzed the efficiency of the so-called Chacón-Patiño asphaltene purification method through distinct thermal analyses. They showed that the purified asphaltene particles by such method were devoid of mathenic co-precipitates (Rürger et al., 2018).

3.2. FTIR analysis

The FTIR spectra also highlights the differences and similarities between the asphaltene fractions precipitated by each precipitation methodology. Fig. 5 shows the spectra for the oil BR1. The sharp double peaks at wavelength of 2920–2850 cm^{-1} as well as the medium one at 1460 cm^{-1} are related to the stretching of the C-H bond in alkanes. The peak at 1380 cm^{-1} is resulted from the bending of methyl. Further, the presence of sulfoxide chemical group was verified through the peak at 1030 cm^{-1} (Wilt et al., 1998). The presence of aromatic compounds is confirmed by the four small peaks at the lower wavelengths (870, 807, 745, 729 cm^{-1}). All those peaks are typically verified in asphaltene aggregates and did not seem to differ when comparing the precipitation

method for the oil BR1 (Asemani and Rabbani, 2016). Further, the elemental analysis (Table 2) shows that the relatively low hydrogen/carbon ratio was the same for all the asphaltene fractions but the one extracted through the NUESC methodology. This one, specifically, showed to have a less aromaticity level. Also, the similar increase in the nitrogen content for the asphaltenes is consistent with the ones reported in the literature (Chacón-Patiño et al., 2016; Marcano et al., 2011; Zheng et al., 2017).

The same typically asphaltene-related peaks were verified for the oils BR2 and BR3, as can be seen in Fig. 6. However, one must notice the appearance of a broad peak at the wavelength of 3400 cm^{-1} , which is related to the stretch of the hydroxyl radical. Once there was no water in the analyzed asphaltenes, such hydroxyl was then related to precipitated molecules. Thus, the hydroxyl presence was addressed to the presence of co-precipitated naphthenic acids due to the considerable total acidity number of those oils (Table 1). Also, the presence of a sharp and well-defined double peak at 720-730 cm^{-1} denotes the presence of a hydroxyl bonded to a CH_2 group. Further, the detection of a carbonyl bond stretching by the peak occurrence at 1630 cm^{-1} confirms the co-precipitation of a complex aggregate composed by both asphaltenes and naphthenic acids.

The inference is reinforced by the melting event of complex wax crystals detected in the thermograms at the lower temperatures (65 °C and 90 °C). Nonetheless, it was verified only for the so-called ASTM 2007 and NUESC asphaltenes from oils BR2 and BR2. However, it is worth highlighting that the asphaltene degradation temperature increases as the harshness of the precipitation method was enhanced. Hence, a lower number of carboxylic molecules should be verified in the precipitated fraction of the harsher method. It matches with the reducing of hydroxyl peak transmittance as going from the ASTM 6560 SOXHLET to the ASTM 6560. Further, this peak was reduced in the asphaltenes precipitated by the NUESC method.

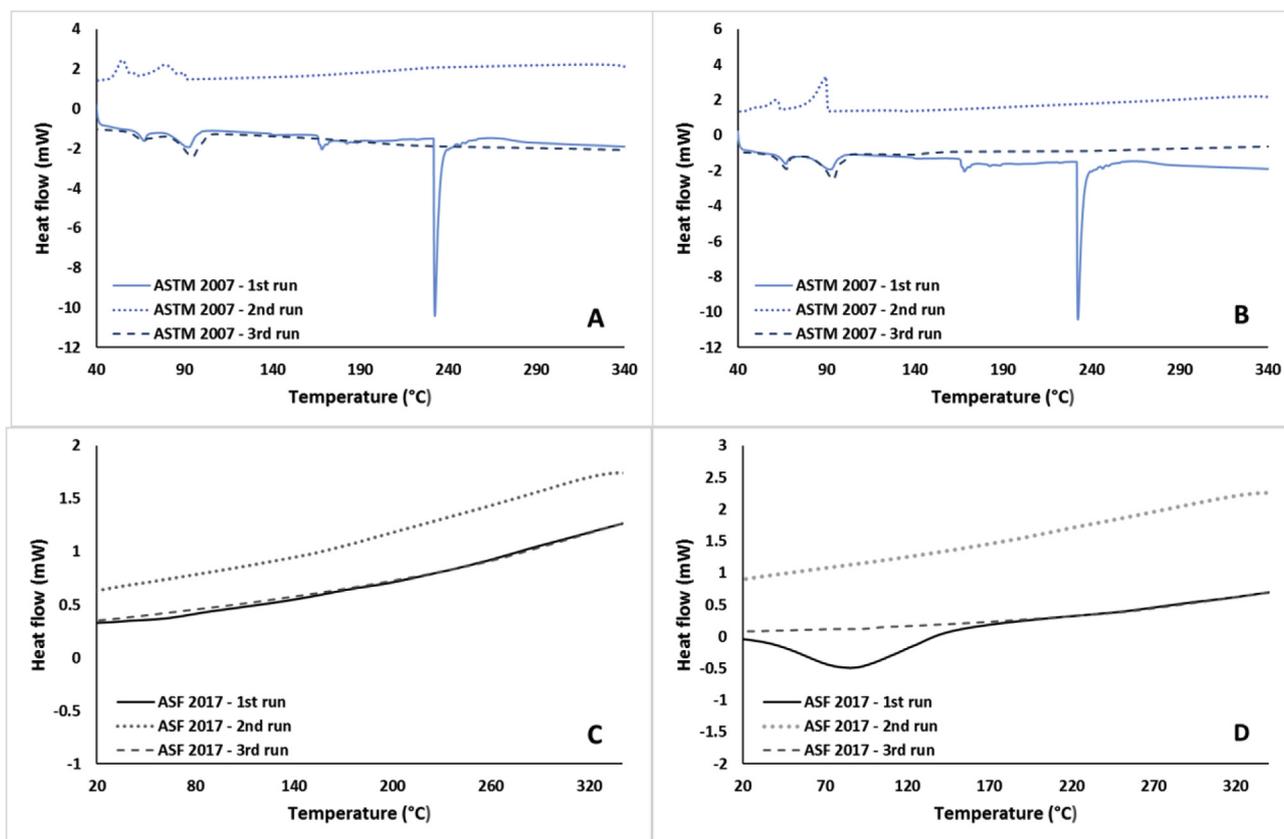


Fig. 4. DSC thermograms for the asphaltene fractions precipitated from oil BR2 (A) and BR3 (B) through the ASTM 2007; and thermograms for the same fractions from oil BR2 (C) and BR3 (D) after the exhaustive cleaning procedure suggested by Chacón-Patiño et al. (2016).

The elemental analysis showed in Table 3 confirm what was evidenced by both the FTIR spectra and the thermograms. One may see that the NUESC asphaltenes had a lower carbon content and consequent higher H/C ratio. Also, a too low nitrogen content was verified for the same asphaltene fractions extracted from both oils BR2 and BR2, which is not expected for typical asphaltene aggregates. The ASTM 2007 asphaltenes showed the same characteristic but in less extent. When comparing the elemental composition of the ASMT 6560 SOXHLET and ASTM 6560 asphaltenes from the mentioned oils, one may see that they showed different trends according to the oil. The carbon content, as well as the nitrogen content, was reduced as the extraction harshness

Table 2
Elemental analysis for the whole oil and asphaltene fractions for the oil BR1.

Samples	C (%)	H (%)	N (%)	H/C
BR1 Whole oil	86.40	11.96	0.19	0.14
NUESC	83.56	8.70	1.60	0.10
ASTM 2007	93.55	7.83	1.77	0.08
ASTM 6560 SOXHLET	93.64	7.65	1.76	0.08
ASTM 6560	91.85	7.43	1.88	0.08

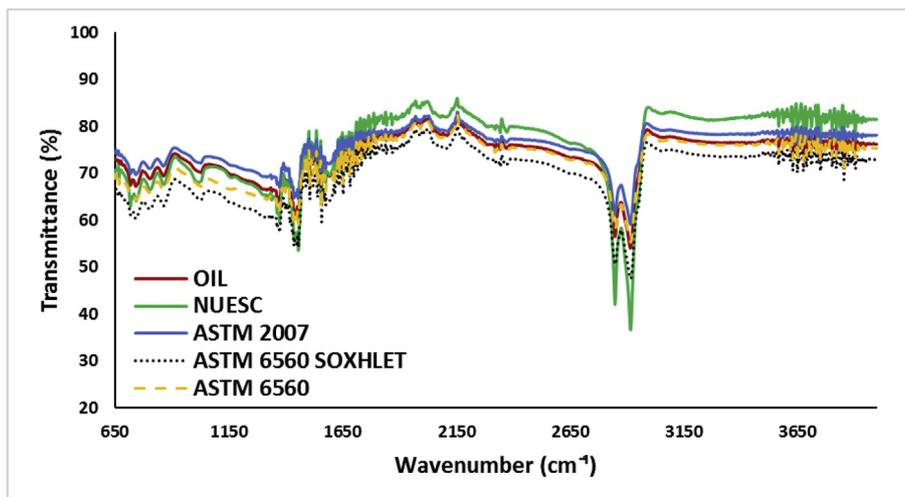


Fig. 5. FTIR spectra for the asphaltene fractions precipitated from oil BR1 through the NUESC, ASTM 2007, ASTM 6560 – SOXHLET, and ASTM 6560 methodologies.

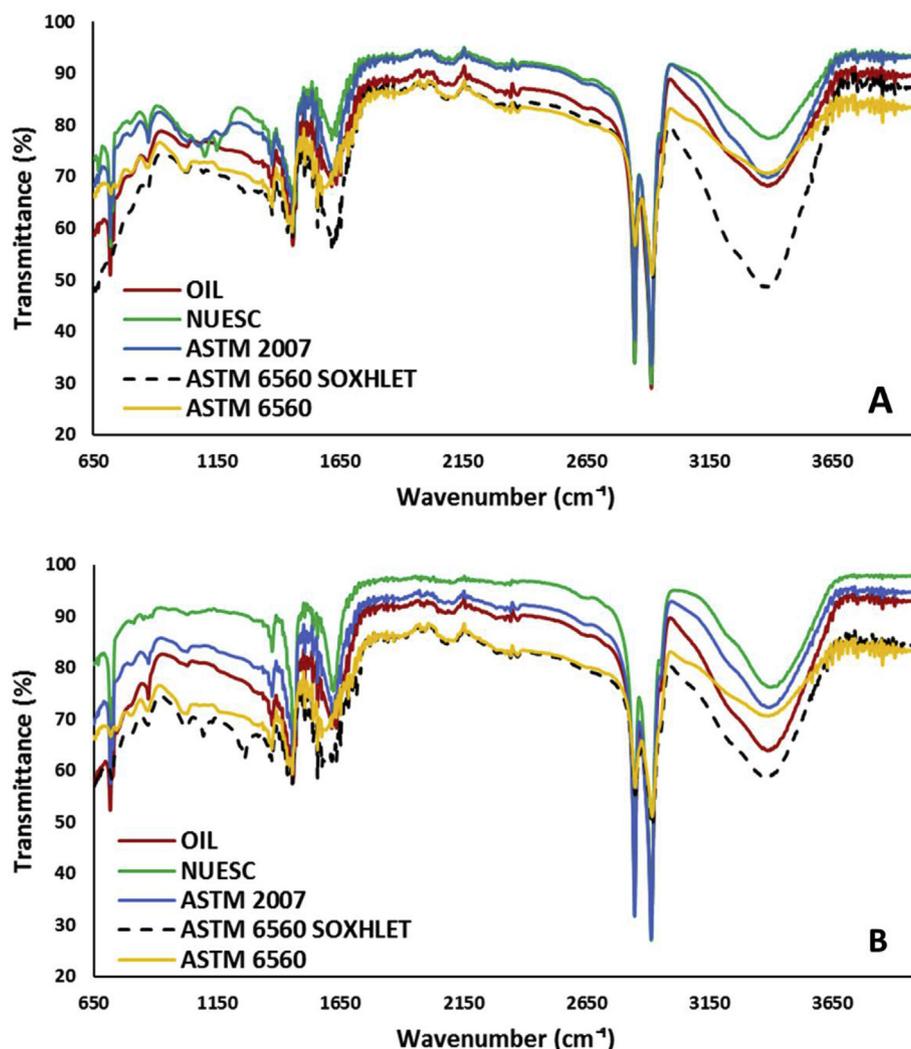


Fig. 6. FTIR spectra for the asphaltene fractions precipitated from oil BR2 (A) and BR3 (B) through the NUESC, ASTM 2007, ASTM 6560 – SOXHLET, and ASTM 6560 methodologies.

Table 3

Elemental analysis for the whole oil and asphaltene fractions for the oils BR2 and BR3.

Samples		C (%)	H (%)	N (%)	H/C
BR2	Whole oil	83.28	12.40	0.20	0.15
	NUESC	43.04	9.43	0.30	0.22
	ASTM 2007	60.73	9.66	0.69	0.16
	ASTM 6560 SOXHLET	94.41	7.43	1.91	0.08
	ASTM 6560	77.76	7.29	1.53	0.09
BR3	Whole oil	80.63	12.22	0.19	0.15
	NUESC	25.20	6.60	0.10	0.26
	ASTM 2007	52.33	9.42	0.58	0.18
	ASTM 6560 SOXHLET	65.27	6.68	1.41	0.10
	ASTM 6560	81.84	7.25	1.82	0.09

was improved for the oil BR2 and the opposite effect was verified for the oil BR3. It seems that such difference is related to the whole oil composition showed in Table 1.

Hence, all the presented analysis confirms that changing the precipitation method can result in distinct asphaltene fractions. Overall, since the chemical composition rules the asphaltene behavior propensity as a deposition component or a surfactant-like, the publication conclusions may depend on the method used to isolate the asphaltenes in those studies developed with model systems (Lache et al., 2012).

4. Conclusions

This study showed that the asphaltene fractions precipitated from two Pre-Salt oils consisted of a complex particle which is composed by both asphaltene and naphthenic acids aggregates. Overall, it highlighted that the chemical characteristics of isolated asphaltenes may be directly dependent on the used precipitation method not only the precipitant solvent, as largely reported. Henceforth, the authors suggest that the future published results regarding asphaltenes in model systems should be linked to the asphaltene extraction method.

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