

A STUDY OF MAGNETIC EFFECTS ON THE PHYSICO-CHEMICAL PROPERTIES OF INDIVIDUAL HYDROCARBONS

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Keywords: magnetic treatment, hydrocarbon, IR and UV spectra

INTRODUCTION

There have occurred a great number of experimental studies which present evidences of the benefits of magnetic treatment on many occasions. Some eye-catching proto-industrial examples ever reported include: the enhancement of oil recovery[1] and prevention of wax deposition[2-4] in petroleum production, transportation and refining; the improvement of fluidity of crude oils[5-7], and the demulsification of oil-water mixtures[1,8]. Even for motor vehicles and industrial boilers, much fuel economy and noticeable soot suppressions could be approached when the magnetic treatment was introduced[9-11]. Over the last decade or so, the magnetic treatment, as a novel technique with great economic potentiality, has been strenuously exploited and widely adopted in the domain of petroleum chemical engineering. However, there remain some blurring issues waiting eagerly for early answers, with the core of the uncertainties being the unfolding of the molecular interaction mechanism(s) governing the macro-behaviors of the magnetically treated hydrocarbons and fuels. In our study, focus has been laid on the understanding of magnetic action modes which have led to the fuel economy and soot abatement in engine applications.

In the present research, measurement was made about the properties of some typical individual hydrocarbons such as viscosity, surface tension and maximum smokeless flame height(MSFH) after they have been treated in the magnetic fields of different intensities. The IR and UV spectra of the magnetized hydrocarbons were employed to elucidate the property changes in terms of molecular structures.

EXPERIMENTAL

An electromagnet of double yokes was devised and utilized. Each of its two poles is 80mm in diameter and the distance between the poles is 11mm. The intensity of the magnetic field was displayed by a Tesla gauge of CT3 type and could be adjusted from 0 T to 1.0 T.

An L-type quartz glass tube of 10mm in diameter was positioned in the center of the magnetic field. The tube had a rotatable piston in one end just like that of the acid buret to be used to control the flowing rate of liquid samples. In the experiment, the liquid samples of individual hydrocarbons were conducted into the glass tube and flowed transversely through the magnetic field to be magnetized at the rate of 7.5 ~ 10.0ml per minute.

The individual hydrocarbons selected were as follows: n-heptane, n-hendecane, n-hexadecane, cyclohexane, methylcyclohexane, toluene, m-xylene, n-butylbenzene and isopropylbenzene. All of them were in analytical pure. The UV analytical samples were the n-heptane solution of individual aromatic hydrocarbon.

After being magnetized the sample was immediately tested at room temperature in strict accordance with China National Standard Test Method of Petroleum Products. For comparison, measurements were also made on the same untreated samples. Of the tests, the viscosity was determined with a capillary viscosimeter, and the surface tension with the DuNouy ring method described in previous studies[12,14]. The MSFH was measured on an apparatus specified by GB5539-86. In data processing, suspected data were judged with the statistic method of t-check test.

The HITACHI 260-50 type IR spectrometer was employed; its sample cell was KBr crystal. The UV spectra were measured on a UV spectrometer of LAMBDA-Q type, and the sample cell was 1cm in width. In the analysis procedure, blank tests were conducted to adjust the absorbance of n-heptane in UV region to be equal to zero for measurement of the real absorbances of each of the tested individual hydrocarbons.

RESULTS AND DISCUSSION

In Figure 1 is listed the changes of the viscosities of three magnetized normal paraffinic hydrocarbons. As is easily seen, there occur slight decreases of the viscosity of the magnetized normal hydrocarbons. The magnitude of the change becomes larger as strength of the magnetic field increases, with more obvious change pace below 0.3T than above 0.3T. Such a phenomenon is very similar to those of the magnetized petroleum fuels[13]. It can also be noticed that, approximately below 0.2T, the viscosity decreases of the studied normal paraffinic hydrocarbons

are almost the same while above 0.2T, they are different and follow the order of n-hexadecane > n-hendecane > n-heptane. In other words, the more the carbon numbers of the normal paraffinic hydrocarbons, the more obvious of the decrease rate of their viscosity after magnetized.

Figure 2 shows the viscosity decrease of the magnetized methylcyclohexane and cyclohexane. It is apparent that the viscosity decrease of the magnetized cycloalkanes also becomes bigger with the increase of the applied magnetic field. Comparatively, the viscosity decreases more rapidly below 0.2T than above it, a very resemblance to those identified for the normal paraffins stated above.

Figure 3 displays the viscosity decreases of aromatics such as n-butylbenzene and m-xylene. Evidently, similar features to those of normal paraffins and cycloalkanes have been demonstrated between their viscosity decrease rates and the strength of the applied magnetic fields. It can be observed that there occur rapid decreases of viscosity below 0.5T, while above 0.5T the decrease of the viscosity becomes more and more slowly with the increase of the magnetic field strength. This indicates that the decrease of the viscosity of the magnetized individual hydrocarbons is not directly proportional to the strength of the applied magnetic field.

Figure 4 displays the relationship between the decrease rates of the surface tension of magnetized n-octane and the applied magnetic intensities, and Table 1 lists the decrease magnitudes of the surface tensions of n-hexadecane, cyclohexane and isopropylbenzene. The results show that, after magnetized, the surface tension of the individual hydrocarbons decreases. However, the decrease rates or the decrease magnitudes do not increase accordingly very well as the strength of the magnetic field increases. At some certain magnetic fields, the surface tension decreases comparatively considerably while at others it decreases comparatively unnoticeably. So, it can be easily concluded that the surface tension of the individual hydrocarbons decreases fluctuately with the increase of the magnetic field strength.

The value of surface tension is determined not only by molecular attraction force but also by molecular orientation state on the liquid surface[15]. It is suggested that the oriented distribution state of hydrocarbon molecules on the liquid surface must have changed after they have been magnetized, and that the oriented distribution state must have changed differently at different magnetic field strength. This can result in high decrease rate of surface tension compared with that of viscosity, and the fluctuation of the decrease of surface tension.

Table 4 exhibits the changes of the MSFH of magnetized toluene and its mixture with n-heptane and methylcyclohexane. It is shown that, after being magnetized, the MSFH of the individual hydrocarbons rises with the increase of the magnetic field strength. This indicates that soot formation has been suppressed after the hydrocarbons are magnetized, implying that the combustion efficiency of the hydrocarbons has been improved.

Theoretical researches have been done to unfold the magnetization mechanism of hydrocarbons. It is proposed that the magnetic treatment can depolymerize molecular aggregates of hydrocarbons in normal conditions[16,17]. In the present study, the molecular structure changes of the magnetized hydrocarbons were analyzed which could reveal the mechanism of the changes of the above physico-chemical properties in terms of microstructure.

From Figure 5 it can be easily seen that, after 1,3,5-trimethyl benzene is magnetized at 1.0T, the absorption peaks of its methyl stretching vibration ($2860\text{cm}^{-1} \sim 2920\text{cm}^{-1}$), skeleton vibration of aromatic ring ($1456\text{cm}^{-1} \sim 1616\text{cm}^{-1}$), methyl symmetrical deformation vibration (1384cm^{-1}), in-plane bending vibration of $\text{C}=\text{CH}$ (1035cm^{-1}), out-of-plane bending vibration of $\text{C}=\text{CH}$ (840cm^{-1}) and out-of-plane vibration of aromatic ring (685cm^{-1}) all shift toward higher wavenumber regions. Also, the peaks of the overtone and combination bands in the region of $2000\text{cm}^{-1} \sim 1660\text{cm}^{-1}$ due to the C-H out-of-plane deformation vibrations are clearly observed in the higher wavenumber regions. Since the frequency is determined by the energy difference between the excited vibration state and the ground vibration state, the vibrational energy levels of above groups must have changed. Because the molecular attraction energy (Vl) of nonpolar hydrocarbon is determined by group vibrational frequency (ν) according to the formula of $Vl = -3/4 \cdot (h \nu e^4) / (K^2 R^6)$ (where $\nu = 1 / (2\pi) \cdot (K / \mu)^{1/2}$), so a conclusion can be easily reached that the higher the frequency the lower the absolute value of Vl, or, the lower the group attraction energy. Thus, it can be deduced that the molecular attraction force among hydrocarbons decreases after they are magnetized. This is why the property indices of hydrocarbons, such as viscosity and surface tension which are influenced by the molecular attraction force, decline after the hydrocarbons flow through magnetic field.

Table 2 and Table 3 list the changes of the UV absorptions of toluene and n-butylbenzene respectively. Figure 6 shows the UV absorption spectra of the magnetized and unmagnetized naphthalene. It is evident that the UV absorption strength increases remarkably after the aromatic hydrocarbons have been magnetized. This means that the transition probability of electrons in the π -bond conjugated system among different energy levels has become higher. Since the transition of the bond electrons from the ground level to the excited level is the main process of molecule

radicalization. This may enhance the splitting of the C=C bonds in the aromatic rings in the course of combustion under intense actions of light and heat, and therefore the oxidation of the aromatic rings can be accelerated and easily completed thoroughly. As a result, the combustion efficiency of aromatic hydrocarbons could be boosted, which gives rise to the noticeable increase of their MSFH.

CONCLUSION

- (1) After individual hydrocarbons are magnetized, viscosity and surface tension decrease slightly and weakly respectively, MSFH rises noticeably. The decrease rate of viscosity increases more and more slowly accompanying the increase of the magnetic field strength, and also increases with molecular carbon atom number increasing, while surface tension decreases fluctuately.
- (2) IR absorption peaks shift toward higher wavenumber regions, and UV absorptions of aromatics increase remarkably in strength, which grants the explanations to the changes of above physico-chemical properties.

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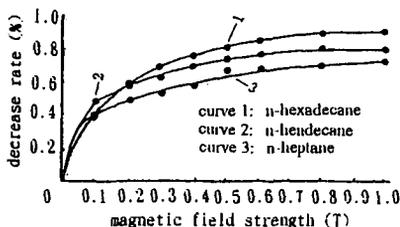


Figure 1. Viscosity decrease rate of normal paraffin versus magnetic field strength

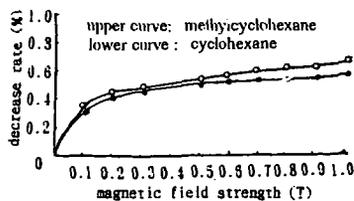


Figure 2. Viscosity decrease rate of cycloalkane versus magnetic field strength

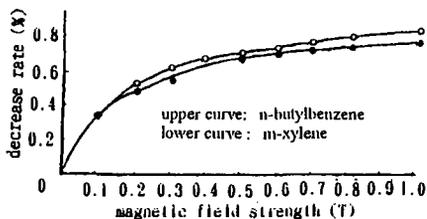


Figure 3. Viscosity decrease rate of aromatics versus magnetic field strength

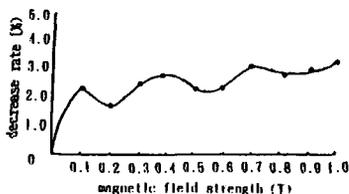


Figure 4. Surface tension decrease rate of n-octane versus magnetic field strength

Table 1 The Surface Tension Changes of Magnetized Individual Hydrocarbons ($\Delta \gamma$, dyn/cm)

sample	B(T)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
n-hexadecane		-0.5	-0.4	-0.6	-0.5	-0.6	-0.7	-0.8	-0.9	-1.1
cyclohexane		-0.2	-0.4	-0.4	-0.4	-0.5	-0.5	-0.7	-0.5	-0.6
isopropylbenzene		-0.4	-0.6	-0.6	-0.7	-0.8	-0.5	-0.5	-0.6	-1.0

Table 2 The MSFH Increases of Magnetized Toluene and Its Mixture (Δh)

sample	B	1.8 T	5.0 T	1.0 T
toluene		1.2mm	1.6mm	1.9mm
toluene + methylcyclohexane		1.7mm	2.1mm	2.5mm
+ n-heptane(1:1:1, vol)				

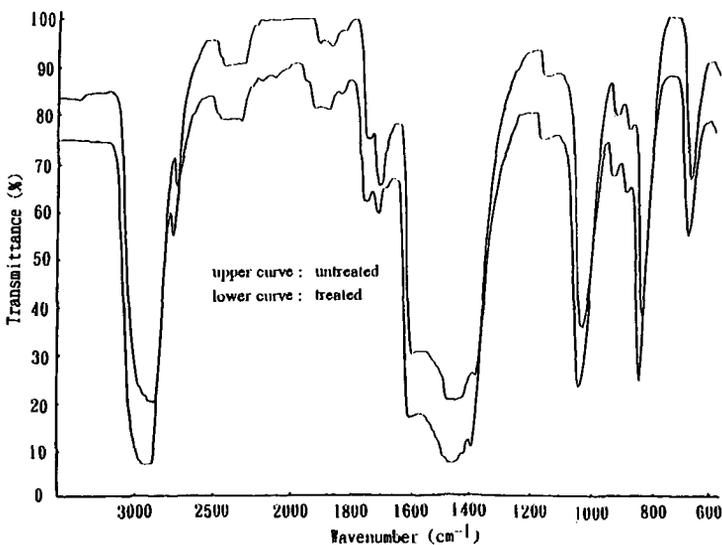


Figure 5. The IR spectra of magnetically treated and untreated 1,3,5-trimethylbenzene at 1.0T

Table 3 The absorbance increase rates of magnetized toluene UV absorption

wavelength	220.4 nm	257.2 nm	263.0 nm
1.0 T	18.1%	6.4%	6.0%
0.3 T	21.1%	5.0%	5.0%

Table 4 The absorbance increase rates of magnetized n-butylbenzene UV absorption

wavelength	220.6 nm	253.0 nm	259.2 nm
1.0 T	16.6%	6.1%	6.8%
0.3 T	11.6%	4.2%	5.6%

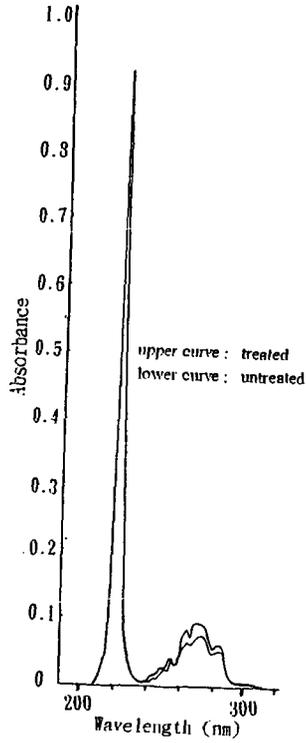


Figure 5. The UV spectra of magnetically treated and untreated naphthalene at the strength of 1.0 T
 notes: sample concentration: 1.5 μ g/ml
 The very similar graph was also achieved at the conditions of 3 cm in width of sample cell and 0.5 μ g/ml in sample concentration