# 不同聚合物分散剂对Pt/SAPO-11催化剂性能的影响

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摘要:采用浸渍法制备了经过不同聚合物分散剂处理的Pt/SAPO-11催化剂,并通过X射线衍射(XRD)、透射电子显微镜(TEM)、N2吸附-脱附和NH3程序升温脱附(TPD)等对催化剂的组织结构进行了表征。结果表明,分散剂不会破坏催化剂的结构,反而提高了其孔体积、孔径和比表面积,同时改变了沸石的酸强度和酸量,其中以聚乙烯吡咯烷酮处理的Pt/SAPO-11催化剂化体积、孔径和酸性分布最佳。在固定床反应器上对不同分散剂处理的Pt/SAPO-11催化剂催化性能进行评价,结果表明聚乙烯吡咯烷酮处理的Pt/SAPO-11催化剂也表现出最佳的催化性能,麻风树油的加氢脱氧率高达99.45%,生物航空煤油组分收率和异构烷烃组分(C<sub>8</sub>~C<sub>16</sub>)的选择性分别达到了44.67%和56.37%。

关键词: 生物航煤; 异构; Pt/SAPO-11催化剂; 分散剂; 麻风树油 中图分类号: 0643.36 文献标识码: A 文章编号: 1001-4861(2023)06-1169-10 DOI: 10.11862/CJIC.2023.070

## Influence of various polymer dispersants on the performance of Pt/SAPO-11 catalysts

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**Abstract:** Pt/SAPO-11 catalysts were prepared by impregnation using different polymer dispersants, and their structural and acidic properties were analyzed and characterized using techniques such as X-ray diffraction (XRD), transmission electron microscopy (TEM),  $N_2$  adsorption-desorption, and  $NH_3$  temperature-programmed desorption (TPD). The results showed that the dispersants did not destroy the structure of the catalysts, but instead increased their pore volumes, pore sizes, and specific surface areas, while also changing the acid strengths and acid amounts of the zeolites. Among the dispersants used in our work, polyvinyl pyrrolidone (PVP) treatment resulted in the optimal pore volume, pore size, and acid distribution for the Pt/SAPO-11 catalyst. Evaluation of the catalytic performance of the Pt/SAPO-11 catalysts treated with different dispersants in a fixed-bed reactor showed that the PVP-treated Pt/SAPO-11 catalyst also exhibited the best catalytic performance, with a hydrogenation deoxygenation rate of *Jatropha* oil up to 99.45%, and bio-aviation kerosene component yield and isoparaffins ( $C_8-C_{16}$ ) selectivity reaching 44.67% and 56.37%, respectively.

Keywords: bio-jet fuel; isomerism; Pt/SAPO-11 catalyst; dispersant; Jatropha oil

Bio-aviation kerosene, derived from biomass, such as animal and vegetable oils, has chemical constituents and physicochemical properties which is similar to conventional aviation kerosene. As a result, this makes bioaviation kerosene a promising alternative that can be directly used. The development of bio-aviation kerosene is of great interest and significance due to its potential for significant carbon dioxide reduction bene-

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fits<sup>[1]</sup>. The production technology of bio-aviation kerosene is based on second-generation biodiesel, use a twostep process that includes hydrodeoxygenation and hydroisomerization to produce a mixture of  $C_{11}$ - $C_{24}$  isoparaffins. The resulting bio-aviation kerosene offers several advantages, including a high cetane number, high fuel heating value, and a low freezing temperature. UOP and Finland Neste have developed an industrial application for producing bio-aviation kerosene from animal and plant oils<sup>[2]</sup>. However, the two-step process is complicated and has high hydrogen consumption and high investment cost for production equipment<sup>[3]</sup>. Therefore, it is necessary to develop an efficient and cost-effective method to produce bio-aviation kerosene, such as a one-step process that obtains the desired isoparaffins from animal and vegetable oils. Nevertheless, the catalytic performance of catalysts is crucial for the one-step process<sup>[4]</sup>.

Previous studies have shown that precious metals Pt and Pd have better hydrogenation/dehydrogenation performance and cracking selectivity than nonprecious metals such as Co, Mo, Ni, etc.<sup>[5-6]</sup>, and can reduce carbon deposit amounts while ensuring a high reaction rate and long catalyst life. Moreover, the acidity and pore structure of supports also influence the catalyst performance. Medium-strong and weak acid sites are favorable for alkane cracking and hydroisomerization reactions, respectively, while the pore structure affects the distribution of products<sup>[7-8]</sup>. Loading Pt or Pd on supports, such as SAPO-11 and ZSM-22, especially the Pt/SAPO-11 catalyst has been reported to exhibit excellent hydrodeoxygenation/isomerization performance<sup>[9-12]</sup>. Hancsók et al. reported that the yield of bioaviation kerosene produced from sunflower oil using the Pt/SAPO-11 catalyst was as high as 88%. In addition, the fuel had a higher cetane number of more than 80, good cold flow properties, and was almost free of sulfur, nitrogen, and aromatics<sup>[13]</sup>. Rabaev et al. investigated the catalytic activity of the Pt/Al<sub>2</sub>O<sub>3</sub>/SAPO - 11 catalyst in treating Jatropha oil via a one-step process and reported that the yield of qualified bio-aviation kerosene components in the products ranged from 42% to 48%[14].

To the best of our knowledge, previous studies have concentrated on the effects of active species and support materials on catalyst activity<sup>[15-18]</sup>. However, the effect of dispersants is rarely mentioned. The dispersant can improve the particle size distribution of precious metals, thus promoting the hydro-dehydrogenation performance of catalysts<sup>[15]</sup>. In this study, industrialgrade SAPO-11 molecular sieves were used as catalyst support materials and various polymer dispersants were used to control Pt dispersion as well as the acidity and acid amount of SAPO - 11. The catalytic performance of resulting catalysts for producing bio-aviation kerosene from Jatropha oil was evaluated in a fixed bed reactor. Systematic characterizations of the catalysts were carried out to facilitate the interpretation of the effects of various dispersants on catalytic performance.

#### **1** Experimental

#### **1.1 Catalyst preparation**

The catalysts were prepared by the impregnation method. The precursor of the active platinum component was Pt(NO<sub>2</sub>)<sub>2</sub>(NH<sub>3</sub>)<sub>2</sub> solution (AR, Kunming Institute of Precious Metals). The SAPO-11 powder (industrial-grade, Nankai University Catalyst Factory, China) was used as the support material. Three different dispersants, polyvinylpyrrolidone (PVP) powder (PVP-k30, AR, Sinopharm Group Chemical Reagent Co., Ltd.), polyethylene glycol (PEG, AR, Sinopharm Group Chemical Reagent Co., Ltd.), and polyvinyl alcohol (PVA, AR, Sinopharm Group Chemical Reagent Co., Ltd.), were used in catalyst preparation, correspondingly, and the catalysts were denoted as Pt/ SAPO-11-PVP, Pt/SAPO-11-PEG, and Pt/SAPO-11-PVA, respectively.

The preparation procedure of the Pt - PVP/ SAPO-11 catalyst was as follows. To eliminate the template, the SAPO-11 powder was first calcined in air at 550 °C for 4 h, with a heating rate of 5 °C  $\cdot$ min<sup>-1</sup> from room temperature. Secondly, the calcined SAPO-11 powder was then impregnated with a certain amount of Pt(NO<sub>2</sub>)<sub>2</sub>(NH<sub>3</sub>)<sub>2</sub> solution and stirred for about 2 h. A certain amount of PVP powder was added to the solution and stirred for 6 h. The solution was then dried in a water bath at 80 °C to remove the solvent. The obtained sample was dried at 110 °C for 12 h before being calcined in a muffle furnace at 550 °C for 4 h at a heating rate of 2 °C • min<sup>-1</sup> from room temperature. Finally, the calcined powder was crushed into particles with 40-60 mesh size. The preparation processes of Pt/SAPO-11-PEG and Pt/SAPO-11-PVA were similar to that of Pt-PVP/SAPO-11. The masses of the active component and the dispersant were 1% and 5% of the mass of the SAPO-11, respectively.

## 1.2 Catalyst characterization

X-ray diffraction (XRD), measurement was carried out on a Rigaku X'pert pro diffractometer operated at 30 kV and 30 mA, with Cu K $\alpha$  radiation ( $\lambda$  =0.154 nm). The diffraction patterns were collected with a  $2\theta$ range from  $5^{\circ}$  to  $50^{\circ}$  with a resolution of  $0.02^{\circ}$ , and a scanning speed of 10 (°) • min<sup>-1</sup>. Nitrogen adsorption desorption isotherms were obtained with a Quantachrome Autosorb-iQ2 instrument at liquid temperature. The samples were degassed in a vacuum for 3 h at 300 °C before analysis. The surface area of the samples was calculated by the Brunauer-Emmett-Teller (BET) method. The micropore volume and micropore area were evaluated by the *t*-plot method. The pore size distribution was calculated by density functional theory (DFT). Scanning electron microscopy (SEM) images were obtained using an FEI HELIOS NanoLab 600i instrument operating at 2 kV. Transmission electron microscopy (TEM) was taken using an FEI Tecnai F30 electron microscope with a field emission gun and operated at 300 kV. The diameter of each particle was determined from the enlarged photographs. The particle size distribution and average diameter were calculated using measurements of about 300 particles.

The actual Pt loading amount in the catalyst was determined using Perkin Elmer Optima-5300DV Inductively Coupled Plasma Atomic Emission Spectrometer (ICP - AES), while the dispersion of Pt was determined using the CO pulse adsorption method. CO pulse adsorption was collected using CHEMBET 3000 Chemical Adsorption Instrument. All samples were reduced in H<sub>2</sub>/He (1:3, V/V) at 300 °C for 2 h with a flow of 75 cm<sup>3</sup>·min<sup>-1</sup>, then pure He was fed to purify the hydrogen left on the catalyst surface for 30 min. After the temperature of the reactor was cooled down to 80 °C, a pulse injection of high-purity CO was provided using a pulse quantification tube of 64  $\mu$ L. The adsorption process of CO was monitored by Thermal Conductivity Detector until the shape of the adsorption curve became stable. Assuming monomolecular adsorption of CO on Pt, the degree of dispersion of the Pt on the catalyst was calculated as a CO/Pt atomic ratio of 1:1.

NH<sub>3</sub> temperature-programmed desorption (NH<sub>3</sub>-TPD) was performed on a Quantachrome CHEMBET Pulsar TPR/TPD Instrument. The samples were first pretreated in Ar flow at 500 °C for 1 h, then NH<sub>3</sub> adsorption was carried out in NH<sub>3</sub>/Ar mixture (1:4, *V/V*) with a flow rate of 75 cm<sup>3</sup>·min<sup>-1</sup> at 80 °C for 1 h. Subsequently, Ar was supplied again to purge to baseline, and the signal of NH<sub>3</sub> desorption was recorded in a range of 80-550 °C with a heating rate of 10 °C ·min<sup>-1</sup>.

#### 1.3 Catalyst assessment

Jatropha oil was selected as the reaction raw material. The saturated fatty acid in *Jatropha* oil mainly comprises C<sub>16:0</sub> and C<sub>18:0</sub>, while unsaturated fatty acid primarily consists of C<sub>16:1</sub>, C<sub>18:1</sub>, and C<sub>18:2</sub>. The Jatropha oil was hydrotreated in a stainless-steel continuousflow fixed-bed reactor with an inner diameter of 5 mm. The catalytic performance of catalysts was evaluated at 5.0 MPa and 397 °C. The volumetric ratio of hydrogen to Jatropha oil was set to 1 000. Typically, a 6.0 g catalyst was placed into the middle of the reactor, then both sides of the reactor were filled with quartz sand of the same size as the catalysts. The catalysts were reduced in situ for 6 h at 400 °C in an H<sub>2</sub> atmosphere. After the temperature cooled down to the desired reaction temperatures, then Jatropha oil was fed into the reactor via a metering pump. The products were condensed by a condenser and analyzed by PerkinElmer Clarus 680-Clarus SQ8T Gas Chromatography-Mass Spectrometer (GC-MS) to provide a detailed distribution of the chemical components.

The relative mass fraction of various substances in

the liquid product was calculated by the area normalization method.

	H	lydrodeoxyger	ation rate =	$= \sum M_0 \times$	100%	(1
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Cracking rate = $\sum M_1 \times 100\%$	(2)
Bio-jet fuel component yield = $\sum M_2 \times 100\%$	(3)

Isoparaffin selectivity rate =  $\sum M_3 \times 100\%$  (4)

Aromatic hydrocarbons yield =  $\sum M_4 \times 100\%$  (5)

Where  $M_0$  is the relative mass fraction of oxygen-free compounds converted from Jatropha oil;  $M_1$  is the relative mass fraction of  $C_7$ - $C_{14}$  components;  $M_2$  is the relative mass fraction of  $C_8$ - $C_{16}$  component in liquid products;  $M_3$  is the relative mass fraction of isoparaffin in  $C_8$ - $C_{16}$ ;  $M_4$  is the relative mass fraction of aromatic hydrocarbon components in the liquid product<sup>[16]</sup>.

#### 2 Results and discussion

#### 2.1 Characterizations of catalysts

XRD patterns for the calcined catalysts were shown in Fig.1. All samples presented characteristic peaks for SAPO - 11 with AEL structure ( $2\theta$  = 8.1°, 9.4°, 13.1°, 15.6°, 20.3°, 21.0°, 22.1°-23.2°)<sup>[19]</sup>. The results indicated that the structure of SAPO-11 was not destroyed, as the positions of the characteristic peaks remained almost unchanged after impregnation with precious metal on SPAO -11 or treatment with various dispersants. However, the intensities of the characteristic peaks became weak after treatment with dispersants. The peak at  $2\theta$ =39.9° corresponds to the active component Pt



Fig.1 XRD patterns of (a) SAPO-11, (b) Pt/SAPO-11, (c) Pt/SAPO-11-PVP, (d) Pt/SAPO-11-PEG, and (e) Pt/SAPO-11-PVA

(111) crystal face. It can be seen that the Pt(111) diffraction peak weakened while the half - peak width increased after the addition of dispersant, suggesting that the active component Pt grain size decreased.

Table 1 lists the loading amounts and dispersion of Pt over various catalysts, with Pt/SAPO-11 serving as a benchmark catalyst. The actual Pt loading amounts of four catalysts were comparative and ranged from 0.79% to 0.85%, indicating that the addition of dispersant did not affect the Pt loading amount of Pt in the catalysts. The dispersion of active components is an important factor affecting a catalyst's activity<sup>[20]</sup>. Generally, increasing catalyst-specific surface area and the interaction strength between the active component and support material promotes precious metal dispersion<sup>[21]</sup>. After the addition of different dispersants, the dispersion of Pt particles on the catalyst increased while the size decreased, indicating that more active component active sites can be provided.

 Table 1
 Loading amounts (mass fraction) and dispersion

 of Pt over different catalysts

Catalyst	Loading amount of Pt <sup>a</sup> / %	Dispersion of Pt <sup>b</sup> / %
Pt/SAPO-11	0.82	15.31
Pt/SAPO-11-PVP	0.83	22.40
Pt/SAPO-11-PEG	0.85	18.21
Pt/SAPO-11-PVA	0.79	20.56

<sup>a</sup> Loading amount of Pt determined by ICP-AES; <sup>b</sup> Dispersion of Pt measured by CO pulse adsorption.

Fig. 2 shows the particle distributions of the samples. It can be seen that after the introduction of the dispersant, the size of the loaded Pt particles was reduced to varying degrees, and the introduction of PVP had the most obvious effect. As given in Table 2, SAPO - 11 had the highest surface area, pore volume, and average pore size. After impregnating the Pt component on the SAPO - 11, taking Pt/SAPO - 11 as an example, the surface area, pore volume, and average pore size all decreased noticeably due to the loading of the Pt active component. Nevertheless, the treatment of the dispersants increased the surface area, pore volume, and average pore size of the catalysts, indicating



Fig.2 Particle distributions of (a) Pt/SAPO-11, (b) Pt/SAPO-11-PVP, (c) Pt/SAPO-11-PEG, and (d) Pt/SAPO-11-PVA

Table 2	Texture	parameters (	of the	catalysts
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Čl.	Surface area /	Pore volume /	Average pore	Micropore	Micropore	External surface
Sample	$(m^2 \boldsymbol{\cdot} g^{-1})$	$(\mathrm{cm}^3\boldsymbol{\cdot}\mathrm{g}^{-1})$	size / nm	volume / $(\mathrm{cm}^3 \! \cdot \! \mathrm{g}^{-1})$	area / $(m^2 \boldsymbol{\cdot} g^{-1})$	area / $(m^2 \boldsymbol{\cdot} g^{-1})$
SAPO-11	260	0.26	4.1	0.085	212	47
Pt/SAPO-11	195	0.15	3.1	0.063	154	41
Pt/SAPO-11-PVP	230	0.18	3.5	0.069	1 689	61
Pt/SAPO-11-PEG	223	0.17	3.3	0.066	162	61
Pt/SAPO-11-PAV	238	0.17	2.9	0.071	178	60

that the dispersant not only benefits the active component dispersion but also enriches the pore structure. The reason is that the decompositions of PVP, PEG, and PVA release gas at high temperatures, resulting in forming new pores when the gas inside the SAPO-11 pore escapes. The increased pore volume and pore size allow reactants to enter the catalyst pores for reaction and prevent carbon deposition on the catalyst surface. In addition, the increase in the specific surface area of the catalyst provides more active sites, allowing the reactants to easily contact the active site. The increase in secondary pores, micropores, and average pore size reduces diffusion resistance in the pores, the reactant molecules are more likely to penetrate the pores, and the active sites in the pores are fully utilized to improve the catalyst's activity<sup>[24-25]</sup>.

Fig. 3 shows SEM images of four catalysts. It can be seen that Pt/SAPO - 11 exhibited spherical aggregates composed of slab-like crystallites. The catalysts with various dispersant additions had spherical aggregates and rougher surfaces that are similar to Pt/SAPO-11, but they had highly mesoporous as shown in Table 2.

Fig.4 shows the TEM images. Compared with Pt/ SAPO-11 catalyst, the active component Pt particles in catalysts with dispersant additives were more uniformly dispersed on the SAPO-11, and their average particle size was also reduced. PVP, PEG, and PVA are nonionic polymer compounds, the dispersion mechanism is to form a steric hindrance to achieve stable dispersion<sup>[26-27]</sup>. For example, in the PVP molecule, the amine nitrogen atom and the carbonyl oxygen atom have a mediating effect and can form a coordination ion with Pt<sup>2+</sup> in Pt(NO<sub>2</sub>)<sub>2</sub>(NH<sub>3</sub>)<sub>2</sub> to form steric hindrance and prevent further agglomeration of Pt particles<sup>[28-29]</sup>. Therefore, the added dispersant acts as a protective agent for the Pt particles, inhibiting particle growth and agglomeration during the impregnation and calcination process, ensuring particle size and dispersion uniformity<sup>[30]</sup>.

Fig.5 shows the  $\rm NH_3\text{-}TPD$  profiles of the catalysts. All of the catalysts exhibited two  $\rm NH_3$  desorption peaks in the temperature range from 100 to 700  $^\circ\!\!C$ . The peaks below 300  $^\circ\!\!C$  belonged to weak acid sites, while the shoulder peak above 300  $^\circ\!\!C$  was attributed to the



Fig.3 SEM images of (a) Pt/SAPO-11, (b) Pt/SAPO-11-PVP, (c) Pt/SAPO-11-PEG, and (d) Pt/SAPO-11-PVA



Fig.4 TEM images of (a) Pt/SAPO-11, (b) Pt/SAPO-11-PVP, (c) Pt/SAPO-11-PEG, and (d) Pt/SAPO-11-PVA

medium-strong acid sites. Although the fact that the acid distributions of the catalysts were similar, the NH<sub>3</sub> desorption peaks tended to shift to higher temperatures with the addition of dispersants, indicating that some acid sites might be present due to the increase in the surface area of the catalyst.

The amounts of acid sites are listed in Table 3. Due to the increase in the dispersion of the active components and the effect of newly created pores, the acid amounts of the catalysts varied after the introduction of the three dispersants. The introduction of PVP increased the catalyst's weak acidity and medium strong acidity. However, the amounts of weak acidity and medium-strong acidity were reduced in Pt/SAPO-11-PEG and Pt/SAPO-11-PVA catalysts, more likely due to fewer newly developed pore channels and more acid sites covered by active components.



Fig.5 NH<sub>3</sub>-TPD profiles of (a) Pt/SAPO-11, (b) Pt/SAPO-11-PVP, (c) Pt/SAPO-11-PEG, and (d) Pt/SAPO-11-PVA

		Weak acid		Medium-strong acid	
Sample	$T / \mathbb{C}$	$\mathrm{Acidity} \: / \: (\mathrm{mmol}_{\mathrm{NH}_3} \boldsymbol{\cdot}  \mathrm{g}^{-1})$	$T / ^{\circ}\mathbb{C}$	Acidity / $(mmol_{NH_3} \cdot g^{-1})$	$(\mathrm{mmol}_{\mathrm{NH}_3}{\boldsymbol{\cdot}}\mathrm{g}^{-1})$
D:/CADO 11	181	0.031	207	0.153	0.273
Pt/SAPO-11	227	0.090	327		
DECADO 11 DVD	185	0.042	250	0.129	0.284
PUSAPO-11-PVP	238	0.113	552		
D <sub>t</sub> /SADO 11 DEC	184	0.035	3/18	0.102	0.237
FUSAFO-11-FEG	234	0.100	548	0.102	0.237
D <sub>b</sub> /SADO 11 DVA	211	0.026	241	0.114	0.220
rusaro-11-rva	254	0.080	541	0.114	0.220

Table 3 Acid amounts of different catalysts

## 2.2 Performance of catalysts

To investigate the influence of different dispersants on the hydrodeoxygenation performance of Pt/ SAPO-11 catalyst, one-step hydrotreating of *Jatropha* oil was carried out at 397 °C, 5 MPa, 1.2 h<sup>-1</sup> liquid space velocity, and hydrogen oil ratio of 1 000. The results are listed in Table 4. Since the dispersant improves the dispersion of the active component of the catalyst, these three dispersant-modified catalysts outperform Pt/SAPO - 11 catalyst in hydrodeoxygenation. The hydrodeoxygenation rate of Pt/SAPO - 11 - PVP and Pt/SAPO - 11 - PVA to *Jatropha* oil was 99.45% and 99.47%, respectively. The cracking rate of the catalyst (C<sub>7</sub> - C<sub>14</sub>) is closely related to its acidity. Among the three dispersant - modified catalysts, the one treated with PVP increased the acid amount of the catalyst and strengthens its acidity, thus promoting its cracking performance  $^{[31-32]}\!\!.$  As a result, the cracking rate of  $C_7$  -  $C_{14}$ components in the Pt/SAPO - 11 - PVP catalyst was 17.86%, which was 10.12% higher than that of the Pt/ SAPO-11 catalyst. In terms of the bio-aviation kerosenebio-jet fuel component ( $C_8$ - $C_{16}$ ) selectivity, the proportion of bio-aviation kerosenebio-jet fuel components over Pt/SAPO - 11 catalytic hydrogenation of Jatropha oil products was 24.22%, and those over Pt/SAPO-11-PEG, Pt/SAPO-11-PVA are almost comparable to Pt/ SAPO-11, while the bio-aviation kerosenebio-jet fuel component in the catalytic products of Pt/SAPO - 11 -PVP was as high as 44.67%, approximately 20% higher than the benchmark catalyst. For the isomeric alkanes ( $C_8$ - $C_{16}$ ) selection rate, the introduction of PVP and PEG affected the catalyst's isoparaffins selectivity,

while the isoparaffins selectivity of Pt/SAPO-11-PAV decreased from 57.22% to 29.57%, indicating that the addition of PVA reduces the catalyst isoparaffins selectivity. Based on the above finding, it can be concluded that Pt/SAPO-11-PVP has the highest catalytic activity and selectivity to isoparaffins.

Pt/SAPO-11 is a bifunctional metal/acid catalyst, the active component Pt provides a hydrogenation/ dehydrogenation reaction site, while the acid sites of the support provide the acid position function of isomerization/cracking of normal kinds of paraffin<sup>[33]</sup>. The process of one - step hydrogenation of fats and oils to form isoparaffins is proposed as follows (Fig.6). Firstly, the oil is hydrodeoxygenated to form saturated normal paraffin via the interaction of the catalyst's mediumstrong acid site, and the active component Pt. Secondly, the obtained *n*-alkanes are adsorbed on Pt and dehydrogenation to form olefins, which obtain protons and form positive carbon ions at the acid centers. Subsequently, the carbon ions undergo skeletal isomerization at the weak acid centers and lose proteinogenic isomers, or crack into a new normal carbon ion and a small molecular olefin at the medium-strong acid centers. Finally, the hydrogenated isomeric olefins and small molecular olefins are desorbed at the metal centers to form isoparaffins and small molecular alkanes<sup>[34]</sup>. It can be seen that the Pt/SAPO-11 catalyst's acid centers and metal centers complete the oil's hydrodeoxygenation and hydroisomerization reactions. Under the same loading amount, the greater the dispersion of the active component Pt on the catalyst, the smaller the particle size, and the greater the hydrogenation/dehydrogenation activity of the catalyst. An increase in the number of acid sites facilitates the transfer of positive carbon ions between the active components and acidic sites. Thus, plausible pathways involve alkanes adsorbed on Pt, then dehydrogenation to form olefins, which obtain protons and form positive carbon ions at the acid centers. Finally, the hydrogenated isomeric olefins and small molecular olefins are desorbed at the metal centers to

 Table 4
 Catalytic performance of different catalysts

Sample	Hydrodeoxygenation	Cracking rate / %	Bio-jet fuel component vield / %	Isoparaffins selectivity / %	Aromatic hydrocarbons vield / %
Pt/SAPO-11	91.25	7.74	24.22	57.22	0.92
Pt/SAPO-11-PVP	99.45	17.86	44.67	56.37	0
Pt/SAPO-11-PEG	91.75	9.12	29.15	51.22	0
Pt/SAPO-11-PVA	99.47	7.34	26.31	29.57	0



Fig.6 Plausible pathways involved in the dispersant modification and one-step hydrotreatment of Jatropha oil

form isoparaffins and small molecular alkanes<sup>[34]</sup>. It can be seen that the Pt/SAPO-11 catalyst's acid centers and metal centers complete the oil's hydrodeoxygenation and hydroisomerization reactions. Under the same loading amount, the greater the dispersion of the active component Pt on the catalyst, the smaller the particle size, and the greater the hydrogenation/ dehydrogenation activity of the catalyst. Since Pt(NO<sub>2</sub>)<sub>2</sub>  $(NH_3)_2$  is easier to combine with PVP, the dispersion of the active components of the catalyst is more uniform. In addition, the removal of PVP during the sintering process changes the pore structure of the support. The combination of the two leads to the improvement of the catalytic activity of the catalyst. An increase in the number of acid sites facilitates the transfer of positive carbon ions between the active components and acidic sites. Thus, plausible pathways involve adsorption on Pt, then dehydrogenation to form olefins, which obtain protons and form positive carbon ions at the acid venters.

### **3** Conclusions

The introduction of dispersants does not affect the skeleton structure of the SAPO-11 molecular sieve but alters the distribution of active components and physicochemical properties of the catalysts, such as pore volume, pore size, and specific surface area. Three dispersants were used to improve the dispersion of Pt particles on the molecular sieve and reduce their particle size. The introduction of dispersants altered the active component distribution and physical properties of catalysts, such as pore volume, pore size, and specific surface area. Compared to the benchmark Pt/SAPO-11 catalyst, the three dispersant-modified catalysts exhibited enhanced weak acidity and medium-acid acidity. The total acidity of the Pt/SAPO-11-PVP catalyst increased, while those of the Pt/SAPO-11-PEG and Pt/SAPO-11-PVA catalysts decreased. Among these modified catalysts, the Pt/SAPO-11 treated with PVP exhibited excellent catalytic performance in the one-step hydrotreatment process of Jatropha oil, owing to its appropriate pore volume, pore size, and acidity distribution. The hydrodeoxygenation rate was up to 99.45%, and the bio-aviation kerosene bio-jet fuel component yield and the isoparaffin selectivity were 44.67% and 56.37%, respectively.

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