

The Catalytic Activity of Modified Zeolite Lanthanum on the Catalytic Cracking of Al-Duara Atmospheric Distillation Residue.

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ABSTRACT

Atmospheric residue fluid catalytic cracking was selected as a probe reaction to test the catalytic performance of modified NaY zeolites and prepared NaY zeolites. Modified NaY zeolites have been synthesized by simple ion exchange methods. Three samples of modified zeolite Y have been obtained by replacing the sodium ions in the original sample with lanthanum and the weight percent added are 0.28, 0.53, and 1.02 respectively. The effects of addition of lanthanum to zeolite Y in different weight percent on the cracking catalysts were investigated using an experimental laboratory plant scale of fluidized bed reactor.

The experiments have been performed with weight hourly space velocity (WHSV) range of 6 to 24 h⁻¹, and the range of temperature from 450 to 510 °C.

The activity of the catalyst with 1.02 wt% lanthanum has been shown to be much greater than that of the sample parent NaY. Also it was observed that the addition of the lanthanum causes an increase in the thermal stability of the zeolite.

Key words: lanthanum exchange NaY, rare earth elements, atmospheric residue fluid catalytic cracking,

تأثير الفعليه الحفازيه للزيولايت المطور باللانثانيوم على التكسير الحفازي لمتبقي التقطير الجوي لمصفى الدوره

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الخلاصة:

تم اختيار تفاعل التكسير الحفازي المائع لمتبقي التقطير الجوي كمجس لاختبار الفعالية الحفازية للزيولايت المحسن والمحضر نوع NaY. الزيولايت المطور تم تصنيعه بطريقة التبادل الايوني البسيط. ثلاثة نماذج من الزيولايت المطور تم الحصول عليها عن طريق استبدال ايون الصوديوم في النموذج الاصيلي باللانثانيوم وبالنسب الوزنيه المؤيه التاليه, 0.28, 0.53, 1.02.

تأثير اضافة اللانثانيوم للزيولايت وبنسب وزنيه مختلفه على الفعالية التكسيريه تم بحثه باستخدام منظومه مختبريه تجريبه لمفاعل الطبقة المميعة. التجارب المختبريه اجريت عند سرع وزنيه فراغيه بين 6 الى 24 ساعه⁻¹ وبدرجة حرارة من 450 الى 510 درجة مئوية.

الفعالية الحفازية للعامل المساعد المحتوي على نسبه وزنيه من اللانثانيوم بمقدار 1.02 كانت اكبر بكثير من الفعالية الحفازية للعامل المساعد الاصيلي. وكذلك تم ملاحظه ان اضافة اللانثانيوم ادت الى زياده الثباتية الحراريه للزيولايت.

الكلمات الرئيسية: استبدال اللانثانيوم بالزيولايت NaY, عناصر الارض النادرة, التكسير الحفازي لمتبقي التقطير الجوي.



1. INTRODUCTION

During the atmospheric distillation of crude oil, as employed on a large scale in the refineries for the production of light hydrocarbon oil distillates, a residual oil is obtained as a byproduct. **Jakob and Peter, 1977**. In the atmospheric distillation of crude oil about half of the crude oil is left behind as distillation residue, it will be clear that there is a pressing need for a process which offers the possibility of converting in an economically justifiable way hydrocarbon oil residue obtained by atmospheric distillation into light, i.e., low boiling hydrocarbon oil distillate such as gasoline, **Pappal, et al., 2003**. Heavy crude oil and residue have many similarities in composition such as low H/C ratio (1.2–1.4), high metals and sulfur contents. Hence, one of the most important parameters is to convert residue into lighter products by increasing the H/C ratio, **Bartholomew, et al., 1994**.

The demand for high value petroleum products such as middle distillate, gasoline and lube oil is increasing, while the demand for low value products such as fuel oil and residue based products is decreasing. Therefore, maximizing of liquid products yield from various processes and valorization residues is of immediate attention to refiners. At the same time, environmental concerns have increased, resulting in more rigorous specifications for petroleum products, including fuel oils. These trends have emphasized the importance of processes that convert the heavier oil fractions into lighter and more valuable clean products, **Gray, 1994**.

Fluid catalytic cracking (FCC) is one of the most important processes in the oil refinery industry. It converts, or cracks, low value heavy ends of the crude oil into a variety of higher-value, light products. The catalytic cracking operation is preferably carried out at a temperature from 400 to 550 °C, a pressure 1 to 10 bar, and weight hour space velocity (WHSV) of from 3 to 200 h⁻¹, **Chen, and Cao, 2005**. This process produces not only gasoline and diesel fuel but also raw material, such as light olefins for a number of petrochemical processes, the later application is gaining increasing importance, **Biswas, and Maxwell, 1990**.

The FCC catalyst is a key point in the optimization of FCC unit. Basically, the FCC catalysts could be divided into three main categories based on the refineries objective i) maximization of valuable product, ii) improving of gasoline quality and, iii) minimization of residue, and in order to achieve those goals, the FCC catalyst has two components, the zeolite and the matrix. Besides these catalyst it can also have other functional ingredients and/or additives for specified function like enhancing gasoline octane, upgrading the conversion of residue feedstock, enhancing the resistance to metallic poisons, promoting the CO combustion, reduction of the NO_x and SO_x emission, among them, **Costa et al., 2004**.

In the past years rare earth exchanged zeolites have attracted much attention as a stable solid acid catalyst because of their high thermal stability, **Magee, et al., 2002**. Modification of zeolites by ion exchange of exchangeable cations provides a useful means of tailoring their properties to particular application. Thus, introduction of rare earth element, in particular into zeolite Y has been an important means of enhancing the performance of catalyst, for example, FCC catalyst and they are known to increase the activity of zeolites in a variety of reactions due to increased acid strength. For example, LaNa–Y plays an important role in the preparation of catalysts for FCC, one of the most widely applied petroleum refining processes that make use of zeolite as catalyst, **Bejoy, et al., 2006**

Rare earth components, such as lanthanum and cerium, were used to replace sodium in the crystal. The rare earth elements, being trivalent, simply form "bridges" between two to three acid sites in the zeolite framework. Bridging protects acid sites from being ejected and stabilizes the zeolite structure. Rare earth exchange adds to the zeolite activity and thermal and hydrothermal stability. Rare earth serves as a "bridge" to stabilize aluminum atoms in the

zeolite structure. They prevent the aluminum atoms from separating from the zeolite lattice when the catalyst is exposed to high temperature steam in the regenerator. The NaY zeolite was mostly ion exchanged with rare earth components. Rare earth components, such as lanthanum and cerium, were used to replace sodium in the crystal. The rare earth elements, being trivalent, simply form "bridges" between two to three acid sites in the zeolite framework. Bridging protects acid sites from being ejected and stabilizes the zeolite structure, **Sadeghbeigi, 2000**.

The modification of faujasite Y zeolites to improve catalyst selectivity and stability has become an integral part of the catalyst manufacturing process. The modification procedure can be accomplished in several ways. Exchanging the native sodium ions for rare-earth ions and protons was shown to increase the hydrothermal stability of the zeolite along with increasing its activity in catalytic cracking. In addition, hydrothermal stability can also be improved by lowering the aluminum content of the zeolite framework, a process called dealumination, **Nery, et al., 1997**.

The aim of present study is to modify the zeolite Na Y prepared from Iraqi kaolin with various weight percents lanthanum exchange. Also the activity of the resulting catalyst were evaluated by using experimental laboratory plant scale fluidized bed reactor by using atmospheric distillation residue as a feed, and the influence of the addition of lanthanum on the thermal stability of the NaY was investigated.

2. EXPERIMENTAL

2.1 Feedstock

Atmospheric residue with boiling range 278°C to 450°C was supplied from atmospheric distillation unit of Al-Duara refinery as a raw material for the catalytic performance of the zeolites synthesized, and its detailed properties are listed in **Table 1**.

2.2 Catalyst

Parent NaY zeolite were prepared from Iraqi kaolin as follows: kaolin was fused by the addition of sodium hydroxide (kaolin/NaOH=1/1.5 by wt.) at 850°C for three hours. A typical procedure performed as follows. Ten grams of fused kaolin powder and 12.67 grams of sodium silicate were dispersed in 150 ml of deionized water under constant stirring for 1 hour. The resultant slurry which has pH 13.6 was subjected to aging at 50 °C for 24 hr in a programmable electrical furnace, then the gel slurry was subjected to hydrothermal crystallization at 100 °C for 48 hr in the same furnace.

Crystallization was carried out at about 100°C. Subsequently the resultant precipitate was separated from the mother liquor by filtration. The crystalline mass is then washed with deionized water until a pH 11.5 and dried at 100°C for 16 hours. The dried powder was activated by calcination in a programmable electrical furnace at 500 °C for 1hr.

2.3 Modified Zeolite Procedure.

Lanthanum exchanged was obtained by contacting Na-Y with 0.5M lanthanum nitrate solution (0.025 moles of lanthanum nitrate / g of zeolite) at 80 °C for 24 hours, then filtrate, and washed to obtain 0.28wt% La Na-Y. This exchange cycle was repeated two times with fresh lanthanum nitrate to obtain 0.53wt% La.Na-Y. Na-Y was contacted with fresh 0.5M lanthanum nitrate solution four times to obtain 1.02wt% La Na-Y. All samples were calcined after each exchange at temperature 150 to 500 °C with heating rate 12 °C /minute and at 500 °C for 5 hours. The degree of Lanthanum exchange in the zeolite was determined by the analysis of each zeolite sample to determine the sodium weight percent in the starting

and those remaining after the Lanthanum exchange. The sodium weight percent loss converted to equivalent lanthanum.

2.4 Apparatus

Cracking experiments were carried out in the experimental laboratory plant scale of fluidized bed reactor system, shown in **Fig 1**. This unit was found in the laboratories of Chemical Engineering Department, Baghdad University, It is comprised of five sections: atmospheric residue and water input mechanisms, reaction zone, temperature control system, products separation, and collection system.

A specified flow rate of water was pumped into pre-heater; the water was converted to steam by heating system. Steam was used to remove the air from reactor. After that atmospheric residue was pumped and heated in a pre-heater, and then entered into the reactor, where catalytic cracking reactions took place. The reaction products were cooled and separated into liquid products and gas product. Cracking liquid product was transferred to distillation unit for separation catalytic cracking gasoline from heavy stock. A sample of gaseous product was collected in a gas bag and then analyzed by gas chromatography to determine the chemical composition of the gaseous product. A sample of catalytic cracking gasoline was analyzed by gas chromatography to determine the composition of catalytic cracking gasoline.

Coke content on catalysts was measured by as follows method below. A sample of catalyst from reactor was weighed and dried by electrical programmable furnace at 100 °C for 16 hr. The dry sample was weighed and returned to electrical programmable furnace to restore catalyst activity by burning off coke deposition on spent catalyst at 650 °C for one hour. The calcined sample after burning coke was weighed. The differences between weight 1 and weight 2 represents moisture and difference between weight 2 and weight 3 represents delta coke. Delta coke is defined as the difference between coke on the spent catalyst after stripping and on the regenerated catalyst. The activity of the catalyst in catalytic cracking was determined by conversion which is defined as the weight percent (wt%)of the feed that is converted into coke, gas and gasoline. The gasoline fraction is that part of the product with a boiling point range between ambient temperature and 220 °C.

2.5 Operating Conditions

The cracking experiments of atmospheric residue were carried out over parent NaY zeolite and modified zeolite catalysts sampled in the experimental laboratory plant scale of fluidized bed reactor system. Operating conditions were catalyst weight hourly space velocity was 6 , 12 ,18, and 24 h⁻¹ , reaction temperature was 450 ,470,490, and 510 °C. The effect of regeneration number (it refers to restoring catalyst activity after each complete reaction) on the catalyst activity of the parent NaY zeolite and modified zeolite(1.02wt%) was carried out at 510 °C, WHSV= 6h⁻¹, and atmospheric pressure.

2.6 Analytical Apparatus

The digital flame analyzer by flame photometer Gallen Kamp in The State Company for Geological Survey and Mining was used to determine the sodium content the parent catalyst and modified catalyst after lanthanum ion exchange.

The gas chromatograph Agilent Technologies 6890N equipped with flame ionization detector (FID) was used to determine the composition of the gases produced from experiment. The equation of state for ideal gases converts the volume data to mass.

The composition of cracked gasoline measured by using simulated distillation gas-chromatography Agilent Technologies 6890N .



Chemical analysis according UOP Method 172- 59 was used to measure the concentration of the hydrogen sulfide.

Gas Chromatograph 373 GASUKURD KDGYO was used to determine the concentration hydrogen gas in the gases mixture produced. All above device was located in Al- Duara Refinery.

3. RESULT & DISCUSSION

3.1 The Effect of Lanthanum Exchange on the Atmospheric Residue Conversion.

The effect of lanthanum exchange and WHSV on the atmospheric residue conversion were studied at different reaction temperatures. **Fig. 2** and **table 2** show the dependence of conversion upon lanthanum weight percent loading and catalyst hour space velocity when cracking was over zeolite catalysts containing different weight percent lanthanum.

At a given catalyst hour space velocity with constant temperature, the zeolite catalysts containing more lanthanum weight percent loading show greater conversion of atmospheric residue and gives more products (gasoline , gases, and coke) than parent Na-Y zeolite, **Fig .2 and Table 2**. This means that the lanthanum indeed contribute to the conversion, which may be explained as a follows :

The effect of sodium ions on the activity of Bronsted type of zeolites in acid reactions has been recognized very early especially in the case of faujasite. It was proposed that these residual cations have a poisoning effect on the acidity i.e., a particular Na⁺ ion present within the decationated zeolite has a neutralizing effect over a large number of the existing protons. Low acid amount of Na-Y zeolite might reduce catalyst activity, which is the crucial step in the formation of the desired product.

The total acid amount increased after introducing rare elements (RE) to zeolite sample. There were two possible reasons for the result. Firstly, the hydrothermal stability had been strengthened on account of the addition of the rare elements (RE) cation, which coordinated with the oxygen atoms in the pore channel. Therefore, the dealumination of the framework was restrained during the hydrothermal disposal. So the loss of acidic amounts would reduce. Secondly, silicon hydroxyl and aluminum hydroxyl in the zeolite framework were polarized by the polarization and induction of the RE cation. So the density of the electron cloud in the zeolite framework increased, stronger acidity of the acidic center appeared. And because of the existence of an empty f orbit RE³⁺, the amount of Lewis acid would also increase, **Xiaoning, et al,2007**. The zeolite activity comes from these acid sites, **Hayward and Winkler ,1990**. From the above the increasing lanthanum exchanged decreases Na⁺ ion in the zeolites and gives more conversion of atmospheric distillation residue.

3.2 The Effect of WHSV on the Atmospheric Residue Conversion.

At a constant temperature with a given lanthanum weight percent loading **Fig. 3** and **table 2** shows that the atmospheric residue conversion increases with decreasing of WHSV. This means that the conversion of reduced crude is a function of reaction time for all catalysts, the increasing of the contact time of the feed molecules with the catalyst increases the atmospheric residue conversion in direct proportion to the amount of the catalyst and inversely proportional to the feed flow rate.

3.3 The Effect of Temperature on the Atmospheric Residue Conversion.

At a given catalyst hour space velocity with constant lanthanum weight percent loading **Fig. 2** and **table 2** show that the atmospheric residue conversion increases with increasing the temperature. This may be attributed to the increase of temperature which accelerates intermolecular motions, assists the transformations of the reactants into new compounds and thus enhances the rate of chemical reaction. It is thermal activation which in the present case acts in conjunction with catalytic activation as mentioned by **Decroocq, 1984**. The higher temperature provided advantages in terms of a better feed vaporization which reduced coke formation by condensation reactions of poorly vaporized feed molecules. Both the higher temperature and the resulting lower coke formation enhanced the diffusion of feed molecules. .

3.4 The Effect of Lanthanum Exchange on the Gasoline Yield.

Fig. 4 and **Table 2** show that the gasoline yields is a function of conversion for the different catalysts when cracking atmospheric residue, when the catalysts contain more lanthanum weight percent loading it gives a higher gasoline yield. Also increasing temperatures and decreasing weight hours space velocity shows graterer gasoline yield obtained. **Table 3** shows chemical composition of cracked gasoline for parent NaY and 1.02 LaNa. This table shows that olefins and naphthenes decreases while paraffins and aromatics increases for 1.02 LaNaY with respect to the parent NaY, due to the rare earth exchanged zeolite that increases hydrogen transfer reactions, hydrogen transfer is a bimolecular reaction in which one reactant is an olefin. Two examples are the reaction of two olefins and the reaction of an olefin and a naphthene. In the reaction of two olefins, both olefins must be adsorbed on active sites that are close together. One of these olefins becomes a paraffin and the other becomes a cyclo-olefin as hydrogen is moved from one to the other. Cyclo-olefin is now hydrogen transferred with another olefin to yield a paraffin and a cyclodi-olefin. Cyclodi-olefin will then rearrange to form an aromatic. The chain ends because aromatics are extremely stable. Hydrogen transfer of olefins converts them to paraffin's and aromatics. In the reaction of naphthenes with olefins, naphthenic compounds are hydrogen donors. They can react with olefins to produce paraffin's and aromatics **Sadeghbeigi,2000**.

On comparing between **Figs. 2 and 4** for the catalyst 1.02 LaNaY at 6 WHSV the reduced crude conversion increases with increasing of temperature at constant WHSV within the limit of study, while, the gasoline yield increases with conversion, with a tendency to reach a maximum (at 490 °C) and after that the gasoline yield remain approximately constant. This is due to the fact that gasoline yield undergoes the secondary cracking (over cracking) to gaseous products and coke.

From **Table 2** the gases yields and coke yield, as a function of conversion when cracking atmospheric residue for the different catalysts are shown. As seen, the total gases and coke yields depend on the lanthanum weight percent loading, temperatures and weight hours space velocity. The composition of the gas phases, estimated at a conversion of 79.3 wt % (as a sample), is shown in **Table 4**.

3.5 The Effect of Lanthanum Exchange on the Thermal Stability.

Fig. 5 shows the relation between the conversion of atmospheric residue and the number of regeneration for NaY and 1.02 LaNaY catalysts. From this figure the difference in activity between NaY and 1.02 LaNaY for zero regeneration (fresh catalysts) was about 12wt%. For first regeneration about it was about 34wt%, while for second regeneration it was



about 37wt%. This means that the catalyst 1.02 LaNaY decreases the activity less than the catalyst NaY due to the fact that sodium ion decreases the hydrothermal stability of the zeolite. It also reacts with the zeolite acid sites to reduce catalyst activity, **Suchuchchai, 2004**. In the regenerator, sodium is mobile. Sodium ions tend to neutralize the strongest acid sites, **Scherzer,1990**. While RE are commonly regarded as insensitive to hydrothermal processes. They have been used as immobile elements, **Lottermoser ,1992**.

To explain this positive effect of the RE elements on zeolites thermal stability, two aspects may be considered: (i) cation valence, and (ii) formation of RE–O–RE bonds in zeolite cavities. In fact, it is acknowledged that divalent cations have a more pronounced stabilizing effect than monovalent cations, whereas zeolites exchanged with trivalent cations tend to be the more stable ones . Moreover, the enhancement on thermal stability has also been attributed to the existence of RE–O–RE bonds in the interior of sodalite cavities, which form bridges with the zeolite tetrahedra, stabilizing the structure, **Trigueiro,et al.,2002**.

4. CONCLUSION

1- The Na–Y modified with La increased cracking activity. The overall conversions obtained on the preparing cracking catalyst show an increasing the gasoline, gas ,and coke yields with increasing lanthanum weight percent.

2-The secondary cracking of gasoline to gaseous products and coke occur at 6 WHSV and 490°C

3-Lanthanum exchanged zeolites exhibit far better stability towards reaction conditions and on an average they lost almost 11.9 % of their initial activity in 1.02LaNaY whereas, NaY lost 33.6% activity with same condition (6WHSV,510°C) for first regeneration and 22.3% to 1.02LaNaY, 50.2% to NaY respectively for second regeneration .

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**Table 1:** Properties of atmospheric residue.

Density (20 °C ,gm / cm ³)	0.908
Molecular weight	486
Carbon residue(wt%)	4.67
ASTM distillation (°C)	
IBP	278
10%	291
30%	352
50%	396
70%	417
90%	450

Table 3: A comparison between the chemical compositions of cracked gasoline at 6 WHSV and 490 °C.

Chemical Composition of cracked gasoline(vol. %)	NaY (C ₅ -220°C)	1.02 LaNaY (C ₅ -220°C)
Paraffins	19.4	27.8
Naphthenes	5.7	3.2
Olefins	40.1	32.3
Aromatics	34.8	36.9

Table 4: Chemical analysis of gases at 6 WHSV and 510°C.

Gases	Yield(wt%)from the total product
Hydrogen	0.5375
Hydrogen sulfide	0.7485
Methane	2.4820
Ethane	2.8345
Ethylene	2.0677
Propane	4.3310
Propylene	3.4025
Iso Butane	2.5930
N. Butene	3.4835
N. Butane	3.2690
Iso Pentane	0.4813
N. Pentane	0.1695



Table 2: Cracking experiments results of the atmospheric residue at different lanthanum weight percent loading.

Catalyst type	Reaction temperature	WHSV(h ⁻¹)	Conversion	Gasoline(wt %)	Gases(wt%)	Coke(wt%)	Heavy oil(wt%)
NaY	510	24	43.2	19.1	15.0	9.1	56.8
	490		40.8	18.3	14.0	8.5	59.2
	470		39.3	18.1	13	8.3	60.7
	450		38.4	17.3	13.2	7.9	61.6
	510	18	50.7	22.5	17.1	11.1	49.3
	490		49.4	22.1	16.3	11	50.6
	470		47.8	21.2	16.1	10.4	52.2
	450		45.6	20.4	15.2	10	54.4
	510	12	58.9	26.2	18.7	14.1	41.1
	490		56.8	25.4	18.1	13.5	42.2
	470		55.4	25.1	17.9	12.4	44.6
	450		52.9	24.1	17.3	11.5	47.1
	510	6	67.2	30.2	21	16	32.8
	490		65.7	29.4	20.1	15.2	34.3
	470		63.1	28.0	19.1	15	36.9
	450		60.2	27.0	19	14.2	39.8
0.28La NaY	510	24	47	21.9	15.1	10	53
	490		44.2	21.1	14	9.1	55.8
	470		42.7	20.0	13.3	8.4	57.3
	450		40.3	19.0	13.1	8.2	59.7
	510	18	54.1	25.2	16.9	13	45.9
	490		52.8	24.8	16.5	12.5	47.2
	470		51.1	23.9	16.2	11	48.9
	450		48.6	23.2	15.3	11.1	51.4
	510	12	61.9	28.2	19.9	13.8	38.1
	490		60.1	27.3	19.1	13.7	39.9
	470		57.8	26.1	18.5	13.2	42.2
	450		56.2	25.3	17.9	13.0	43.8
	510	6	71.1	31.9	23.1	16.1	28.9
	490		68.9	30.8	22.3	15.8	31.1
	470		67.2	30.0	21.9	15.3	32.8
	450		64.5	29.8	20.7	14.0	35.5
0.53La NaY	510	24	51.3	21.2	18.0	11.1	48.7
	490		47.5	20.0	17.3	10.2	52.5
	470		45.1	19.2	16.4	9.5	54.9
	450		43.4	18.6	15.7	9.1	56.6
	510	18	57.8	24.5	20.1	13.2	42.2
	490		56.5	24.1	19.6	12.8	43.5
	470		54.3	23.2	19.0	12.1	45.7
	450		52.6	22.7	18.4	11.5	57.4
	510	12	65.7	28.2	22.4	15.1	34.3
	490		63.4	27.1	21.5	14.8	36.6
	470		61.6	26.4	21.0	14.2	38.4
	450		59.1	25.2	20.3	13.6	40.9
	510	6	74.6	33.2	24.0	17.4	25.4
	490		72.8	32.4	23.5	16.9	27.2
	470		70.9	31.6	23.1	16.2	29.1
	450		67.5	29.4	22.2	15.9	32.5
1.02La NaY	510	24	55.8	26.1	18.4	11.3	44.2
	490		52.2	24.2	17.1	10.9	47.8
	470		50.6	23.7	16.5	10.4	49.4
	450		48.6	22.8	16.1	9.7	51.4
	510	18	62.8	29.3	20.4	13.1	37.2
	490		60.5	28.2	20.0	12.3	39.5
	470		58.7	27.4	19.5	11.8	41.3
	450		57.1	27.0	18.8	11.3	42.9
	510	12	70.4	32.3	23.0	15.1	29.6
	490		67.6	31.2	22.4	14.0	32.4
	470		65.9	30.3	21.9	13.7	34.1
	450		63.0	28.8	21.1	13.1	37.7
	510	6	79.3	34.1	26.4	18.8	20.7
	490		77.6	34.2	25.6	17.9	22.4
	470		74.8	33.5	24.1	17.3	25.2
	450		72.5	32.1	23.2	16.2	27.5

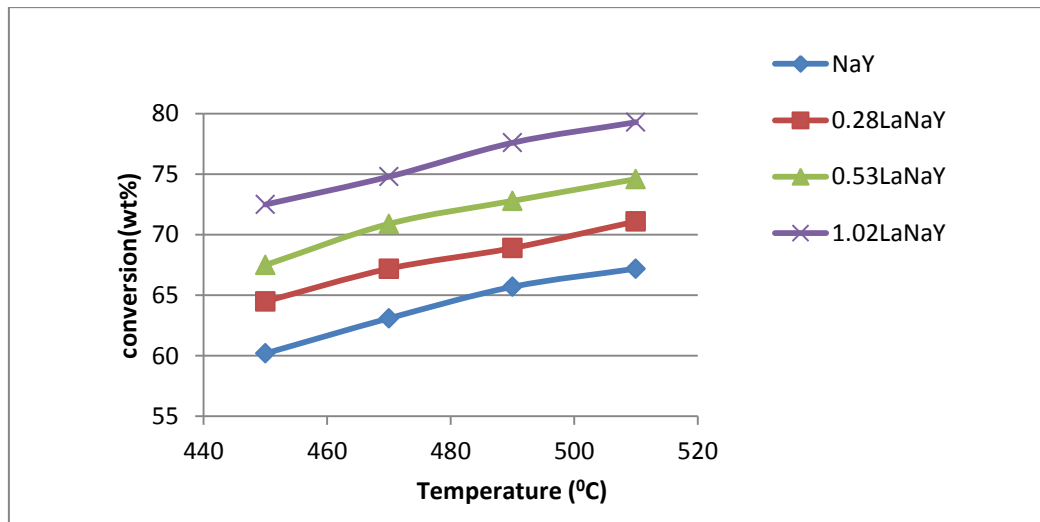


Figure2. Effect of lanthanum weight percent loading on the atmospheric residue conversion at different temperatures and 6 WHSV.

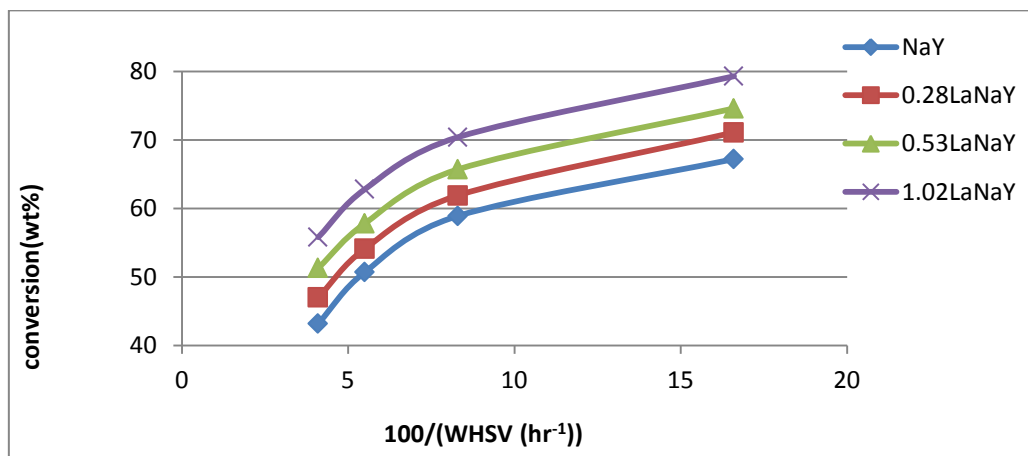


Figure3. Effect of lanthanum weight percent loading on the atmospheric residue conversion at different WHSV and temperatures 510°C.

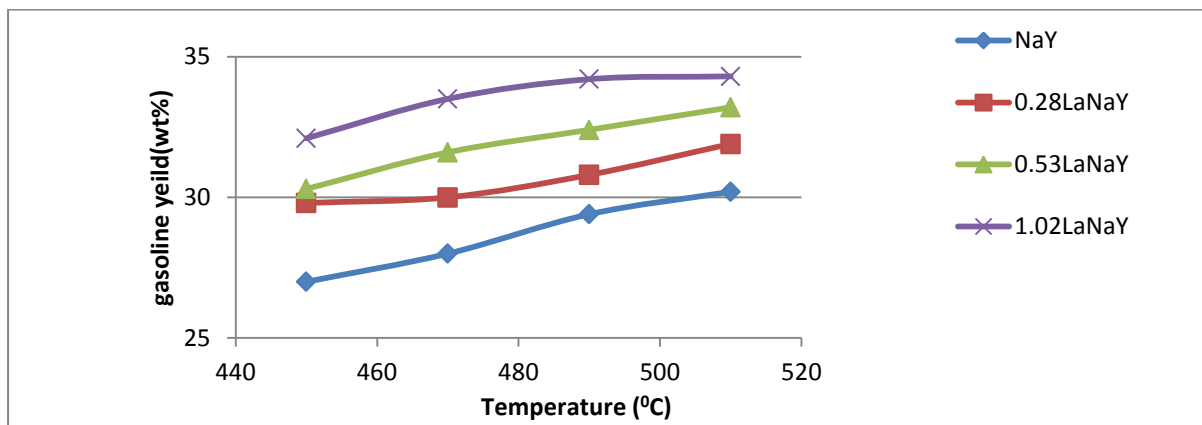


Figure4. Effect of lanthanum weight percent loading on the yield of gasoline at different temperatures and 6 WHSV.

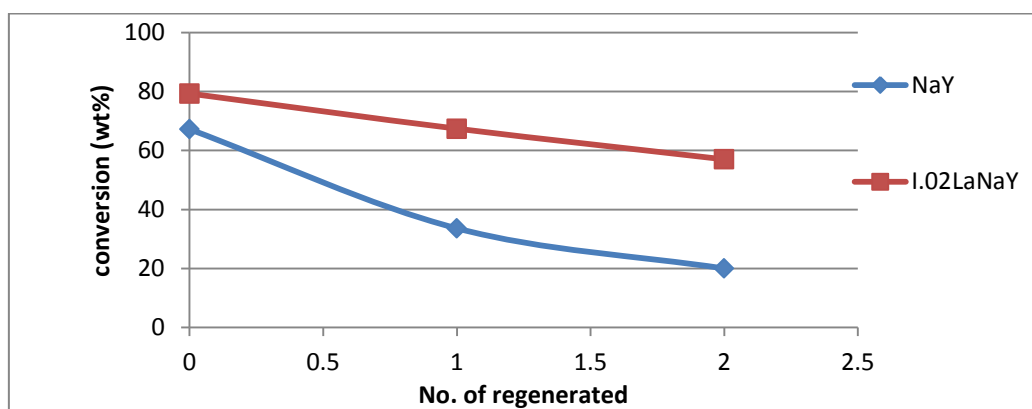


Figure5. Relation between the conversion and the number of regeneration for NaY and 1.02 LaNaY catalysts.