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## Catalytic Decomposition of Sulfones in Oxidized Iraqi Kerosene Using Prepared Mg-Al Layered Double Hydroxide Catalyst

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**Abstract**

The present study deals with the catalytic decomposition of sulfones which are the oxidized sulfur compounds generated from a fuel subjected to a pre-oxidation- desulfurization step so that to recover the hydrocarbons present in sulfones through the release of $SO_2$ gas. Raw kerosene (2296 ppm) was oxidized (using hydrogen peroxide in a batch oxidative desulfurization technique), separated, analyzed for sulfur content of 2004 ppm in the top phase and 985 ppm in bottom phase. Both phases (containing the oxidized sulfur compounds) was fed separately and continuously to the trickle bed reactor loaded with the prepared Layered double hydroxide (LDH) catalyst at 250, 325, 400, and 475 ˚C,100 psi and liquid hourly space velocity (LHSV): 1 hr$^{-1}$. Results showed that LDH catalyst was superior in achieving 75% of sulfones removal at 475 ˚C after 150 min compared to MgO catalyst achieving 49% using the top phase. In contrast 84% of sulfur compounds were removed when the bottom phase was introduced to the reactor under the same operating conditions. Catalyst stability during 21 hours of operation gives evidence to a promising fuel recovery process and to integrate the oxidative desulfurization. No previous study is found for the recycle of the sulfones from high sulfur content kerosene fuel in a trickle bed reactor and in both phases.

"Keywords: Sulfone Decomposition; Oxidized Kerosene; Layered Double Hydroxide"

## 1. Introduction

The presence of sulfur compounds has a dominant negative impact on petroleum refineries. The removal of these compounds had become an important task for fuel upgrading. Commonly, Hydrodesulfurization (HD) is the widely used process to reduce sulfur content in many petroleum fractions and products. It is carried out by introducing hydrogen gas under sever conditions of high pressure (3 -7 MPa) and temperature (320 -380 ºC) and catalyzed by NiMo or CoMo catalysts [1]. Sulfur compounds in oil may exist as active and inactive species. Mercaptan and hydrogen sulfide are examples of active types. On the other hand, thiophene (TH) and its derivatives, sulfide and carbon disulfide, are examples of inactive types that cannot react directly with the metal. Sulfur compound expressed as thiophene and alkyl derivatives (mostly Benzothiophene BT and dibenzothiophenes DBTs) are the most known compounds remaining in the fuel being processed by hyrodesulfurization [2]. Fuel oxidative desulfurization (ODS) can be implemented through the reaction between a certain oxidant and the sulfur species present in the fuel. The target in the ODS is the thiophenic sulfur compounds which can be oxidized at the ambient conditions to facilitate desulfurization.

This removal of the aforementioned compounds faces a difficulty in the hydrodesulfurization process, due to the effect of steric hindrance around the sulfur atom in the molecule [3]. By using ODS, the sulfur oxidation reaction changes the nature of the sulfur compounds where the organosulfur compounds are oxidized to their corresponding sulfoxides or sulfones. The oxidation of the fuel in ODS process can be carried out using an oxidant (normally hydrogen peroxide) and a homogenous catalyst (like acetic acid) or a heterogeneous catalyst [4]. Processing refractory sulfur compounds like DBT and alkyl DBTs requires harsh operating conditions in HD because the electron density creates a strong steric hindrance and reaction barrier [5, 6]. Recently heterogeneous catalysts were introduced in the field. Gu et al [7] described the reduced graphene oxide as an efficient catalyst in ODS compared to other nanocarbon catalysts [8]. Also, Ghubayra et al have introduced heteropoly acids $H_{3+n}PMo_{12-n}VnO40$, (HPA-n, n = 0–3)) as novel catalysts for ODS process [9]. Gao et al studied the desulfurization of model fuel and gasoline using a combined photochemical reaction catalyzed by $Cu_2O$ catalyst and liquid-liquid extraction [10]. Du et al investigated the oxidation potential of sulfones and fluorinated sulfones and concluded that the fluorination had a weak impact except for the

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branched methyl isopropyl sulfone [11]. However, the use of a homogeneous catalyst is the traditional way for catalyzing ODS. Ahmedzeki et al studied the production of low sulfur content of untreated naphtha from Al-Qayarah Refinery units(Iraq) by the comparison of three processes; oxidation, oxidation-adsorption, and adsorption. The results showed that the oxidation- adsorption process was the most efficient method achieving high removal efficiencies of 93%. Also they indicated that the best sequence of sulfur removal on sorbent materials were; Ni/AC > AC > Ni/$\gamma$-Al$_2$O$_3$> $\gamma$-Al$_2$O$_3$ [12]. Sulfones and sulfoxides (oxidized sulfur compounds) differ than the un-oxidized sulfur compounds by their high polarity which increases their selectivity toward decomposition. Additionally, the carbon–sulfur bond strength is weakened during oxidation. Therefore, it will be easier to remove the oxidized sulfur compounds by thermal decomposition [13]. Hydrocarbon recovery from the oxidized fuel containing sulfones and sulfoxides is essential and acquires attention worldwide. Dibenzothiophene sulfones with attached alkyl groups, as an example of oxidized compounds, are of high boiling points, high polarity and high molecular weight. Separation after the ODS can be achieved by an adsorption or extraction process. Sulfones separated by solvent extraction can be recovered by distillation. A common draw back can be reported by the continuous need for feeding the solvent which had a negative impact on the process costs and the possibility of fuel pollution. In case of using adsorption, sulfones may be recovered by desorption with a suitable solvent hence will be separated by distillation. Therefore, to overcome all the aforementioned difficulties, another approach was adopted for the hydrocarbons recovery through the thermal decomposition of sulfones (derived from the ODS process) producing sulfur dioxide gas and the attached hydrocarbons [14, 15]. Kim et al studied the decomposition of DBT sulfones (500ppmw) in pure toluene and oxidized diesel (300ppmw) on LDH. They reported that the catalyst surface was free of sulfur and this process produces aromatic hydrocarbon and SO$_2$ gas. High activity and stability during operation were reported [14]. Park and others prepared MgO-SiO$_2$, MgO-Al$_2$O$_3$, and MgO-SiO$_2$-Al$_2$O$_3$ catalysts by spray pyrolysis. The catalytic performance was investigated in DBT sulfones decomposition in a fixed-bed reactor [16]. Koseoglu and Bourane disclosed an integrated ODS where solid catalysts including LDH accompanied by caustic solution were used for treating a mixture of hydrocarbons and the sulfones [17]. Liu et al studied dibenzothiophene sulfone decomposition present in diesel fuel over potassium-based gamma alumina catalyst. They concluded that the removal could reach 63% using 10%K$_2$O/3Al$_2$O$_3$ [18]. Weh and de Klerk studied the thermochemistry of selected types of sulfones. They reported important findings about the vapor pressure, melting point and the enthalpy of fusion [19].

LDHs are clays of anionic type, basically have the structure of brucite magnesium oxide. Magnesium ions take the octahedral positions in the complex layers and could be substituted with other cations like aluminum ions which LDH was originally discovered. Complex layers of LDHs have a positive charge balanced by an anion that can be exchanged. This affords LDHS a unique characteristic in the ability of anion exchange rather than cation exchange which most clays possess. Direct synthesis of LDH by co-precipitation using two or more metal salts (like chlorides or nitrated as precursors) are the common method for preparation [20, 21]. Highly specific surface areas and basicity are reasons behind the catalytic applications which are acquired by the art in the preparation and activation conditions. Thermal activation of the LDH catalyst can promote their specific activity [14, 22]. Jiang et al investigated Li - Al LDH catalyst in the transesterification of Soybean Oil [23]. Jin et al studied the adsorption of phenol and nitrobenzene by modified type of LDH [24]. Other technological importance is in the medical science; as orthopedic implant coating [25], optics, separation technology, and nanocomposite material synthesis [26] anion exchangers, in photocatalysis, antacids and delivery systems for pharmaceuticals, traps for anionic pollutants including some kinds of nuclear waste, additives for polymers and as fire retardants [21].

In the present study, Mg-Al LDH catalyst was prepared, characterized by X-Ray diffraction (XRD) and BET surface area. It was utilized in the decomposition reaction of sulfones formed from ODS of Iraqi kerosene fuel in an attempt to achieve an integrated process of desulfurization (ODS and decomposition). A trickle bed reactor was loaded with the prepared LDH catalyst to treat two portions of the pre-oxidized kerosene fuel with different sulfur content. Results were compared with the activity of MgO catalyst (as a familiar catalyst for the decomposition reaction of sulfones [15,27]) in the same oxidation pilot plant unit located in the Petroleum Research and Development Center (PRDC). Past studies on catalytic decomposition of sulfones are rare; mostly, focused on the synthesis of new catalysts—and on the investigation of the performance of these new catalysts or LDH catalyst in treating a certain petroleum fractions by dissolving pure sulfur compound like thiophene or dibenzothiophene (DBT) in a model fuel prepared from pure chemicals. No previous study can be found about treating all sulfones generated from kerosene fuel with high sulfur content in a trickle bed reactor.

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## 2. Experimental Section

### 2.1 Materials.
Kerosene was supplied from Al-Dura Refinery, Mid Land Oil Company. Properties as received from the supplier are shown in Table 1. Chemicals that are used in this research are shown in Table 2.

Table. 1. Properties of Kerosene

| Property | Value |
|---|---|
| Sulfur content [ppm] | 2296 |
| Density [g/cm$^3$] | 0.797 |
| Boiling point [$^o$ C] | 160 – 235 |

Table 2. Chemical list.

| Substance Formula | Molecular Weight [g/mole] | Purity [%] |
|---|---|---|
| Al (NO$_3$)$_3$.9H$_2$O | 375.13 | 97 |
| MgO powder | 40.30 | 99.9 |
| NaOH | 40 | 96 |
| Na$_2$CO$_3$ | 106 | 99.8 |

### 2.2 Mg -Al-LDH Preparation
Mg -Al-LDH Preparation

Hydrotalcite with Mg: AL ratios of 3 was prepared by the co-precipitation method following Kim et al [14] with some modifications. Two solutions (A & B) were prepared by mixing a certain amounts of the precursors. The first (A) was a solution of magnesium nitrate(15.384g) and aluminium nitrate (6.26g) with 100ml of deionized water. The second solution (B) was a mixture of sodium hydroxide (7g) and sodium carbonate (7.5 g) with 100ml of deionized water. A was added to B with pH control at 10±0.5 so that to get a precipitate of hydrotalcite. The precipitate was aged for 18 h at 65$^o$C with stirring, filtered, washed thoroughly with deionized water and subsequently dried at 90° C for 24 h. Then, 100 g of Mg-Al-LDH was formulated in the granulator machine (as extrudate shape) with 10% of bentonite clay as a binder using appropriate amount of water to form a paste. The extrudates were dried at 110°C for 6 h and calcined at 300°C for 3h. Also, MgO catalyst was formed as extrudates for further use. The structure of the prepared catalyst was examined by X- Ray diffraction (XRD). The pattern was recorded by diffraction Shimadzu type located in Ibn AL-Haytham College. Other tests were carried out in PRDC. BET surface area of the catalysts was measured using surface area analyzer (0.1 g of dried catalyst; nitrogen was the adsorption gas at the temperature of liquid nitrogen; degassing was at 150 $^o$C for 1 h). The bulk and real density of the catalysts after formation was measured by using tab bulk density and gas pycnometer, respectively.

### 2.2.1 Kerosene Oxidation-Desulfurization (ODS)Process
This step is carried out to obtain the required sulfones to be fed to the catalytic decomposition process in the next step (see Sulfone Decomposition Reaction). Raw

kerosene was placed into a 500 ml flask connected to condenser, heated to 60$^o$C with continuous stirring at 550 rpm on a magnetic stirrer heater. At this temperature 20 ml of H$_2$O$_2$ and 5ml of acetic acid were added. These amounts were fixed following the results from other studies [28]. After three hours, a clear two distinguishable phases were observed in the separating funnel indicting the presence of sulfones. The top phase was designated as solution (I) which refers to the kerosene after the oxidation step and the bottom phase was designated as solution (II) which refers to the aqueous phase containing the separated oxidized sulfur compounds i.e. rich in sulfones due to their increased polarity after oxidation, and water which was produced from the oxidation reaction with H$_2$O$_2$. Each phase was analyzed for sulfur content and kept separately for further use.

### 2.3 Sulfone Decomposition Reaction
A continuous high-pressure trickle bed reactor unit was used to test the catalytic activity of the prepared LDH catalyst. The multipurpose unit (RTK-1100, China) located in PRDC laboratory is represented by the schematic diagram in Fig. 1. It consists mainly of a vertical tubular stainless steel reactor (4 cm O.D. and 60 cm length), electrical controlled oven, dosing pump, gas meter, condenser, and high pressure vessel separator. Nitrogen gas is used to keep the unit under the desired pressure and it was supplied from a cylinder connected to the unit. 100 g catalyst (LDH or MgO) was loaded inside the middle zone of the reactor. Ceramic balls were used to fill the space up and down the catalyst inside the reactor to support the catalyst and distribute the feed thoroughly. Both phases (I and II) from the abovementioned kerosene oxidation- desulfurization step were tested as the feed using two types of catalyst (LDH or MgO). For the desulfurization of kerosene with the catalyst, the following conditions were used: temperature (250, 325, 400, and 475 $^o$C), constant feed LHSV1 hr $^{-1}$-and pressure 100psi. The products were collected periodically after stabilization in a receiver and lastly the samples were taken for analysis. Sulfur content was measured by X-Ray fluorescence (XRF) located in the PRDC laboratory.
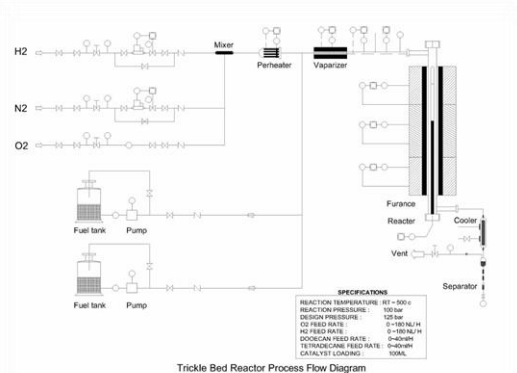


Fig. 1. Schematic diagram of the reaction unit.

## 3. Results and Discussion

### 3.1. Catalyst Characterization

Results of the X-ray diffraction patterns, presented by Fig. 2, confirmed that Mg-Al-LDH catalyst was successfully prepared by comparing its pattern with the standard values. The sharp peaks at 12°, 23°, and 35° agreed well with the reference prepared with Mg: AL ratios of 3 which are the typical characteristic peaks of Mg-Al-LDH [14]. Other peaks are attributed to the existence of $Mg(OH)_2$, $Al(OH)_3$, AlOOH or unconverted nitrate because no thermal treatment (calcination) was subjected to the prepared LDH [29, 30]. Table 3 shows the results of surface area, real and bulk density for the formulated catalyst and all results were acceptable. BET surface area of the prepared Mg- Al- LDH was 158.968 $m^2/g$ and it was decreased when bentonite binder was added to 88.115 $m^2/g$ for the Mg- Al- LDH Extrudates. This decrease can be attributed to the calcination process after formulation to get better mechanical strength of the extrudates while the original powder of LDH powder was not calcined during preparation as reported by [14] because the thermal treatment decreases its surface area but after formulation the extrudates were calcined to acquire better mechanical properties and stability in the reactor.
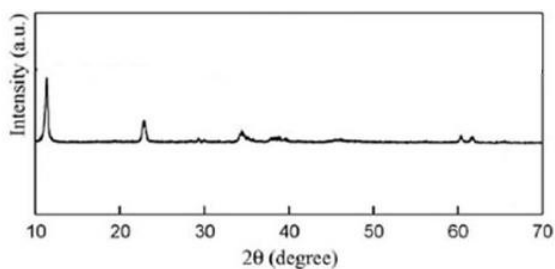


Fig. 2.XRD pattern of the prepared Mg-Al-LDH catalyst.

Table 3. Catalysts designation and results.

| Catalyst | Surface Area $(m^2/g)$ | Bulk Density $(g/cm^3)$ | Real Density $(g/cm^3)$ |
|---|---|---|---|
| MgO powder | 33.904 | ------- | ------- |
| MgO Extrudate | 45.018 | 0.651 | 3.496 |
| Mg- Al- LDH Powder | 158.968 | ------ | ------- |
| Mg- Al- LDH Extrudate | 88.115 | 0.440 | 2.175 |

### 3.2. Catalytic decomposition of Sulfones

LDH catalytic activity was investigated for the decomposition reaction of sulfones, and was compared with MgO catalyst. After the oxidation desulfurization process, Kerosene showed a decrease in the sulfur content from 2296 ppm to 2004 ppm in phase (I) i.e. upper phase. Sulfur content was 985 ppm in phase (II) i.e. bottom phase. Fig. 3 shows a comparison of the catalysts activity in case of using the upper phase (I) as the feed. It can be seen that the highest sulfur removal reached 73% for LDH catalyst and 45% for MgO after 30min at 475 °C. Constant reaction conditions were pressure = 100 psi and LHSV = 1 hr$^{-1}$. Therefore, LDH catalyst had higher activity
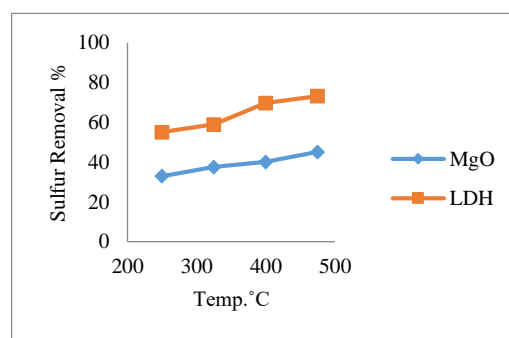


for removing sulfones than MgO catalyst nearly by a factor of 1.6. Therefore, the presence of aluminum in Mg-Al-LDH compared to MgO besides its basicity added an extra activity to the reaction media [32].

Fig 3. Comparison between LDH & MgO catalysts for the top solution (I) at the reaction conditions; total sulfur in feed = 2004 ppm, 100 psi, LHSV = 1 hr$^{-1}$.

The bottom solution phase (II) from the separating funnel after ODS, was also investigated as a feed to the sulfone decomposition reaction unit using the prepared LDH catalyst at the reaction conditions; Total sulfur in feed =985 ppm, Pressure = 100 psi, LHSV = 1 hr $^{-1}$, and temperature =250, 325, 400, and 475°C. Fig. 4 shows the results of sulfur removal as considered as the target reaction for sulfone removal. It is obvious from these results that LDH catalyst's performance was quite satisfactory for sulfones decomposition. A decrease in the sulfur content after 30 min was from 985 ppm to 158 ppm achieving about 84% removal and this removal is higher than the removal (73%) for the top solution (I) with an initial sulfur content of 2004 ppm and was presented in Fig.3 The reason behind this is attributed to the type and the concentration of sulfur compounds present in each phase. Thiophene derivatives and their alkylated forms are the candidate types in phase II [13], according to the boiling point range of kerosene cut which is given in Table 1. The Sulfones and sulfoxides were concentrated in the bottom phase after kerosene oxidation due to their higher densities and increased

polarity [28]. The aforementioned types of sulfones are the most favourable compounds for oxidation and are susceptible to thermal decomposition thereafter. The reaction proceeds in fact by breaking the bond of S-O or S=O attached to the carbon bond at the high temperature of the reaction then releases sulfur dioxide gas. Comparing the performance of the present LDH catalyst with the previous studies matches the results of Kim et al who reported that the removal of sulfones was 82% from real diesel fuel which originally contains 313 ppm of sulfur compounds [14]. Sundararaman and Song investigated a similar decomposition reaction for and 97% of the dibenzothiophenic sulfones were decomposed over 30 $MgO/SiO_2$ in diesel fuel and jet fuel respectively at temperature range of 400-450 °C [15] and JP-5 jet fuel (1050ppm). They found that about 77% sulfones present in BP-325 diesel fuel (350ppm). As previously reported DBT is favourable to ODS and is the target component in most previous studies dealing with fuel cuts of higher boiling point than the kerosene cut. Table 3 shows a review of the previous studies in the field in comparison with the present work.

## 3.3 Effect of Temperature

By observing the results displayed in Fig. 5, it is obvious that the removal on LDH catalyst (for both solutions I & II) was increased by increasing the reaction temperature at constant Liquid hourly space velocity, and pressure. The maximum removal was achieved at 475°C. The same trend for MgO catalyst was found earlier in Fig. 3.

The temperature rise accelerates the reaction rate by decreasing the activation energy of the reaction [30]. This reflects the efficient thermal cracking of sulfones to the corresponding hydrocarbon and $SO_2$ gas.

At each temperature rise there is a definite conversion to some extent. The C-S bond is weakened after the ODS process, therefore it would be easier to remove the generated sulfoxides and sulfones through thermal decomposition [13].

The same results were obtained by Park et al using three types of catalysts; $MgO-Al_2O_3$, $MgO-SiO_2-Al_2O_3$ and $MgO-SiO_2$ where it was reported that the degree of conversion to biphenyl hydrocarbons and $SO_2$ were 53.1, 68.9% and 76.2 % respectively. They concluded that $MgO-SiO_2$ catalyst had the highest activity for dibenzothiophene sulfons (DBTS) decomposition due to the high and strong basic sites included in the porous structure [16].

Table.3 . Previous sulfone decomposition processes in  comparison with this study

| | Feed | Catalyst | Reactor type | Temperature, °C | % Removal | Reference |
|---|---|---|---|---|---|---|
| 1 | DBTS/ Dodecane | $H_4PMo_{11}VO_{40}$ (HPA-1), | Continuous Fixed bed reactor | 60 | 100 | [9] |
| 2 | FCC Gasoline 740ppm | $Cu_2O$ | Photochemical reactor with magnetic stirrer | 25 | 79 | [10] |
| 3 | -DBTS -Real diesel fuel, 313ppm | Mg-Al /LDH | Continuous Fixed bed reactor | 475 | 71.4  82 | [14] |
| 4 | -Real diesel fuel 350 ppm -JP-5 jet fuel 1050ppm | $30MgO/SiO_2$ | Continuous Fixed bed reactor | 450  400 | 77  97 | [15] |
| 5 | DBTS | $MgO-SiO_2$ | Continuous Fixed bed reactor | 475 | 76.2 | [16] |
| 6 | DBTS/ oxidized diesel fuels | $K_2O/3-Al_2O_3$ | Continuous reactor | 260 | 63.9 | [18] |
| 7 | Real Kerosene cut 2296ppm | Mg-Al /LDH | Continuous Trickel bed reactor | 475 | 84 | This study |
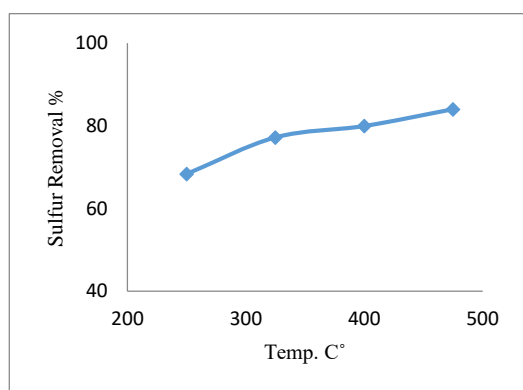


Fig. 4. Sulfur removal on LDH catalyst for the bottom solution (II) at the reaction conditions, total sulfur in feed =985 ppm,100 psi, LHSV = 1 hr$^{-1}$.
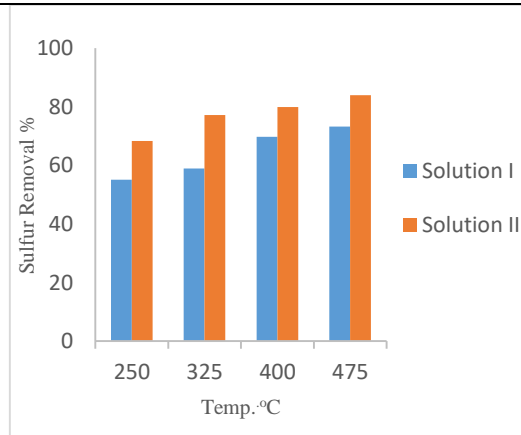


Fig. 5. Effect of temperature on sulfur removal on LDH catalyst for both solutions at reaction conditions, pressure = 100 psi, LHSV = 1 hr$^{-1}$.

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### 3.3. Effect of Temperature

By observing the results displayed in Fig. 5, it is obvious that the removal on LDH catalyst (for both solutions I & II) was increased by increasing the reaction temperature at constant Liquid hourly space velocity, and pressure. The maximum removal was achieved at 475°C. The same trend for MgO catalyst was found earlier in Fig. 3. Temperature rise accelerates the reaction rate by decreasing the activation energy of the reaction [28]. This reflects the efficient cracking of sulfones to the corresponding hydrocarbon and $SO_2$. The same results were obtained by Park et al 2010 using the catalysts $MgO-Al_2O_3$, $MgO-SiO_2-Al_2O_3$ and $MgO-SiO_2$ catalysts where the conversion to biphenyl hydrocarbons and $SO_2$ were 53.68 and 76% respectively. They concluded that $MgO-SiO_2$ catalyst had the highest activity for DBTS decomposition (in a model fuel) due to the high and strong basic sites included in the porous structure [13].

### 3.4. Effect of time and Catalyst Stability

The effect of time on the removal of sulfur compounds was studied at the best reaction temperature 475 °C which was used in treating solution I using both LDH and MgO catalysts. Results, as shown in Fig.6, revealed that there is a sharp decrease in the sulfur concentration and high percentage removal was obtained at the start of the operation during the first 30 minutes and almost constant after 120 min. The sharp decrease is represented by achieving 73% removal which corresponds to sulfur concentration decrease from 2004 to 536ppm using the prepared LDH catalyst. Commercial MgO achieved 45% with sulfur decrease from 2004 to 1100ppm. All experiments in this study were carried out using the same sample of the prepared LDH catalyst and the results of the various conditions were recorded by feeding different feed streams. Therefore, high activity and stability of LDH catalyst were explored. The catalyst sustained its catalytic and mechanical properties during the whole cycle and did not lose its ability of for sulfur removal, matching the same behavior of the commercial MgO catalyst. Also, Fig.7 shows the whole time that the LDH catalyst worked in all experiments for the treatment of the two types of feed. It reflects the whole time on stream. The experiments were started with the top solution I and ended with the bottom solution II. The time in this figure is the cumulative time on stream. Working for 1260 minutes (21 hr.) under these conditions with acceptable removal efficiencies demonstrates good LDH stability. A similar study was introduced by Kim et al [14] revealed that the LDH catalyst maintained its activity for 48 hr at 82% sulfur removal. It is worth to mention that the feed (in their study)was oxidized diesel with low sulfur content of

313ppm. Diesel fuel is rich in organosulfur compounds of alkylated forms of biphenyl derivatives of thiophenes like dibenzothiophenes which are preferable and selective for the oxidation reaction on the contrary to the lower boiling range kerosene cut [33] which contains different types of sulfur compound ( like thiophenes )which are less favorable to the oxidation reaction.
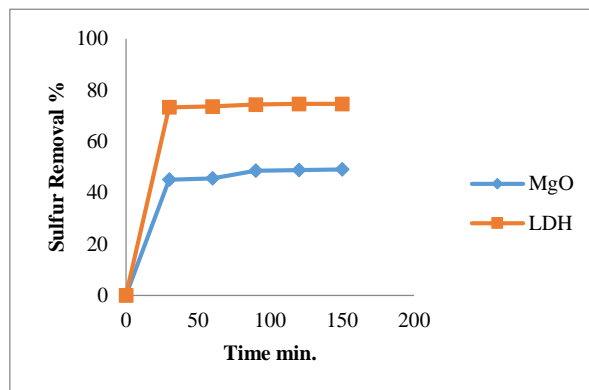


Fig.6. Effect of Time on Sulfur Removal using MgO and LDH Catalysts for Top Solution (I) at the reaction conditions; 475°C, 100 psi, LHSV 1 hr⁻¹.
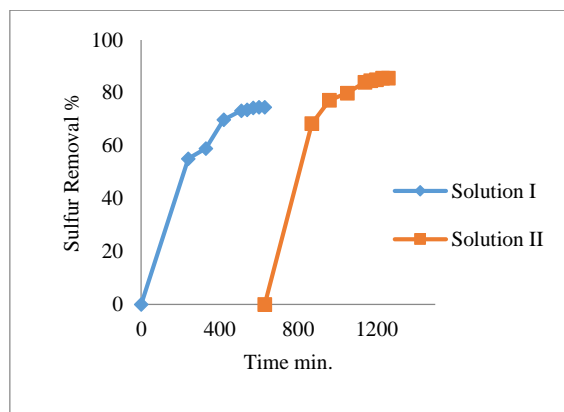


Fig. 7. Sulfur removal on LDH catalysts at whole working time for top (I)and bottom(II) solutions.

### 4. Conclusions

From the present study it can be deduced that the prepared Layered Mg-Al hydroxide is an effective catalyst for sulfone decomposition so that the hydrocarbons in kerosene fuel (2296ppm) can be recycled after fuel treatment by the ODS process. Sulfones which are separated from ODS incure a thermal decomposition to $SO_2$ gas and the corresponding hydrocarbons. LDH showed a powerful activity for sulfones decomposition which were accumulated in the bottom solution.  The  decrease in sulfur content  was from 985 ppm to 158ppm at 475°C,

210min, 100 psi, and LHSV 1 hr $^{-1}$ . Increasing the time slightly to 300min revealed further sulfone decomposition reaching 142 ppm. Decreasing sulfur content was achieved at all temperature range but 475ºC was the utmost. The prepared LDH catalyst achieved superior activity compared to MgO catalyst where the maximum removal of sulfur compounds was about 74.5% after 120 min when treating the upper phase of oxidized kerosene while the removal was 49% using MgO catalyst at the same experimental conditions; total sulfur in feed = 2004 ppm, 475 ºC,100 psi and LHSV= 1 hr$^{-1}$. Sulfur compound removal starting from raw kerosene containing 2296ppm was descending consecutively until a fuel of 510 ppm was produced. Also, the stability of the prepared LDH catalyst was pronounced throughout the operation for 21 hours which is expected to be a promising process if adopted. The catalytic decomposition of sulfones can be a better candidate process for fuel recovery. On the other hand, it may be an efficient complementary to the oxidation- desulfurization process so that to obtain ultra-clean low sulfur fuel.

## 5. Conflicts of interest

There are no conflicts to declare

## 6. Acknowledgment.

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