



Hydrogenation of coconut oil into Biofuel (bio-jet fuel and high-value low molecule hydrocarbons).

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DECLARATION

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ABSTRACT

The performance of Ni/HZSM-5, HZSM-5, and without a catalyst have been investigated for the hydrogen pressure range of 10-40bar hydrocracking of coconut oil in a packed-bed tubular reactor between 300-450°C. This study concentrates on the effect of the operating parameters (reaction pressure, type of catalyst and reaction temperature) on the yield of transportation fuel carbon range (C5-C22) using the One-Variable-At-A-Time approach. The objectives of this study are to evaluate the effect of process conditions which includes: temperature, pressure, and presence of a catalyst, and to compare the activity of Ni/HZSM-5, HZSM-5 and without catalysts. All tested catalysts were effective in attaining biofuel range in the liquid product.

The highest yield and performance of gasoline liquid composition 83.03% was obtained from the reaction pressure at constant temperature of 450°C in 40bar where HZSM-5 catalysts was used, the yield of gasoline liquid composition 82.25% was also produced at constant pressure of 40 bar in 300°C where promoted catalyst(Ni/HZSM-5) was used.

Hydrocracking coconut oil under Ni/HZSM-5 catalysts produced the highest yield of jet fuel liquid compositions 78.73% at constant temperature 300°C, and pressure of 10 bar, this was due to less coke that was formed within a reactor and less temperature of 300°C. The highest yield of jet fuel liquid composition 75.67% was also produced at constant pressure of 10 bar at maximum temperature of 450°C, this was also due to less coke that was formed within a reactor where HZSM-5 was used because of less pressure applied.

For the highest yield of diesel liquid composition 24.04%, constant temperature at 400°C of 20 bar where Ni/HZSM-5 was used in figure:5-9 and the highest yield of diesel liquid composition 25.15% was also produced at constant pressure of 20 bar in 450°C where HZSM-5 was used.

X-Ray Diffraction (XRD), Scanning Electron Microscope (SEM) coupled with Energy-dispersive X-ray spectroscopy (EDS) analyses were employed for catalyst characterization. XRD patterns confirm the success of metal doping on ZSM-5. Major peaks at 9.1° and 22.9° corresponding to ZSM-5 crystals were observed in ZSM-5. Impregnation with metals reduced the crystallinity of ZSM-5 supported catalysts.

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% XRD Relative crystallinity of ZSM-5.....	A1
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Particle size of the crystalline structure.....	A2
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Parameters

<i>B</i>	Full width at half max
<i>d</i>	Particle size of crystalline
<i>H_r</i>	Peak Height of a Reference
<i>H_s</i>	Peak height of a Sample
<i>K</i>	Crystalline constant
λ	X-Ray Wavelength
θ	Brass angle

NOMENCLATURE

Abbreviations

NH ₄ ⁺ ZSM-5	Ammonium Zeolite socony mobil-5
BTX	Benzene, Toluene and Xylene
FWHM	Full Width at Half Maximum
GC-MS	Gas Chromatography–Mass Spectrometry
HPLC	High Performance Liquid Chromatography
ID	Inside Diameter
M	Motor octane number
OD	Outside Diameter
R	Research octane number
SEM	Scanning Electron Microscope
WHSV	Weight hourly space velocity
XRD	X- Ray Diffraction
ZSM-5	Zeolite Socony Mobil-5
Ni/HZSM-5	Nickel Zeolite Socony Mobil-5
HDS	Hydrodesulfurization
HDN	Hydrodenitrogenation
HDO	Hydrodeoxygenation
LHSV	liquid hourly space velocity
OVAT	One variable at a time

CHAPTER 1

1. INTRODUCTION

1.1 Background

Currently, the critical problems on economic growth are energy crisis and global warming. Due to increase in population and change in lifestyle, the demand for energy has been radically increased since the last century. Much of the energy demand has been satisfied through fossil fuels. Main and biggest consumers of fossil fuels are transport and the industrial sectors. Transportation fuel production is dependent on crude oil as its raw material. In the future the demand for fuel may increase since the availability of fossil fuel is limited; the price of fossil-based fuels will frequently rise. Figure 1-1 indicates the world consumption of crude oil as from 2006 to 2020 in million barrels per day. It can be seen from the diagram that approximately 85.3million barrels were utilised per day in 2006, whereas by maximum year of 2020, that number increased to approximately 101.6 million barrels per day. The overall trend shows a growing demand for crude oil as the raw material for energy products around the world.

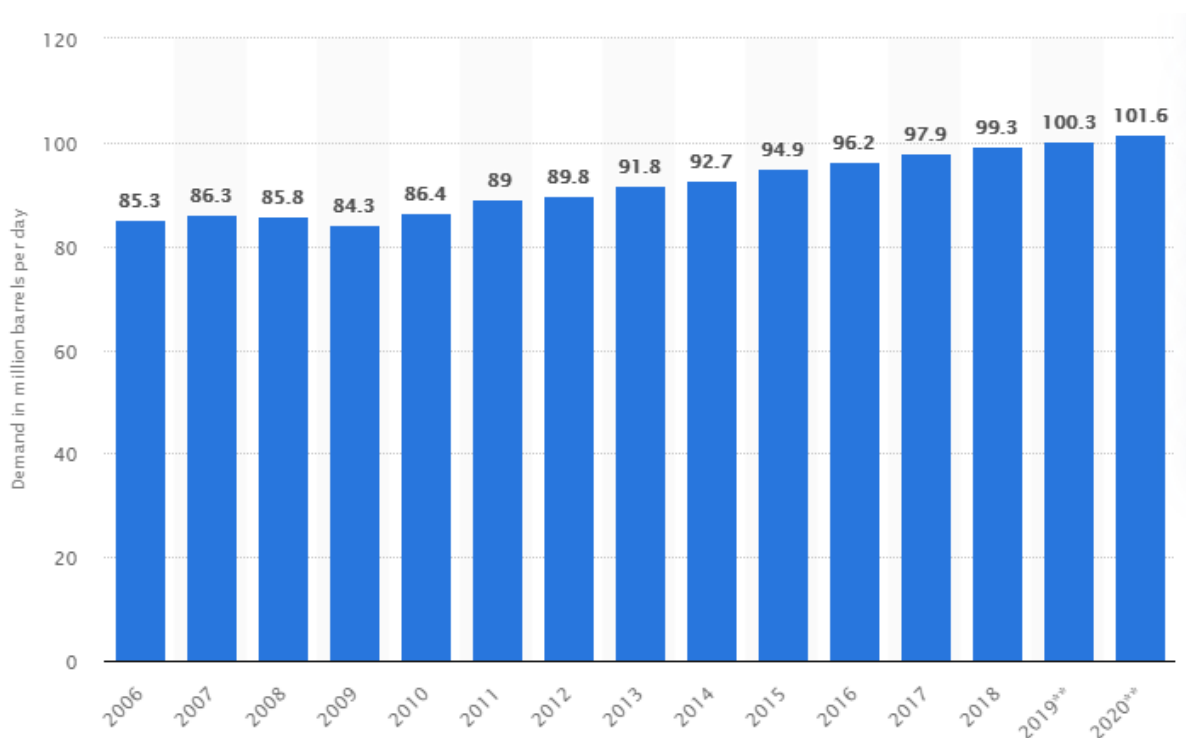


Figure1-1. World crude oil consumption (Peng, 2012)

Moreover, environmental implications such as global warming (caused by the release of the greenhouse gas carbon dioxide) and acid rain (related with NO_x and SO_x emissions) are contributed by the burning of fossil fuels and its derivatives (Van Gerpen, 2005).

Many governments are implementing rigid regulations against harmful emissions from the burning of fossil fuels and their derivatives. These governments are also keen in implementing policies which provide full tax exemptions to large corporations and individuals as a reason to encourage the use of sustainable fuels. The European Union (EU) has established a target that 10% of the total transportation fuels will be biofuels by 2020 (Van Gerpen, 2005). As a result, research into an alternative source of transportation fuel has become popular in recent years.

1.2 An alternative source of transportation fuel

Biomass has been considered as a vital alternative energy source for fossil fuels. The use of biomass (material resultant from living matter) for production of transportation fuels is becoming increasingly important and necessary. In recent years, research into a renewable sources of energy has been intensified due to the quick diminishing of crude oil reserves. The manufacturing of alternative fuel for aviation is mostly encouraged by increased petroleum costs fluctuation and environmental concerns. One of the major problems that is related to fossil fuels is the difficulty in supply with increasing demand (Faaij, 2012). A potential alternative source is a coconut oil obtained from renewable plant seed extracts. Fuels resulting from this source are considered environmentally friendly than current petroleum fuel and are named biofuels. Biofuels are regarded as cleaner burning fuels. Basically, they result in no sulphur emissions. The other advantage of biofuels is that carbon dioxide produced by the burning of biofuels does not contribute to the carbon dioxide level in the atmosphere (Peng, 2012). Fuel and energy crisis are the main concern of society for the reducing world's non-renewable energy resources, that results in the interest of the mission for alternative fuels.

Hydrocracking of coconut oil is a promising technology for the production of biofuels. In the past years, national and international regulations have endorsed the use of biofuels as an alternative source of transportation energy. Energy is an essential source of the development of human society, including social activities and daily life. As the reserves of crude oil are falling and the energy demand to compensate for the growth of the economy and population is

persistently increasing, the price of fossil-based fuels will frequently rise. The main focus is finding a renewable fuel source, and one that does not contribute to environmental pollution which could lead to environmental problems such as global warming caused by the emission of greenhouse gas carbon dioxide and acid rain-related with nitrite and sulphate (NO_x and SO_x) (Van Gerpen, 2005). Biofuel can be produced from plant oils through catalytic hydrocracking method.

1.3. Aim and objectives

The main aim of this research is to investigate hydrogenation of coconut oil into biofuel (bio-jet fuel and high-value low molecule hydrocarbons) in the presence of HZSM-5 and Ni/HZSM-5 catalysts. This study focuses on obtaining biofuel using high-pressure flow apparatus for boiling point and carbon range of transportation fuels of (C₅-C₂₂) saturated hydrocarbons.

The objectives of this study are to:

- Evaluate the effect of process conditions (temperature, pressure, and presence of a catalyst).
- Comparing the activity of Ni/HZSM-5, HZSM-5 catalysts, and without a catalyst.

1.4 The aviation fuel

Fuel is considered as one of the major operating costs for the aviation industry. Aviation fuel is a type of petroleum-based fuel used to power aircraft, and has special requirements as compared to fuels used in road transport. Jet fuel is a type of aviation fuel considered especially to power the gas-turbine engines. U.S. Department of Energy's (DOE's) Bioenergy Technologies Office (Krog, 2016), discovered that out of one barrel of crude oil, 4 gallons are utilised in the manufacturing of jet fuel. The worldwide aviation industry consumes roughly 1.5–1.7 billion barrels (47.25–53.55 billion gallons) of conventional jet fuel per year (Kar *et al.*, 2009). The challenges of crude oil are high prices, national security, environmental impact, and sustainability results to difficulties in terms of having a long-term plan as well as a budget for operating expenses. Maintainable biofuels manufactured worldwide helps with a solution to address these challenges.

Biomass-derived jet fuels (bio-jet fuels) are a potential alternative to petroleum jet fuel. There are many process technologies which are available, that are used to convert biomass-based materials into jet fuel substitutes. Some technologies are obtainable at a commercial or pre-commercial scale, and others are currently under research. These technologies depend strongly on the nature of the feedstock. Oil-based feedstocks are typically converted into bio-jet fuels over hydroprocessing technologies, including hydrotreating, deoxygenation, and hydrocracking. Processes such as catalytic hydro-thermolysis (CH) have been advanced to treat triglyceride-based oils. Solid-based feedstocks are converted into biomass by gasification process, into alcohols via biochemical or thermochemical processes, into sugars via biochemical processes, and into bio-oils via pyrolysis processes. Syngas, alcohols, sugars, and bio-oils have the potential to further advanced to bio-jet fuel through a variety of syntheses, fermentative, and catalytic processes. Presently, bio-jet fuels from Fischer–Tropsch (F–T) synthesis together with oil hydro-processing technologies have been permitted by the ASTM International Method D7566 (Wang and Tao, 2016) to produce jet fuel at levels of 50%. Hydro-processing technologies utilising vegetable and other waste oils symbolize the conversion techniques ready for large-scale utilization (Levine *et al.*, 2011). Currently industries are busy working on advancing optimal processes that use maintainable and renewable feedstocks that can be manufactured economically. Production cost is considered as the main challenge of the commercial possibility for bio-jet fuel.

U.S. passenger and cargo airlines need over 18 billion gallons of jet fuel annually. Current increase in the price of jet fuel results in an additional \$180 million yearly for U.S. airlines (Cairns, 2013). The value of petroleum-derived jet fuel is directly related to the price of crude oil (Wang and Tao, 2016). Deviations of crude oil price become problematic to budget long-term functional expenses for jet fuel refining. In 2012, the yearly fuel cost for all airlines was estimated to be \$47 billion (Kawai, 2013). It is expected that by 2030, the bio-jet fuel production cost may fall to as low as \$2.54/gal due to improved conversion technologies (Caldecott and Tooze, 2009).

Kerosene-type fuels are chosen as a fuel having the best combinations properties. Wide-cut jet fuel (Jet B) is still used in some parts of Canada and Alaska because it is suited for cold climates, but kerosene-type fuels (Jet A and Jet A-1) predominate in the rest of the world. Jet - A is mostly used in the United State, while the rest of the world uses Jet A-1. The important difference between the two fuels is Jet A-1 has a low maximum freezing point than Jet-A (Lenz and Aicher, 2005).

Aircraft manufacturers are well organised to minimise emissions and also fuel consumption of their systems. To keep the technology very simple, there is only one fuel (Jet A-1) that needs to be used onboard aircrafts (Lenz and Aicher, 2005).

Table: 1-1 The main fuel properties of Jet A, Jet A-1, Jet bio, and Bio jet fuel

Properties	Jet A	Jet A-1	Jet bio (B)	Bio jet fuel
H/C ratio	1.96	2.01	1.98	
Molecular weight (g/mol)	142±20	143±4	172±5	210
Aromatic content(%)	25.0	25.0	9.4	
DCN (ignition delay)	47.1±0.3 (4.37ms)	46.6±0.6(4.42ms)	62±0.6(3.24ms)	
Density (kg/m ³ at 15°C)	775-840	793.8	786	767
Flash point (°C)	38 min	38min	52	66
Freezing point (°c)	-40 max	-47 max	-58	-49
Net heat of combustion(MJ/kg)	42.8 min	42.8min	43.44	
TSI smoke point	17.2(25mm)	17.3(25.14mm)	43.44	

1.5 Process conditions

The study was performed at three different conditions which were reaction temperatures; reaction pressures and different catalysts. Their range were at the temperature of 300- 450°C, operating pressures of 10-40 bar, and the different of catalysts (NI/HZSM-5, HZSM-5 and without a catalyst).

Chapter 2

2. Literature review

South African Airlines (SAA) is obliged to find and use fuel that will give off fewer emissions especially carbon dioxide gas. They are required to use a blend of fifty per cent (50%) biofuel by the year 2020, to avoid fines and penalties of environmental pollution or carbon dioxide emissions from the European Commission. Therefore it is highly important to find the best suitable fuel which will be environmentally friendly and not affect the ozone layer negatively by emitting excessive gases into the atmosphere. Aircraft manufacturers are ordered to reduce emissions and specific fuel consumption of their systems (Lenz and Aicher, 2005).

Jet fuel requires high energy intensive to maximize or improve aircraft range and a low freezing point to prevent the development of crystalline wax particles during the high-altitude flight (Sacia *et al.*, 2015; Wang *et al.*, 2015). Fortunately, these requirements are readily met by branched and cyclic hydrocarbons. Furthermore, increasing consumption of jet fuel and CO₂ emissions have resulted in the innovation of biomass-derived hydrocarbons in the jet fuel industry (Zaidi and Pant, 2008; Grilc *et al.*, 2015).

The conventional technologies for biomass-derived jet fuel mostly consist of hydrodeoxygenation (HDO) of plant oil, HDO of pyrolysis oil, and biomass gasification followed by Fischer-Tropsch (F-T) synthesis. HDO of plant oil is effective and have the potential to yield high-quality distillate fuel. But it is guarded by the cost and obtainability of triglycerides from oil-producing plants (Grilc *et al.*, 2015). F-T synthesis is also effective for manufacturing liquid fuels from coal and natural gas, but it is not suitable for biomass conversion as it is principal intensive and thus necessitates centralized processing in large facilities (Zaidi and Pant, 2008). Also, linear alkanes produced by these processes requires deep hydrocracking and isomerization to decrease their molecular weight and introduce branching for proper fuel stability (Wang *et al.*, 2015) .

2.1 Hydro-processing

Hydroprocessing is defined as any of the several chemical engineering processes including hydrogenation, hydrocracking and hydrotreating particularly as part of oil refining. The products of petroleum refining should adhere to tight specifications, with limits on sulfur, nitrogen, olefins, aromatics, and other contaminants. Hydrotreating is a process which specialises in eliminating these contaminants from distilled crude oil fractions and middle process streams. Hydrocracking process uses changes in heavy oil fractions into lighter, and into more valuable products. Hydrotreating and hydrocracking processes have similar features, therefore they can be categorised as “hydroprocessing.” Most hydroprocessing units employ certain catalysts. Important chemical reactions consist of hydrodesulfurization (HDS), hydrodenitrogenation (HDN), hydrodeoxygenation, as well as the saturation of olefins and aromatics. The best catalysts typically consists of active metals and promoters on solid supports.

For the hydrotreating process, the active component is molybdenum disulfide (MoS_2). Molybdenum compound is also utilised in some hydrocracking catalysts whilst other hydrocracking catalysts employ either palladium or platinum. Promoters for MoS_2 and WS_2 catalysts consist of nickel and/or cobalt. The main support for hydrotreating catalysts is γ -alumina. Hydrocracking process needs extremely acidic supports like amorphous silica/alumina or synthetic zeolites. Catalysts can be prepared in numerous ways. At times, the support is manufactured or produced from scratch first and the metals are then added afterwards. In other cases, the support is bought directly from the suppliers, followed by drying and calcination afterwards. Hydroprocessing formations can contain fixed-bed reactors, or slurry-phase reactors, each of these needs different types of catalysts or (during the slurry-phase processing) a non-catalytic additive. Catalyst deactivation is the main role in the economics of hydroprocessing.

2.1.1 Hydrotreating and hydrocracking methods are opposite extremes of the general hydroprocessing.

2.1.1.1 Hydrotreating method.

This is used to break those bonds that permit the elimination of undesired atoms (sulfur, nitrogen). Higher severity is required to meet ultra-low sulfur product limits. It can also be used to regulate wax formation tendencies and tend to create smaller molecules due to the position of sulfur in the feedstock molecule.

2.1.1.2 Hydrocracking method

The Hydrocracking method, breaks carbon-carbon bonds to make smaller molecules. Products have vital zero sulfur-feed which must be strictly hydrotreated to protect the catalyst, and in this method, the product possesses the potential to be highly saturated good jet, diesel and poor gasoline.

2.2 Description of hydrogenation process

This is a process which involves treatment with hydrogen, and can be described as a chemical reaction that takes place between molecular hydrogen (H₂) and another compound or element, generally in the presence of a catalyst such as nickel, palladium, platinum and etc. The process is commonly used to diminish or saturate organic compounds. Hydrogenation usually set up the addition of pairs of hydrogen atoms to a molecule, often an alkene. Catalysts are usefully in the reaction to be functional; non-catalytic hydrogenation occurs only at very high temperatures. Hydrogenation (addition of hydrogen) decreases double and triple bonds into single bond in terms of hydrocarbons (Staff, 1998).

2.3 Description of hydrocracking and gas oil hydrocracking methods

The hydrocracking method specialises in processing aromatic rings without coking than in catalytic cracking. Hydrogen utilised with hydrogenate polynuclear aromatics reduces the frequency of aromatic condensation. Hydrocracking is normally delaying coking for residuals high in session, asphaltenes and heteroatom compounds. Heteroatoms and metals are prevalent in resins and asphaltenes poison hydroprocessing catalyst. The high concentration of resins and asphaltenes will still ultimately coke.

During the 1980s and early 1990s, the demand for middle distillates (C11 – C18 saturated hydrocarbons) increased in such an extent that it resulted in steady growth for hydrocracking processes around the world. New catalysts were also advanced and designed to advance catalyst activity and selectivity (Scherzer and Gruia, 1996).

Since the hydrocracking method is considered as mature and a well-developed technology, substituting the feedstock from crude oil to a sustainable alternative to yield biofuels seems to be the main option, rather than substituting the whole process which will need large capital costs. That is why in the 21st century, oil and gas companies are investing resources and time into researching sustainable and renewable feedstocks such as vegetable oils and animal fats (Demirbas and Karslioglu, 2007).

2.3.1 Gas oil hydrocracker product

Hydrocracking is mostly utilised in the United State for producing the distillates(Ward, 1978). Again, in US the hydrocracking method is treated as a specialist method in operation, used to optimise catalytic cracker operation. Catalyst cracking is mostly used when gasoline is produced and taken from heavier fraction. The ability of hydrocracking method is above 8% of the distillation capacity. The main intention of hydrocracking is to decrease the production of heavy fuel oil. Light ends are usually roughly 5% of the feed and middle distillates (kerosene, jet fuel, heating oil) still consist of uncracked polynuclear aromatics.

2.3.2 Related or competing reactions during hydrogenation

The catalysts and conditions utilised in hydrogenation reactions can also result in isomerization of the alkenes from cis to trans. The hydrogenation process is interesting because it produces most of the trans-fats in foods. Reaction where bonds are cracked while the addition of hydrogen is taking place is called hydrogenolysis. A reaction may take place with carbon-carbon and carbon-heteroatom (oxygen, nitrogen or halogen) bonds. Some hydrogenations of polar bond occurs by hydrogenolysis.

2.4 Hydrogen sources

For hydrogenation, the main source of hydrogen is H₂ gas itself, which is characteristically obtainable commercially inside the storage medium of a pressurized cylinder. The hydrogenation process frequently uses greater than 1 atmosphere of H₂, typically transported from the cylinders and increased by "booster pumps". Gaseous hydrogen is manufactured industrially from hydrocarbons by the process known as steam reforming. Main sources for the commercial manufacture of hydrogen are categorised into four groups: natural gas, oil, coal, and electrolysis; which consists of 48%, 30% 18% and 4% of the world's hydrogen production respectively (Mangold, 2009). Fossil fuels are considered as the main source of industrial hydrogen (Häussinger *et al.*, 2011). Carbon dioxide can be excluded from natural gas with a percentage of 60-70% efficiency for hydrogen manufacture and from other hydrocarbons to changing degrees of efficiencies. Especially, bulk hydrogen which is typically manufactured by the steam reforming of methane or natural gas. Natural gas is the cheapest source of hydrogen production currently.

2.5 Catalysts preparation, properties and use.

Catalysts are considered as very special substances, they axially increase the rate of reaction without taking part in the a reaction (Moulijn *et al.*, 1993). Catalysts possess the potential to produce materials or improving appropriate chemical reactions for the production of designated products (Roberts and Poignant, 2003). Catalyst has got the ability to affect the reaction of kinetics by reducing the activation energy (Scott and Lukehart, 2013). It offers low energy paths for chemical reactions. In solid catalysts like zeolites, it offers an adequate surface area for reactions to occur particularly in active sites of the catalyst (Weckhuysen and Yu, 2015). Basically, a catalyst not only speed up the reaction, but it also advances the selectivity in reaction. It can also act as a deactivation as well (Richardson, 2013).

Hydrogen gas is inactive to organic compounds specifically in the absence of metal catalysts. The unsaturated substrate is chemisorbed into the catalyst. In heterogeneous catalysts, hydrogen forms surface hydrides (M-H) from which hydrogens can be conveyed to the chemisorbed substrate. Platinum, palladium, rhodium, and ruthenium are transitional metals which form highly active catalysts, are typically operated at lower temperatures and lower pressures of H₂. Metal catalysts which are not valuable, especially those based on nickel (such as Raney nickel and Urushibara nickel) have also been advanced as economical alternatives, however they are frequently slower or need higher temperatures. The adjustment of the speed of reaction vs cost of the catalyst and cost of the equipment is needed for the use of high pressures. It has been discovered that the Raney-nickel catalysed hydrogenations need high pressures (de Brabander-van den Berg and Meijer, 1993). Normally catalysts are typically categorised into two broad classes: homogeneous catalysts and heterogeneous catalysts. The difference between them is that, a homogeneous catalyst has got the potential to dissolve in the solvent that contains the unsaturated substrate whereas heterogeneous catalysts are solids that are treated with the gaseous substrate.

The examples of homogeneous catalyst consists of the oldest industrial catalyst, nitric oxide, which was utilised in the lead chamber process for the manufacture of sulphuric acid. Currently, applications of transition metal-based homogeneous catalyst are different. Their general contribution towards industrial organic chemicals is not large, but is increasing steadily. Their vital advantage is high product selectivity which is linked to the uniformity of catalyst species that may be improved by changing the coordination ligands. It is then concluded that the reaction paths of homogeneous catalysts are always clearly understood. In common cases, all of the metal atoms form catalytically active centres which consist of a high degree of consistency. It is opposite to the situation with the heterogeneous catalyst where relatively few metal atoms are directly involved in catalysis. Furthermore, some homogeneously catalysed reaction consists of unknown or unsuitable heterogeneously catalysed counterparts.

The removal of the catalyst from the product formed can not easily to be obtained at moderate cost with some homogeneously catalysed reactions. This could be a serious disadvantage if the catalyst is costly (e.g precious metal compounds), when even small losses cannot be accepted. In the event the catalyst remainders consist of undesirable properties that may be highly toxic, complete removal of catalyst from the product is also vital. Separation is much simpler where catalyst and product have different volatility. The problems begin when no simple means for separating the catalyst from the product are available. This difficulty has been a stumbling block of widespread adoption of processes using a homogenous catalyst.

However, these problems are being overcome, and currently, many new processes have been introduced. It has been discovered that demand on product selectivity produced by increasing feedstock costs has the potential to create more opportunities for implementation of processes using a homogeneous catalyst.

2.5.1 Heterogeneous catalyst

Heterogeneous catalysts are different from homogeneous catalysts, because solids have to be made-up into suitable shapes with suitable physical properties, as a result that there may be many stages in their manufacture while homogeneous catalysts are dispersed at the molecular level. Heterogeneous catalysts are convenient to be utilised on a large scale because problems in separating the catalyst from the product are avoided and that they are applicable, almost in all main catalytic processes.

Table:2-1 Types of heterogeneous catalyst

Type	Example	Application	Comment
Unsupported metals	Raney nickel, platinum gauzes Silver granules	Organic hydrogenation ammonia oxidation to nitric oxide. Methanol oxidation/dehydrogenation to formaldehyde.	Generally unsupported metals rapidly lose activity by sintering, but the surface area of gauzes used for ammonia oxidation increase during use.
High surface area materials.	Synthetic silica- alumina's with zeolite.	Catalytic cracking of hydrocarbons	
Supported distributions binary system	Copper supported on zinc. Nickel on refractory support. Palladium on alumina	Hydrogenation of carbonyl compounds to alcohols. Steam reforming of natural gas and organic hydrogenation. Selective acetylene hydrogenation.	-Supported distributions make use of an inert high surface area support which always noticeably retards sintering.
Multicomponent system	Cu/ZnO/Al ₂ O ₃ Fe/Al ₂ O ₃ /CaO/K ₂ O Co + Mo sulphides on Al ₂ O ₃ .	Methanol synthesis Ammonia synthesis Hydrodesulphurisation	

Support liquid phase	Phosphoric acid on porous support e.g kieselguhr	Ethylene hydration to $\text{CH}_3\text{CH}_2\text{OH}$ isopropylbenzene from propylene and benzene	Supported liquid acids deactivated by alkaline impurities, many catalyst may include a liquid phase under operating condition.
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Several industrial catalysts are categorised in the above table. The common feature of heterogeneous catalyst is the performance of a relatively high surface area of the catalytically active phase to the reactants. Surface areas of commercial catalysts are known to cover a wide range surface areas from a minimum of $10 \text{ m}^2\text{g}^{-1}$ to the maximum of $1100 \text{ m}^2\text{g}^{-1}$. Special aluminas could consist of an area above $200 \text{ m}^2\text{g}^{-1}$. In the absence of physical factors which may minimise the efficiency of the catalyst, activity is proportional to the surface area of the active phase.

2.5.2 Surface area and crystallite size

The crystallites in a supported catalyst are spherical or cubic, relationships between size, number and the total surface area of the crystallites are simply derived, and are presented below.

Spherical crystallites	Cubic crystallite
$N = 6M/\rho\pi d^3$	$N = M/\rho d^3 \dots\dots\dots 1$
$SA = 3M/\rho d$	$SA = 6M/d\rho \dots\dots\dots 2$

Where N = number of crystallites in catalyst consisting of mass M of the active phase

- ρ = density of active phase
- d = diameter of crystallite
- SA = total surface area of crystallites

Basically, the crystallites of the active phases in the most common industrial catalyst fall in the range of 50 Å to 500 Å. Therefore, based on the above equations 1 and 2, one gram of a catalyst consisting of 25% of a metal like copper (i.e 0.25g) in the formation of 50 Å crystallites consist nearly 10^{18} particles of copper, with a surface area of about 30 m² (basically contact regions minimises this by a factor of two). Therefore, some 10^{20} molecules each covering 10 Å would be needed to completely cover the copper surface in the one gram of catalyst.

2.5.3 Role of the support

Most heterogeneous catalyst sinter to some degree in use, the metal catalyst is the best subject: the performance of Raney nickel for instance soon decreases when utilised at a higher temperature. Supported metal catalyst produces much higher resistance to sintering. This result has been understood in terms of both steric and energetics. For support to be effective, it should at least be finely divided as the dispersed metal. Support stands for a physical spacer between the metal crystallites, and again in the event there is enough support that is available it will prevent sintering of the metal crystallites. This model can be made semi-quantitative using the application of geometric consideration. The other method relies on an interaction between the metal and the support.

2.5.4 Promoters

It has been discovered that there is evidence that some support consists of promoting effect. The correct choice of the support material can thus be vital. A common example of a promoted catalyst is the ammonia synthesis catalyst. This is an iron catalyst manufactured by the fusion of a mixture of oxides.

2.5.5 Catalyst size and shape

Industrial catalysts can be manufactured in a range of sizes and shapes. The size and shape utilised for particular duty is reliant on the design requirement of the process and the type of reactor used. In normal operating conditions the effective activity of many catalysts is to some extent regulated by mass-transfer effects (either pore diffusion, or film diffusion limitations). Therefore, the activity of a catalyst is proportional to the total external surface area of the catalyst particles in the reactor. The total external surface area increases as the size of the individual particle decreases, thus in terms of activity, it is necessary for them to be as small as possible, though it is difficult. In large fixed bed reactors there is more power required to force the reactants gases or liquids via a bed of very fine particles. Therefore a compromise has to be reached between effective activity, the pressure drop across the reactor, the amount (volume) of catalyst utilised, as well as catalyst particle size. Shape as well has the potential to affect the external surface area and pressure drop characteristics.

At times catalyst size can influence the life of a catalyst charge. When a catalyst charge is gradually poisoned (i.e from inlet to exit) under conditions where the progress of the poisoned zone is inversely proportional to the total external surface area of the catalyst particles, thus a reactor containing small catalyst particles has a longer life than one containing larger particles.

2.5.6 Manufacturing methods

Unsupported metals: some other industrial catalysts are utilised in the form of unsupported metals since they cannot present a very high surface area of active phase (the metal). The relevant and noticeable example is platinum alloy gauze utilised for selective oxidation of ammonia to nitric oxide, which needs short contact times. Raney nickel can also be treated as an unsupported metal catalyst, though it may consist of some residual alumina which acts as a support. Raney nickel is also utilised as an aqueous suspension. In this form, it consists of a

good activity for the mild hydrogenation of organic compound. It is also sensitive to poisons and loses its activity when is used at higher temperatures.

The reason why zeolites (HZSM-5) is so unique when compared to other catalyst and other crystalline inorganic oxide materials, it because of its properties, which are: the microporous character permits certain hydrocarbon molecules to pass in the crystals while discarding others based on a big molecular size, the ion-exchange properties which permit to perform all types of ion exchange reactions, the ability to develop internal acidity which results in favourable zeolites for catalysing organic reactions and the high thermal stability of the zeolites. It was discovered that "Zeolites Material Science" field have simultaneously taken place in developments such as change of the composition outside alumina silicates, particularly the crystalline alumina phosphates Ga, Fe, B and Ti consisting of structures. An increasing number of zeolite framework structures, insight into crystallization mechanisms also increases.

2.6 Zeolites theory

Zeolites are defined as microporous, aluminosilicate minerals generally utilised as commercial adsorbents and catalysts (Grace, 2010). The term zeolite was originally conceived in 1756 by Swedish mineralogist Axel Fredrik Cronstedt, who discovered that speedily heating the material, results in the production of large amounts of steam from water that has been absorbed by the material. The word zeolite is taken from the Greek word ζέω (*zédō*), meaning "to boil" and λίθος (*lithos*), meaning "stone"(Cronstedt, 1756). Zeolites occur naturally but are also manufactured industrially on a large scale. As of September 2016, 232 exclusive zeolite frameworks have been recognised, and over 40 naturally taking place zeolite frameworks were identified (Sastre and Gale, 2003). Every new zeolite structure that is obtained has to be approved by the International Zeolite Association Structure Commission and receives a three letter designation. Zeolite consists of large surface area and complex structure which is a tetrahedral network surrounded by cavities and channels (Baerlocher *et al.*, 2007) interconnected by small windows (Modi and Trivedi, 2012).

2.6.1 Zeolite structure

Zeolite structure is formed by SiO_2 and Al_2O_3 tetrahedral which is considered as the elementary constructing unit in zeolite structure although each of the four oxygen anions in tetrahedral are joint with silica or alumina tetrahedron. The schematic diagram in Figure 2-1 shows the development of zeolite structure from alumina silicates (Meier *et al.*, 1992).

The ZSM-5, its silica and analogue silica-1 show the intersecting system of ten-numbered-ring pore which is sinusoidal and straight in structure. The framework of zeolite ZSM-5 has the configuration of linked tetrahedral, the connection of the sheets of HZSM-5 which leads to a formation of a dimensional framework of channel structure (Baerlocher *et al.*, 2007). The cross-section of both straight and sinusoidal channel comprises of 10 oxygen atoms. The straight channel and opening are of 0.54 x 0.65 nm in dimension and 0.51 x 0.55 nm sinusoidal. The silicon to aluminium (Si/Al) ratio is the one responsible for the 22 strength of acid site of the zeolite and its hydrophobicity observed in ZSM-5 catalyst while channel structure and its dimensions are responsible for high stability and strong shape-selective action (Weitkamp and Puppe, 2013).

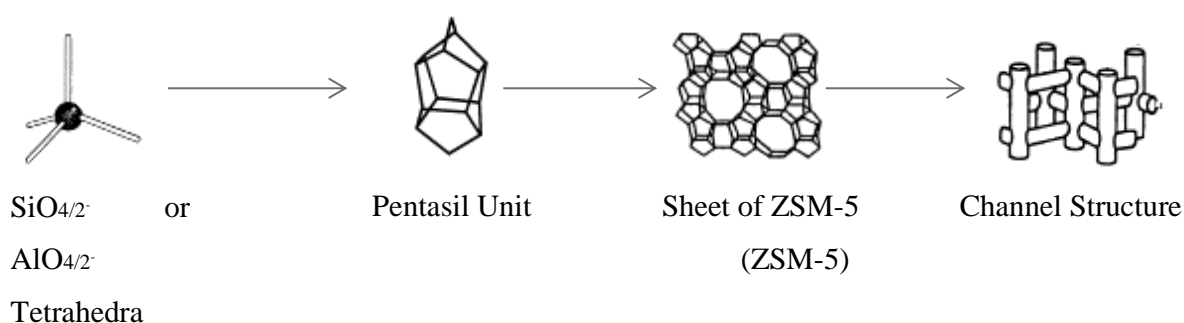
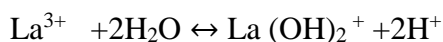


Figure 2-1. Development of zeolite structures from aluminosilicates (Meier, 1992)

Hydrogen-exchanged zeolites are generally made by heating ammonium exchanged zeolite. They normally go through degradation during use as a cracking catalyst. Rare earth-exchanged zeolites, consisting for example La^{3+} , are known to be stable. Such polyvalent cation cannot take the place of numerous charge imbalance sites, and those not directly associated with a cation become acid sites in association with the hydrolysis of the hydrated rare earth cation.



Stable rare earth-exchanged zeolites consisting shape selectivity are now utilised as cracking catalyst. Some application of zeolites are shown in the table2-2 below

Table:2-2 Some application of selected zeolite catalysts

Catalysts	Applications
RE-Y,H-Y	Catalytic cracking of heavy hydrocabons
Pd,H-Y	Hydrocracking of heavy hydrocarbons
Pt,H-erionite H-ZSM-5 H-mordenite	Selective hydrocracking of linear alkanes in the presence of branched alkanes
Pt, H-mordenite	Linear to branched isomerisation of alkanes
H-ZSM-5	Ethylbenzene synthesis
Ni,H-ZSM-5	Isomerisation of xylenes
H-ZSM-5	Disproportionation of toluene
H-ZSM-5	Conversion of methanol to gasoline

The catalytic reaction is easy to occur in the type of structure above. The product selectivity typically occurs when part of the product produced at the active sites diffuses out of the framework, and another part of the product has got larger in size as compared to zeolite lattice porous which makes it difficult to pass through the zeolite framework and which may further react to produce smaller molecular size that may result to catalyst deactivation. The coke which may be formed has the potential to result in catalyst deactivation. It is discovered that HZSM-5 catalyst is far less sensitive to coke deactivation compared to other types of zeolite because of its pore size (Armengol *et al.*, 1997).

2.6.2 Zeolite application

Zeolites are applied in three main different parts which are as follows:

Adsorbents, desiccants, and separation processes. This involve applications as drying agents, in gas purification, and in important separation processes like n-paraffins from branched paraffin, p-xylene from its isomers etc. The chief industrial catalytic applications are

in three different classes or areas are as follows: petroleum refining, synfuels production and petrochemicals production.

In the Petroleum refining area, the catalytic cracking is considered as the largest application (Y, ZSM-5) followed by hydrocracking catalysts (Y, Mordenite). Added applications are in hydro-isomerisation and dewaxing, using mostly mordenite and ZSM-5. The process called Methanol-To-Gasoline which is well known for Synfuel production uses ZSM-5 as a catalyst. There are other important petrochemical processes such as ethylbenzene by alkylation of benzene, xylene isomerisation, toluene disproportionation processed over ZSM-5 catalysts. Zeolite A serves as a sequestering agent to substitute phosphates. Miscellaneous zeolites either synthetic or natural zeolites are used in different types of applications such as Wastewater treatment, nuclear effluent treatment, animal feed supplements and soil improvement.

2.6.3 Zeolite acidity

The acidity in zeolite is mostly due to the occurrence of Bronsted Acid sites, after high treatment with temperature, which results in it acting favourably to catalytic reactions. Lewis acid sites may also take place. The diagrams in Figure 2-2 represent an example of acid sites in a zeolite (Barthomeuf, 1991).

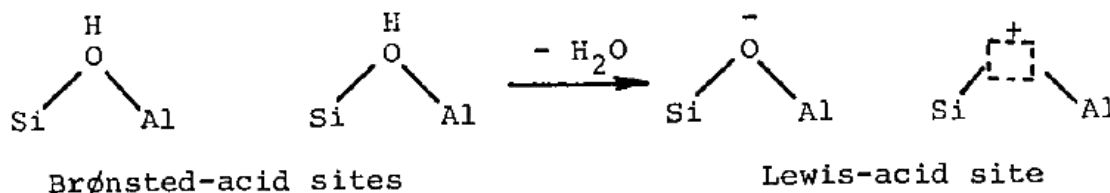


Figure:2-2 Zeolite acidity (Barthomeuf, 1991)

The reaction conditions determine the obtainability of these two acid sites above. Bronsted acid sites can be attained in treatment of acid-stable zeolites like ZSM-5 together with ammonium chloride mainly in converting zeolite Na-HZSM-5 to its proton form H-ZSM-5. Again Lewis acid sites can be attained by a process called dihydroxylation by heat treatment of temperature above 477 °C. In this reaction water is extracted and in step unsaturated Al₃₊ ion is formed (Barthomeuf, 1991; Armengol *et al.*, 1997).

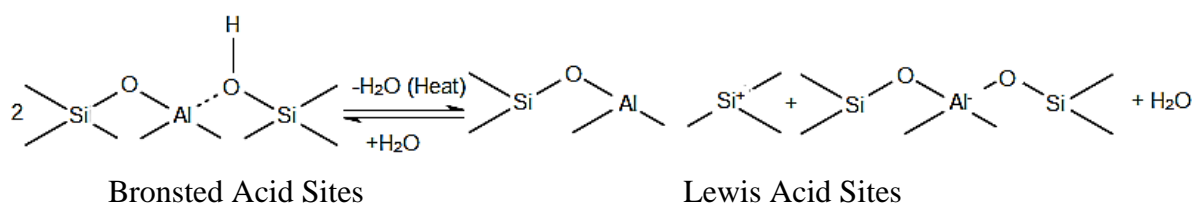


Figure 2-3. Zeolite acidity dehydration (Armengol *et al.*, 1997)

ZSM-5 is also considered as high silica zeolite because of unlimited silica to alumina ratio. Changing of Si/Al ratio has numerous effects in zeolite performance in catalysis. The zeolite stability in high- temperature reactions and its activity relies on the ratio of Si/ Al. ZSM-5 is very stable at the maximum temperature of 1027 °C. It is also revealed that low Si/Al ratio zeolites like zeolite X and Y are inactive at the pH less than 4 whereas ZSM-5 zeolites are stable in boiling concentrated acid solutions (Baerlocher *et al.*, 2007).

2.6.4 Zeolite as support for metals

Zeolite supported metals are utilised in chemical industries more so for improvement of reactions, and for conversions of different organic compounds to the selective product. Zeolite also has the potential to increase high atomic metal dispersion because of its structure and pores. Metal particles can only be stabilized by zeolite framework inside pores that offer a large surface area. Zeolites as supports become bifunctional catalyst by a metal function and acid Bronsted sites function, and what makes it different from other support is that they are very stable in reaction conditions and obtain the maximum surface area of 800 m²/g (Weitkamp and Puppe, 2013).

2.6.5 Transition metals in catalyst

In many other chemical reactions, transition metals and other compounds have shown some catalytic activity. The catalytic activity depends on metals' capacity to demonstrate multiple oxidation states and development of complexes. These metals are a common example of a heterogeneous catalyst that are based in a car exhaust whereby Pt/Ph alloy supported ceramic transforms the mixture of CO₂, CO, NO_x and hydrocarbons in exhaust gases to H₂O, CO₂ and N₂. For conversion to take place, the reaction requires only metals as they possess Lewis acid sites (Crabtree 2009).

2.6.6 Methods of manufacturing heterogeneous catalyst.

a) Unsupported metal

Some of the industrial catalysts are normally used in the form of unsupported metals since they do not consist of the high surface area of the active metal. The main notable example is platinum to allow the gauze utilised for the selectivity oxidation of ammonia to nitric oxide. The other example of a vital metal catalyst is silver which is used in the manufacturing of formaldehyde from methanol and air. The silver is used in the form of small granules.

Raney nickel is also considered as an unsupported metal catalyst, though it may consist of some residual alumina which acts as a support. Raney nickel consists of the highest surface area of the unsupported metal catalyst and is normally utilised as an aqueous suspension. It also consists of a good activity for the mild hydrogenation of organic compounds and sensitive to poisons and loses activity fairly rapidly when used at higher temperatures.

b) Fusion method

This method is not widely utilised for the production of catalysts. Though, the vital ammonia synthesis catalyst is made in this way. The procedure for preparation includes melting the component catalyst oxides (involving promoters) in an electric furnace (~1600 °C). After the stage of cooling, the solid mixture is ground to give the needed particles size (e.g 0.5 to 1.0 cm) for charging into a reactor. Normally in this level, catalyst that is used consists of very low porosity.

c) Impregnation of preformed support

Impregnation methods are mostly used in the production of commercial catalysts, either when catalysts consisting of low content of active phase are needed (as with valuable metals), or when catalyst with high strength is required. The preformed support is normally few refractory oxides, always alumina, which is fabricated into small cylindrical pellets, or rings. Many methods are utilised to manufacture supports. The preparation of alumina pellets includes precipitation of hydrated alumina from solution, drying and processing the precipitate so that it readily forms pellet when compressed. At this level, pellets become weaker. High temperature produces partial sintering of the alumina which increases mechanical strength. The material that is normally produced is highly porous. It is always vital that the support material has defined physical properties, like surface area.

The main purpose of the support material is to give the final catalyst shape and mechanical strength and to separate the crystallites of the active phase (deposited in the pores through impregnation), and so to minimise their sintering rates. In other cases (e.g cracking catalysts)

support is utilised to minimise the cost of the catalyst. The impregnation procedure includes filling the pores of the support with a solution of a compound (e.g nitrate) which is easily converted to the active phase.

There are two types of industrial impregnated catalysts that are available. One consists of unchanging supply of active material by the support pellet. The nickel-based catalysts utilised in steam reforming natural gas to hydrogen and carbon oxides are of this form as well. The other type of impregnated catalyst does not consist of uniform supply of active material by the catalyst and again the second type is limited to the outer regions of the catalyst particle. This type of shell catalyst is mostly suitable for impregnated valuable metal catalyst where it is vital to make the most effective use of the metal and also decrease the overall catalyst cost.

d) Precipitation methods

Precipitated catalysts are normally prepared by rapid mixing of concentrated solutions of metal salts. The product precipitates in a finely-divided high surface area form; generally mixed hydroxides are prepared in this method. After cleaning out the undesirable soluble salts, the precipitate is then dried and heated to decay the hydroxides to the matching oxides, before adding a lubricant like graphite which enables the compression of the powder into pellets. Most precipitated catalysts are multicomponent systems. A classic example is the copper-based low-temperature carbon monoxide shift catalyst. The main catalyst, broadly used, is made by precipitating basic copper and zinc carbonates with alumina.

e) Crystallisation(zeolite manufacture)

Zeolites are considered as the only catalyst in which crystallinity is principally vital. They are produced by mixing solutions of silicon and aluminium compound (e.g silicates and aluminates) and with any other additives at an appropriate pH. A gel is formed, which in some cases must be venerable at room temperature before heating it to crystallise the needed product. The exact zeolite which crystallises, relies critically on the silicon/aluminium ratio, concentration, the presence of additives, and conditions like temperature.

2.7 Vegetable oils

Triglycerides (vegetable oils or animal fats) are categorised as the hydrophobic substances that are made by one molecule of glycerol and three molecules of fatty acids. There are various types of vegetable oils have been identified as potential raw feedstocks for biofuel

production typically according to geography and climate. Rapeseed oils are used for biodiesel production in Europe, corn and soybean oils are favoured in the USA. While the plentiful palm

and coconut oils are employed in tropical countries. Also, other types of vegetable oils, e.g., cottonseed, canola, peanut, and sunflower oils have also been investigated and studied (Van Gerpen 2005). The fatty acid compositions of typical vegetable oils are presented in Table 2-3 (Knothe, 2005). It also has been discovered that most of the vegetable oils are highly unsaturated and the main compositions are C₁₈ fatty acids, excluding palm oil having saturated palmitic acid as chief component.

2.8 Technology for triglyceride conversion

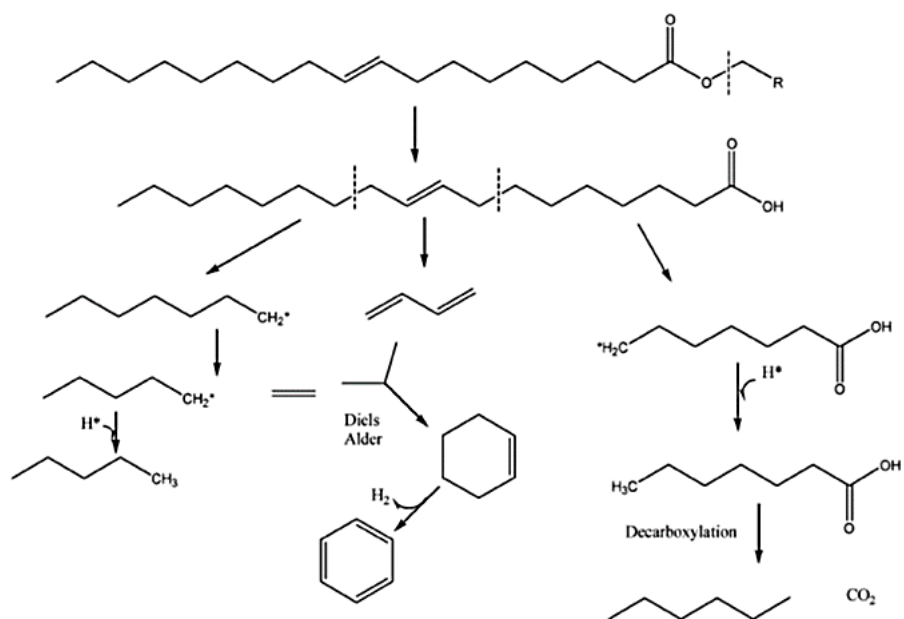
It has been discovered that triglycerides can be used straight in diesel engines, but due to high viscosity and low volatility of triglycerides, direct combustion causes many engine problems, those problems are carbon deposits, coking on the injector, and oil ring sticking (Ma and Hanna, 1999). These problems need triglycerides to be improved before being used as biofuel. The commercial improvement process consists of the transesterification of triglycerides and alcohol into fatty acid alkyl esters (FAAEs) and glycerol which is also useful in the production of first-generation biodiesel. Triglycerides can also be advanced by processes of cracking, pyrolysis, hydrotreating and deoxygenation to yield hydrocarbons as next generation biofuel.

Table:2.3 Fatty acid composition of typical vegetable oils (Knothe, 2005)

Fatty acid composition (wt%)	Myristic	Palmitic	stearic	Oleic	Linoleic
Coconut Oil	14.0 ^a	16.0	18.0	18.1	18.2
Rapeseed	0.1	5.1	2.1	57.9	24.7
Corn	-	7-13	2.5-3	30.5-43	39-52
Soybean	-	2.3-11	2.4-6	22-30.8	49-53
Palm	0.6-2.4	32-46.3	4-6.3	37-53	6-12
Cottonseed	0.8-1.5	22-24	2.6-5	19	50-52.5
Canola	-	4-5	1-2	55-63	20-31
Peanut	0.5	6-12.5	2.5-6	37-61	13-41
Sunflower	-	3.5-6.5	1.3-5.6	14-43	44-68.7

2.8.1 Cracking

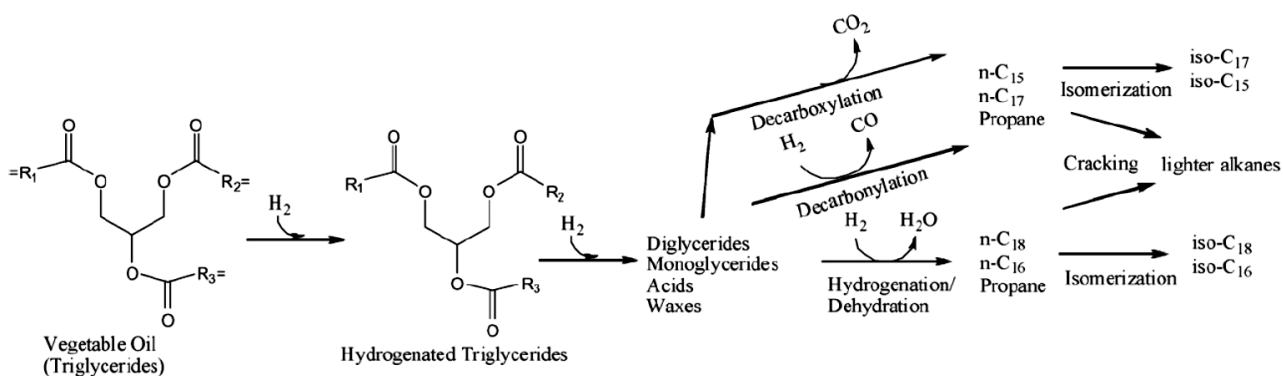
Though most of the present or current biofuels are manufactured through transesterification process, these fatty acid alkyl esters have the disadvantage of possessing a relatively high oxygen content and poor flow property at low temperatures, limiting their application as high-grade fuels (Šimáček *et al.*, 2009). Catalytic cracking is an alternative method for advancing triglycerides to yield fuels, and it has been studied with many different zeolite catalysts (Twaiq *et al.*, 2003; Corma *et al.*, 2007). HZSM-5, HBeta and USY are zeolites that have been used to study under the method of cracking of palm oils in a fix-bed reactor at the temperature range of 350-450 °C and atmospheric pressure. These three zeolites have the potential to produce 99%, 82% and 53% conversion with gasoline selectivity of 28%, 22% and 7%, respectively (Corma *et al.*, 2007). The key products are achieved from zeolite catalyzed cracking and their characteristics are linear, cyclic paraffin, olefins, oxygenated compounds together with aldehydes, ketones and carboxylic acids. Various reactions, e.g. cracking, hydrolysis, isomerization, dehydrogenation, aromatization (Diels-Alder reaction) and coking are taking place in the course of this process. The operation of the cracking method to upgrade triglycerides has many disadvantages. It has been discovered that the great number of oxygenated compounds in the products would hinder the application as fuels caused by the challenges both in storage and in an internal combustion engine. The other problem is that the products consist of various aromatic compounds, and their usage is strictly controlled in Europe. Most essentially, zeolite cracking is a non-selective process that yields an extensive range of compounds and undesired coking formation. Scheme 2-1 below presents a proposed reaction mechanism for soybean oil conversion (Schwab *et al.*, 1988).



Scheme 2-1 Mechanism for triglycerides cracking (Schwab *et al.*, 1988).

2.8.2 Hydro treating

Triglycerides can be processed by the process called hydrotreating together with conventional hydrotreating catalyst (e.g., sulfided NiMo and CoMo) through petroleum refinery structure to yield straight-chain alkanes in a range of C_{12} to C_{18} at 350-450 °C in the presence of 40-150 bar H_2 (Gervasini and Auroux, 1991; Duan and Sun, 2003). It has been introduced by Nestle Oil and UOP. Matched with the following methods, catalytic cracking, hydrotreating process is more unique in manufacturing diesel range hydrocarbons (Maire *et al.*, 1965). There are a number of bonds that occur in the alkyl chain of fatty acids, (i) hydrogenolysis of saturated triglycerides to fatty acids, (ii) hydrodeoxygenation, or decarbonylation, or decarboxylation of fatty acids to alkanes. In this process, the carbon backbone of triglycerides is transformed into propane as a vital by-product. The oxygen in the triglycerides process is removed either by decarboxylation/decarbonylation to CO_2/CO or via hydrodeoxygenation to H_2O .



Scheme 2-2 Reaction pathways for conversion of triglycerides to alkanes (Huber *et al.*, 2007).

2.8.3 Deoxygenation

Catalytic deoxygenation can be defined as the other technique that can be used for fatty acids and triglycerides improvement (Maier *et al.*, 1982; Snåre *et al.*, 2006). Transitional metal-supported catalysts (e.g., commercial Pd/C and Pt/C) are typically used. Catalytic deoxygenation has numerous advantages compared to the hydrotreating process, together with higher selectivity to linear hydrocarbons and few additional hydrogen costs because of no or very low hydrogen requirement. Stearic acid can be transformed into linear C17 alkanes with

95% selectivity over 5 wt% Pd/C in semi-batch mode at 300 °C under 17 bar of 5% H₂ in argon. Catalyst screening shows that the deoxygenation rates fall in the sequence of Pd > Pt > Ni > Rh > Ir > Ru > Os (Maier *et al.*, 1982). Decarboxylation, decarbonylation and hydrodeoxygenation are the major reaction paths. Hydrogen consumption for the deoxygenation of fatty acids follows the increasing trend of decarboxylation < decarbonylation < hydrodeoxygenation, in principle, the decarbonylation or decarboxylation path is most appropriate than the hydrodeoxygenation pathway. The reaction of vapour phase, methanation and water-gas shift are considered as the major reactions. Thermodynamic data are supplied for the conversion of palmitic acid to C₁₅ and C₁₆ alkanes involving the gas-phase reactions at 260°C. These noble metal catalysts presented high activities and selectivities for fatty acids change; however, they showed much lower activities and selectivities to the target alkanes when transforming triglycerides. The performance was upgraded by a Pt-Re/ZSM-5 catalyst (Murata *et al.*, 2010). Furthermore, the high price of noble metal also restricts the application in large-scale industrial manufacture.

Liquid phase

$\Delta G_{533}(\text{kJ/mol})$

$\Delta H_{533}(\text{kJ/mol})$

Hydrodeoxygenation: $\text{R-COOH} + 3 \text{H}_2 \longrightarrow \text{R-CH}_3 + 2 \text{H}_2\text{O}$

Decarbonylation: $\text{R-COOH} + \text{H}_2 \longrightarrow \text{R-H} + \text{CO} + \text{H}_2\text{O}$

Decarboxylation: $\text{R-COOH} \longrightarrow \text{R-H} + \text{CO}_2$

Gas phase

Methanation: $\text{CO} + 3 \text{H}_2 \longrightarrow \text{CH}_4 + \text{H}_2\text{O}$

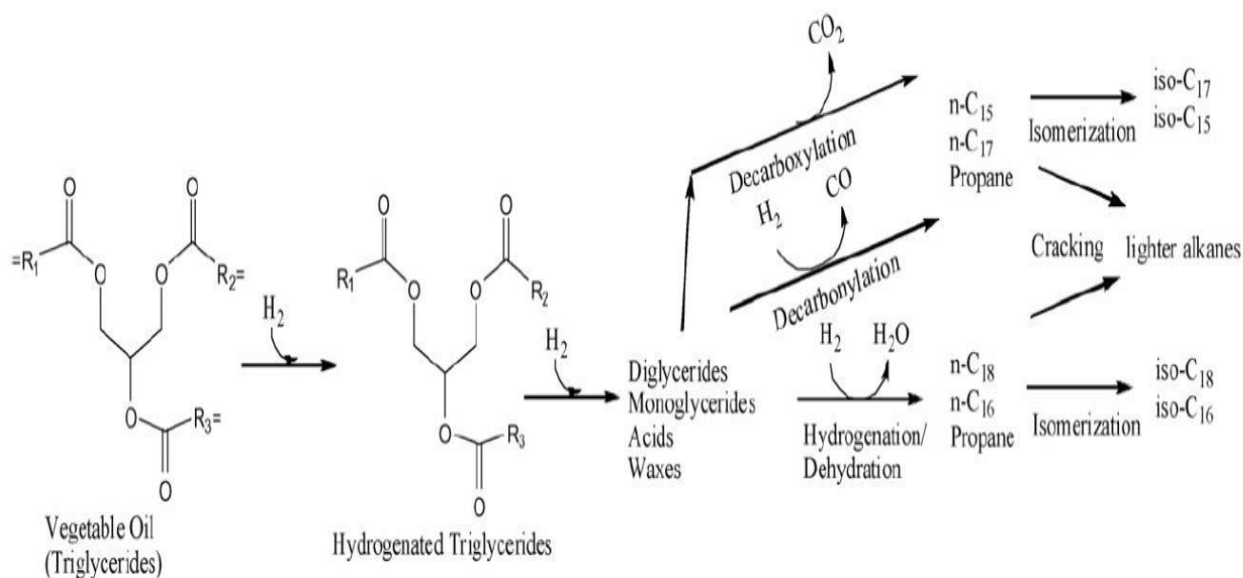
Methanation: $\text{CO}_2 + 4 \text{H}_2 \longrightarrow \text{CH}_4 + 2 \text{H}_2\text{O}$

Water gas shift: $\text{CO} + \text{H}_2\text{O} \longrightarrow \text{CO}_2 + \text{H}_2$

Scheme :2-3 Reactions for Decarboxylation during hydroprocessing(Donnis et al., 2009)

2.8.4 Reaction mechanisms for catalytic hydrotreatment of liquid biomass.

The mechanism of the hydrocracking process has been investigated by many researchers, especially on the conversion of vegetable oils into biofuels. Scientists admit that the triglycerides are first saturated on their side chain, which is then followed by the bond of C-O resulting in the formation of the following methods which are diglycerides, monoglycerides, carboxylic acids and waxes (Huber *et al.*, 2007). These are followed by decarboxylation, decarbonylation and hydrogenation/dehydration reactions including isomerisation and cracking. The reaction pathways are presented in scheme 2-4 . Proposed reaction mechanisms from different studies are discussed in this section.



Scheme :2-4 Reaction pathways for the conversion of triglycerides to alkanes (Huber *et al.*, 2007)

In a fixed bed hydrotreating process, the reactions occur in a three-phase system: the first one is liquid feed which drops down over the solid catalyst in a high-pressure system where there is a hydrogen-rich gas phase (Wang, 2012). Many types of reactions occur during the catalytic hydrotreatment of liquid biomass. These reactions rely on the type of biomass, the operating conditions and the type of catalyst used. The types of reactions the liquid biomass go through during catalytic hydroprocessing consists of: saturation (hydrotreating), cracking (hydrocracking), heteroatom removal and isomerisation.

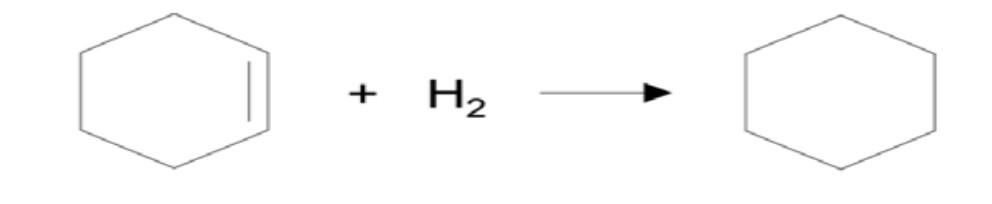
2.8.5 Saturation reactions

These reactions are defined as hydrotreating reactions as they consist of non-destructive hydrogenation and are utilised to advance the quality of petroleum distillates excluding the boiling point range (Sotelo-Boyás *et al.*, 2012). In these reactions the introduction of extra hydrogen permits for the breaking of C-C double bonds and their successive conversion to single bonds. The main reaction is the conversion of unsaturated carboxylic acids into saturated ones in feedstocks which is vegetable oils as depicted in Scheme 2-5 (Bezergianni, 2013b).



Scheme 2-5 Saturation reaction of unsaturated carboxylic acid (Bezergianni, 2013b).

In the advancement of pyrolysis oils, saturation reactions results into the formation of naphthenes by altering unsaturated cyclic compounds and aromatics compounds as illustrated in Scheme 2-6 below.

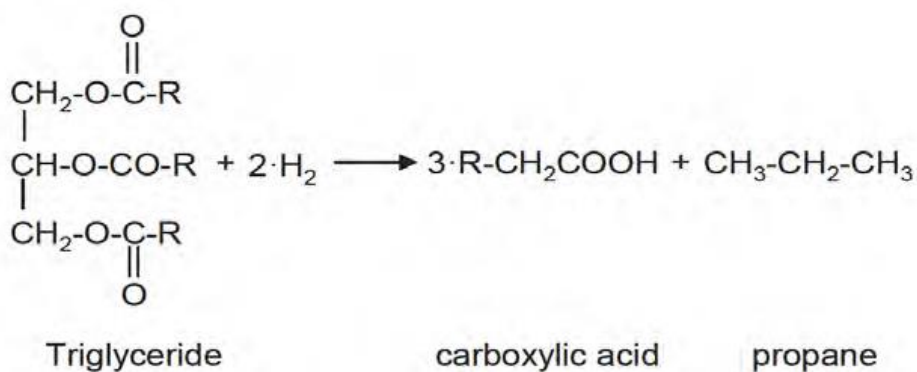


scheme:2-6 Conversion of benzene to cyclohexene through hydrotreating reactions (Bezergianni, 2013b)

In the result of saturation reactions, it is shown that the produced saturated compounds is less active to polymerisation and oxidation reactions. This kind of reaction helps in improving the residue formation and corrosion appearing in engines. In a study performed by (Bezergianni *et al.*, 2009), it was discovered that saturation reactions were not preferred by increased temperature which was expected as saturation is a competing reaction mechanism to the cracking one.

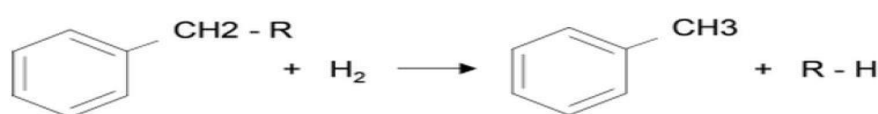
2.8.6 Hydrocracking

Hydrocracking reactions are the type of reactions that are needed when there is a need to convert liquid biomass whose chemical structure is large and complex, into molecules of the size and boiling point range of transportation fuels i.e. gasoline (C₅ – C₁₀), kerosene (C₁₁ – C₁₃) and diesel (C₁₄ – C₁₈) (Bezergianni, 2013b). A characteristic reaction that takes place through catalytic hydroprocessing of vegetable oils is known as cracking of triglycerides into its containing carboxylic acids (fatty acids) and propane as in Scheme 2-4 (Donnis *et al.*, 2009). This is considered as a serious reaction in the hydroprocessing scheme as it changes the initial large triglycerides compounds of high boiling points (>600 °C) into mid-distillate range compounds which are gasoline, kerosene and diesel.



Scheme :2-7 Hydrocracking a triglyceride to form a fatty acid and propane (Donnis *et al.*, 2009)

Other cracking reactions may take place, depending on the components of the feedstock. Scheme 2-8 shows a cracking reaction which may take place during catalytic hydroprocessing of pyrolysis oils. On the other hand, Scheme 2-7 follows the deoxygenation of carboxylic acids on the formed long-chain paraffinic compounds, resulting in smaller chain paraffin. One such example is during the upgrading of Fischer-Tropsch wax (Bezergianni 2013b).



Scheme 2-8 Cracking reaction during hydroprocessing of pyrolysis oils (Bezergianni, 2013b)

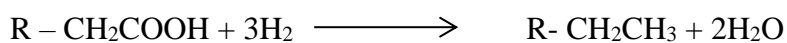


Scheme 2-9 Cracking reaction of long chain paraffins to smaller chain ones (Bezergianni, 2013b)

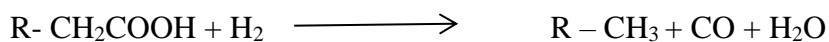
2.8.7 Heteroatom removal

Heteroatoms describe the other atoms, other than carbon and hydrogen, which are frequently present in bio- and fossil-based feedstocks. Oxygen removal specifically is vital as the presence of oxygen reduces oxygen stability (due to carboxylic and carbonylic double bonds), acidity and corrosivity are increased (due presence of water) and the heating value of the biofuels

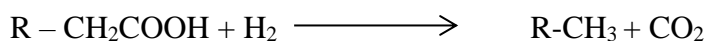
produced is minimised (Bezergianni, 2013b). The three chief deoxygenation reactions that take place are deoxygenation, decarbonylation and decarboxylation as shown in Schemes 2-10, 2-11 and 2-12 respectively (Donnis *et al.*, 2009).



Scheme 2-10 Deoxygenation reaction during hydroprocessing (Donnis *et al.*, 2009)

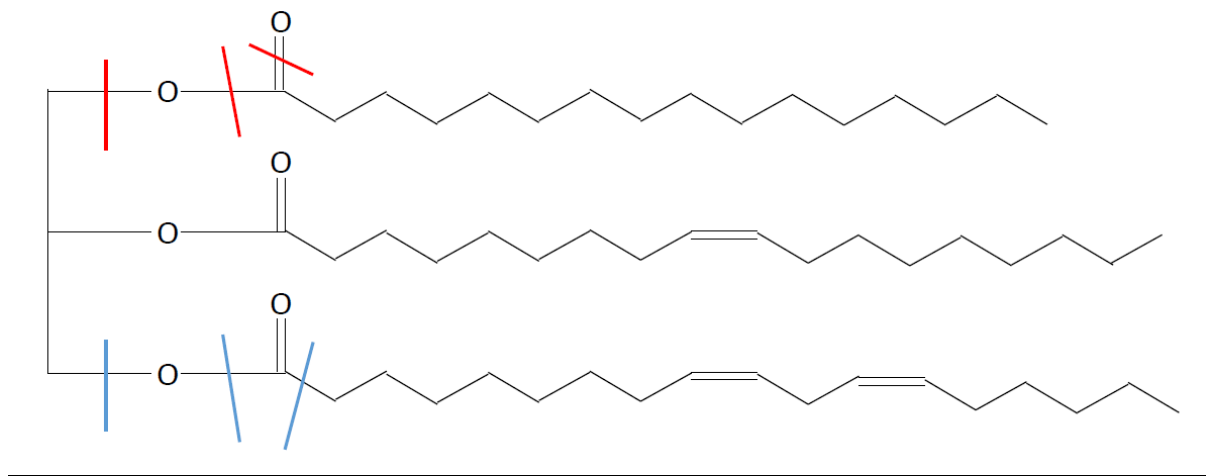


Scheme 2-11 Decarbonylation reaction during hydroprocessing (Donnis *et al.*, 2009)



Scheme 2-12 Decarboxylation reaction during hydroprocessing (Donnis *et al.*, 2009)

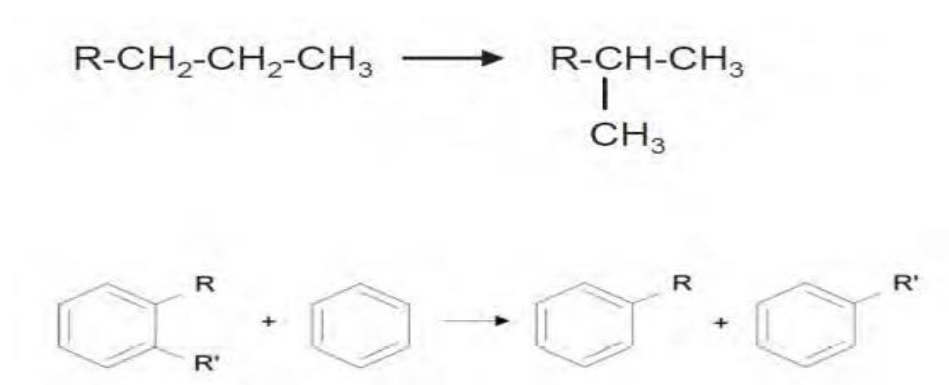
The above schemes were developed in a study by (Donnis *et al.*, 2009). A schematic illustration of the two different mechanisms for the removal of oxygen from the triglyceride is presented in schematic 2-13 below. The unbroken red lines show the reaction of hydrogenation/hydrodeoxygenation (HDO), in which it was planned that the oxygen was excluded as a form of water. The blue lines shows the decarboxylation and decarbonylation reactions (the reactions are presented in both scheme 2-13). In this whole illustration the triglyceride is changed into propane, carbon dioxide and/or carbon monoxide and into an n-alkane.



Scheme : 2-13 Schematic representation of the two different pathways for removal oxygen from triglyceride by hydrotreating .

2.8.8 Isomerisation reactions

The straight chain paraffinic compounds produced from the above give an increased cetane number, heating value and oxidation stability in the biofuels which consists of them. Though, they degrade their cold flow properties. Cold flow properties can be enhanced by isomerisation reactions.



Scheme 2-14 Examples of isomerisation reactions (Bezergianni and Dimitriadis, 2013)

Other proposed reaction mechanisms for hydroprocessing triglycerides

A relevant study which was performed by (Nasikin *et al.*, 2009) offered a reaction mechanism (Figure 2-5) for the simultaneous catalytic cracking and hydrogenation reactions of palm oil by means of a zeolite catalyst to yield bio-gasoline.

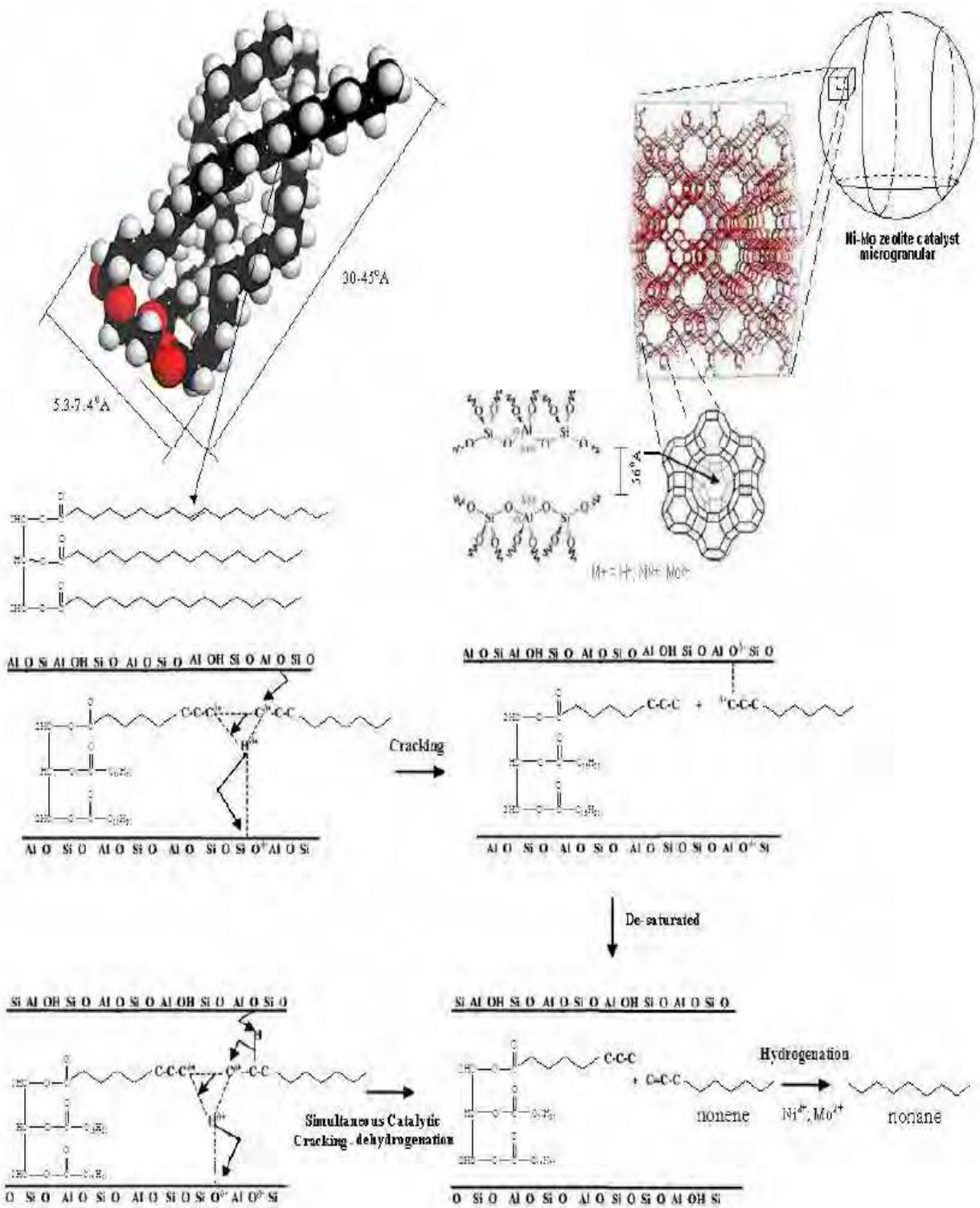


Figure: 2-4 Expected mechanism of the simultaneous catalytic cracking and Hydrogenation of palm oil over zeolite catalyst to produce nonane (Nasikin *et al.*, 2009)

It was observed that the triglyceride molecule was capable to enter the zeolite catalyst pore first followed by cracking. This was very likely since its longitudinal section diameter (around 5.3 – 7.4 °A) and chain length (around 30 – 45 °A) was lesser than the catalyst pore (approx. 0.56 °A, diameter). Afterward, the double bond in the nonene that was removed from the catalyst pore was saturated by the metallic sites of the catalyst to produce nonane. Though, while 37.97 wt. % of the product was nonane, 37.26 wt. % included of heptadecane having the balance of small amounts of C8,10,13,17 and 19 n-alkanes (< 8 wt.% each) (Wang 2012). This shows that the experimental results did not match the planned mechanism.

An additional study by (Sotelo-Boyás *et al.*, 2012) suggested reaction pathways for triglyceride processing as represented in Figure 2-11. This mechanism shows a path in which three triglycerides are transformed into linear paraffins. In this study, the oil is made out of triolein, tripalmitin and triolein. The first step proposes a formation of free fatty acids by separation of propane from the glycerol support of the triglyceride molecule in the hydrogen. The production of fatty acids relies on the formation of oleic, palmitic and linoleic acids (Sotelo-Boyás *et al.*, 2012). The next steps follow the same saturation, cracking and heteroatom removal reactions defined above.

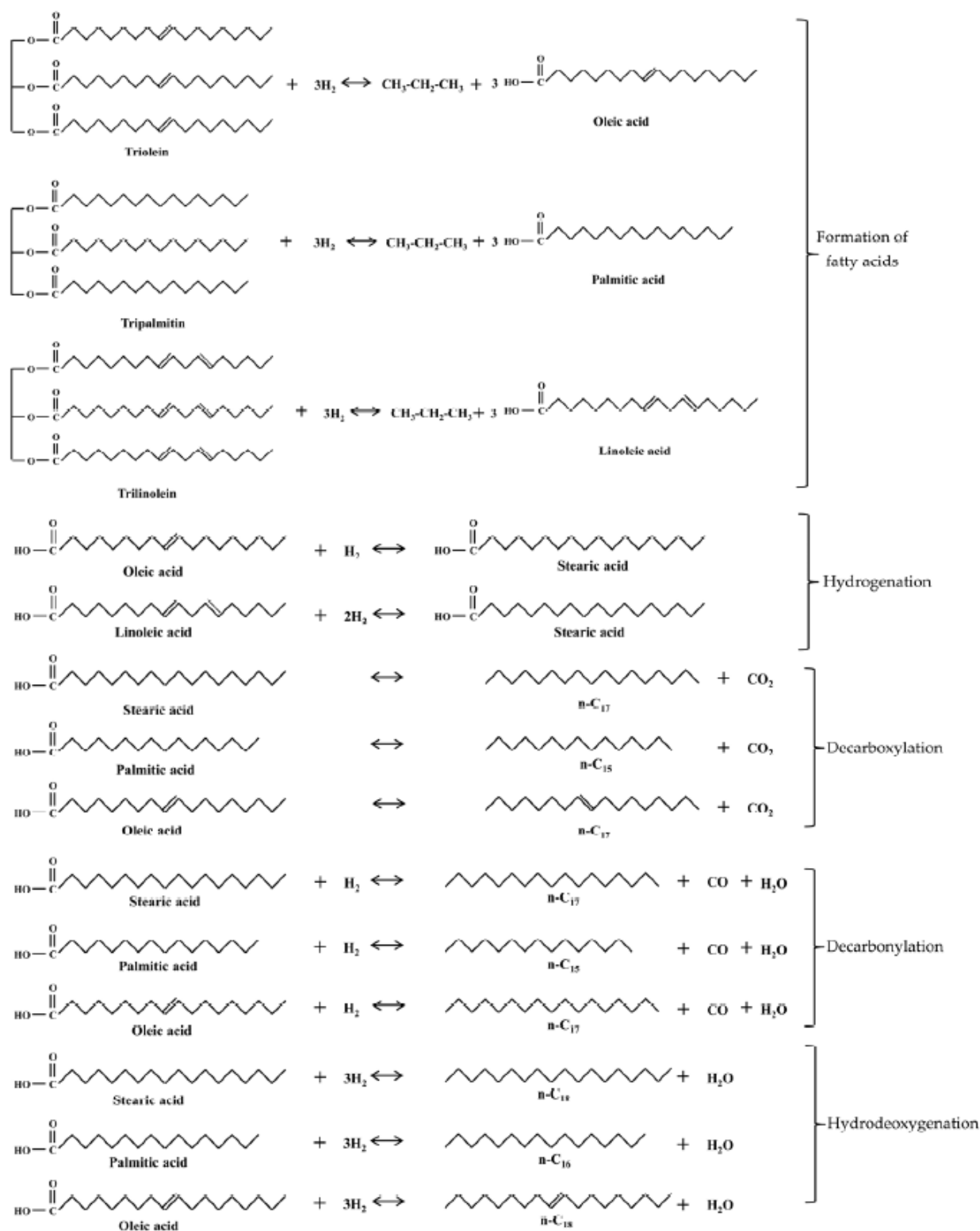


Figure: 2-5 Reaction pathways for hydroprocessing of triglycerides (Sotelo-Boyás *et al.*, 2012)

2.10 Hydroprocessing catalysts

Hydroprocessing catalysts are described as double function catalysts. The concept of a double function catalyst with two specifically different kinds of sites were made known by (Mills *et al.*, 1953) and later extended by (Weisz, 1962). Their studies introduced that both metallic and acid sites should be present on the catalyst surface for desired hydroprocessing reactions to be achieved, that hydroprocessing are hydrogenation, dehydrogenation, hydrocracking, etc. The acidic sites advance the cracking reactions and the isomerisation reactions while the metallic sites encourage the hydrogenation-dehydrogenation reactions.

The acidic sites are those supports that include: a) amorphous oxides (such as silica, alumina or silica-alumina), b) a crystalline zeolite including a binder such as an alumina, or c) a grouping of crystalline zeolite and amorphous oxides. The metals could be: a) noble metals (palladium, platinum) or b) non-noble metals from group VIA (molybdenum, tungsten) and group VIIIA (cobalt, nickel) (Scherzer and Gruia, 1996). Also, hydrogenation favours successive cracking by forming an active olefinic intermediate compound via dehydrogenation (Bezergianni, 2013b).

The composition of the metal relative to the amorphous oxide support has the potential to dictate the ratio of the catalyst between the cracking and hydrogenation functions. The performance of catalyst and product selectivity can be improved by regulating the composition of the metal and support. The comparative strength of different hydrogenation and hydrocracking functions in hydroprocessing catalysts are presented in Table 2-4.

Table 2-4 Strength of hydrogenation and hydrocracking function in dual-functional catalyst (Scherzer and Gruia, 1996)

Hydrogenation function	<u>Co/Mo < Ni/Mo < Ni/W < Pt(Pd)</u>
activity	Increasing hydrogenation
Hydrocracking function	Al ₂ O ₃ < Al ₂ O ₃ -halogen < SiO ₂ - Al ₂ O ₃ < zeolite
activity(acidity)	Increasing hydrocracking

For a hydroprocessing catalyst to be more effective, the rapid molecular transfer must occur between the acid sites and the metal sites for unwanted side reactions to be avoided. This can be attained only if a metal site is in closeness to the acid sites. For examples in the literature, it has been observed that noble metal content for hydroprocessing catalysts frequently consists of 1 wt. % or less, whereas non-noble catalysts are larger: 3-8 wt. % for nickel oxides, and 10-30 wt. % for molybdenum or tungsten oxides. Moreover, the metal ratio and amount contained by the metal used and other main factors concerning the metal component consist of the metal types, the degree of metal distribution over the support, the metal-support relations and the location of the metal on the support (Scherzer and Gruia, 1996).

2.11 Choice of of coconut oil as a raw feed stock.

There is an estimated hundreds of millions of people who use coconut and coconut products for different purposes every day (Foale, 2003). Coconut trees are natural to the Pacific and most suitable to local conditions compared to various other food crops. Coconut in the Pacific is known as the crop which consists of high economic, subsistence and cultural importance and it yields an extensive range of products from many parts of the tree and nut. Copra and coconut

oil are operated as supplies from many Pacific Island countries. Coconut oil as biofuel/biodiesel feedstock offers a petroleum substitute in remote regions with high inbound freight costs.

The coconut palm grows on the tropics and is extensively called the “tree of life” since it has a crucial role in smallholders’ livelihoods as a source of cash income, nutrition and materials (Warner *et al.*, 2007). In the Pacific, the coconut palms provide benefits such as shade for other crops, land stabilisation, food and drink, and for construction material, containers, fuel and other uses. Though, the greatest economic profit to coconut manufacturers has been derived from drying the coconuts into copra to be processed into copra oil. Smallholders dominate coconut harvesting and primary processing, as large coconut lands turn to more profitable crops. India, Indonesia and the Philippines yield three-quarters of the world’s coconuts, much of this in farms, and fully process it locally. The world copra trade has developed as canola, palm, peanut, soybean and sunflower oils, have overtaken coconut oil as the world’s important edible oils. Changing copra and coconut oil prices and increasing market standards in terms of quality and consumer safety have strictly affected the viability and competitiveness of all Pacific Island copra manufacturers, and many coconuts are not being reaped. Coconut shell and coconut wood products are also increasing in trade outlets.

2.11.1 Coconut products and by-products

Pacific islands use, fresh coconut flesh in every day life. Fresh coconut flesh provides dried copra and coconut cream and milk. Fresh mature coconuts are shipped from countries like Fiji, Samoa and Tonga for the Australian and New Zealand mass markets. However growth period of coconut plant is hindering market access and variable shelf life is disturbing retail sales.

Water extracted from the coconuts is produced from the immature nut, are a traditional fresh drink for Pacific Islanders and visitors, and a new micro-filtered and cold-processed packaged drink considered as a premium-priced sports and health drink is developing quickly in international markets and inspiring consumer interest in coconut and its nutritional benefits. Great global drink manufacturers are supporting new farms of dwarf varieties for immature nuts to be picked, but processors of coconut water and distributors of fresh mature coconuts are engaged in very serious competition for supply in the meantime.

Pacific coconut manufacturers usually extract and dry coconut flesh as copra for the oil to be extracted by the mills called local copra. The crude copra oil is advanced by methods of refined, bleached and deodorised under high pressure in industries to be the main ingredient of culinary oil, soaps, shampoos and lotions, or used as a moisturiser. The common characteristic about coconut and palm oil, is that they remain essential oils for soap-manufacture because of their solidifying characteristics.

All levels of coconut producers which are, small, medium and large coconut producers are shifting to processing their coconuts into VCO across the Asia-Pacific region, and testing many techniques to advance quality and efficiency – from persistent lightly dried grated flesh to fermentation for separating the oil and water – and using rotary and drum drying, centrifugal extraction, and commercial copra-making machinery. Benefits to producers consist of higher prices and income and also benefits to customers by making ready to work favourable to men and women, new small business chances minimised merchandise costs by conveying only the main product; nutritious local cooking oil; and a local fuel. Most VCO is very useful locally for skincare (moisturisers, lotions, massage oils and soaps), cooking and fuel, permitting import replacement and local retail. In other countries, VCO has made an important contribution to increasing the standard of living in the community level (Shahi and Pulkki, 2015).

While expert distributors have advanced places in terms of health product stores (those places are located in Australia and New Zealand), most VCO is distributed via product oil traders, subsequent in little of any new market expansion. Claims that VCO is much safe to consume frequently, and is a useful food oil and skin treatment (Marina, 2009) with antioxidant, anti-inflammatory and other properties. There needs for more research to be done before consumer claims be made (Intahphuak *et al.*, 2010). Constraints to value-adding consist of the need for quality assurance, testing that is reasonably priced, product consistency, reliable shelf life, commercial and cheap packaging, expensive organic certification for skincare products, and identification of available markets and their requirements and supply chains to support the market entry.

Pacific Island governments and private energy providers have conducted tests of copra oil, and VCO, for biodiesel fuel to exchange imported petroleum for vehicle, household fuel and power generation. Though, low prices compared to prices for other uses, and the desire for costly upgrading of equipment to provide accommodations to coconut fuel shows that capability is limited to outer areas producing their coconut biofuel at a lower cost to importing petroleum.

Coconut by-products are extensively used for construction, household items as well as fuel. Coconut shell produces fibre for geotextile mats, local woven goods, insulation filler for car upholstery and plant mulch. The dust can be utilised and treated as much and for fertiliser preparation. Coconut shell is sometimes used for fire coconut dryers. Coconut shell is used and converted into different materials such as bowls, jewellery, ornaments and other handicrafts, as well as for high value activated carbon used for filters. Copra meal and copra cake (expeller) are produced from copra oil and are in demand for cattle feed, both locally and exported (if the quality is enough and steady), and food grade meal is usefully in bakery goods. By allowing higher value markets specifically for entirely by-products would advance benefits for all copra processors and deliver another solution to disposal applications. The typically patterned timber “coco wood” is applicable in craft making, used for utensils, furniture and other household items.

Table: 2-5 The physical properties of coconuts oil

Apparance odour	Virgin coconut oil from wet coconut, colourless, and coconut smell	Unrefined coconut oil from copra slight brownish coconut smell	Refined coconut oil colourless odourless
Melting point °C	24	24	24
Moisture(%)	<0.1	<0.1	<0.1
Iodine value(cg12/g)	12-15	12-15	10-12
Peroxide value(meq .02/kg)	0-1	0-1	0-1
Saponification value(mg KHO/g)	245-255	245-255	250-255
Phospholipids(%)	0.1	0.1	00
Unsaponifiable matter(%)	-	0.42%	0.19%
Tocophorols (mg/kg)	150-200	150-200	4-100
Phytosterols(mg/kg)	6.40	6.18	20
Saturates	92.0	92.0	92.0
Monounsaturates	6.0	6.0	6.0
polyunsaturates	2.0	2.0	2.0

2.12 Description of Biofuel and its product

Biofuel is one of the most effective alternative energies. Biofuel is a product which can be derived from animals and plant oils by the conventional method of esterification, transesterification processes and cracking processes. The conventional method of esterification and transesterification processes mostly produces biodiesel of fatty acid methyl esters (FAME). And the cracking process produces biofuel by producing the mixture of gasoline, diesel and kerosene. Biofuel can be described as a liquid or gaseous fuel which can be manufactured from biomass or bioresource substrate.

Many types of researchers have been focusing on studies of biofuel and catalysts since the world is facing the crisis of shortages in energy and fuel. The study of many types of catalyst for producing biofuel was developed by Farouq, Chew and Bhatia (2012). Studies on the hydrocracking process of different oils to biofuel were done by Bezergianni and Kalogianni, (2013). Biofuel can be manufactured from different types of plant and animals oils.

Biofuel contributes towards a large portion of the demand for transportation fuels and has the potential to minimise the current demand from crude oil derivatives. Furthermore, combustion of biofuels reduces the negative impact and neutralise the carbon dioxide balance, that could help in decreasing the rate of global warming. The other main advantage of biofuel, is that it improves rural environments by creating job opportunities and minimising the dependency on imported fuel.

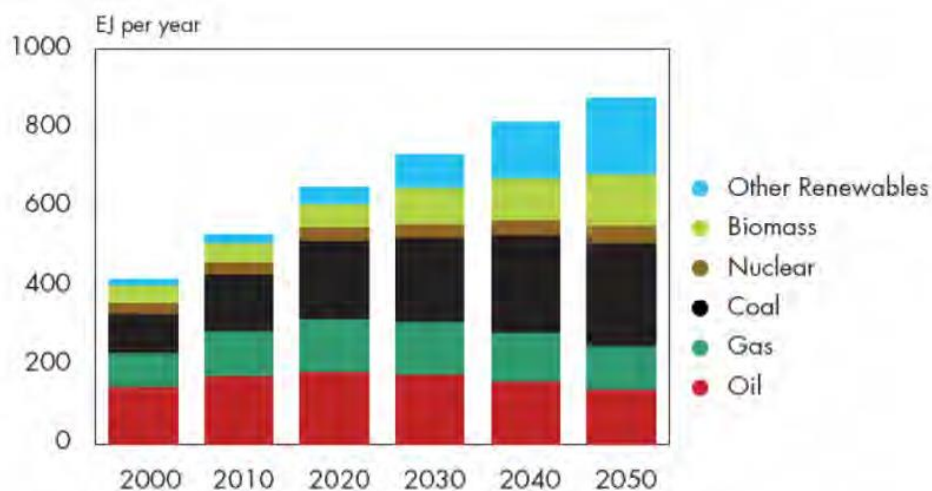


Figure : 2-6 Shell's world energy consumption outlook (Peng, 2012)

Shell is one of the companies which has predicted the world's energy consumption by the year 2050. The results above shows that energy produced from biomass and other renewable sources will significantly increase.

It is estimated that global energy consumption will be doubled in size by 2050. Coal, gas and oil will still be the leading fuels and stable energy sources, but the energy resulting from biomass will increase radically in this half-century. Plant biomass has also been discovered as the only sustainable source for fuels and chemicals. Before the discovery of cheap fossil fuels, the energy demands of society were met by plant biomass. Its has also been discovered that biomass has many advantages in comparison with fossil fuels, e.g., abundant, carbon-neutral in the life cycle, and sulfur-free.

2.12.1 Fossil fuel

Fossil fuels are considered as the main source of energy globally (Khan and La Thangue, 2012) and at presently fossil fuels are the best reliable sources of energy , produced in the earth over millions of years using decay of land vegetation and animals. Basically when layers are heated over time, deposits of hydrocarbons are formed, these are considered as non-renewable since they take longer to form (Williams, 2002). Fossil fuels are divided into three categories oil, coal and natural gases (Dincer, 2000).

Fossil fuels have the greatest disadvantage when burnt as harmful gases such as carbon dioxide, carbon monoxide, sulphur oxides and hydrocarbons are produced into the atmosphere (Reddy and Venkataraman, 2002) which results in global warming and damage of the ozone layer. Damaging of ozone layer results in the increase of the temperature on the earth surface and flooding in other areas, melting of polar ice caps and rise in sea levels. It is revealed that the continued utilisation of fossil fuels could result in the change of climate and increase the temperature of the earth by 2 to 6 degrees Celsius by the year 2100 (Khan and La Thangue, 2012). Therefore the continued use of fossil fuels could lead to disasterous consequences for the planet.

Accidents involving fossil fuels could also cause serious damage to the environment and its surroundings. Oil spillages have once occurred in the past, and they have got potential to kill aquatic animals including those living offshore. The environment around the seashore is venerable (Barbeira *et al.*, 2007) as a result of oil spillages. It is also evident that toxic compounds which are the result of fossil fuel combustion can result in health complications such as chronic asthma, low lung functioning, chronic bronchitis and cardiovascular diseases

(Wuebbles and Jain, 2001). Fossil fuels are highly dependent on the price fluctuations and market manipulation (Hari *et al.*, 2015). This is experienced by developing countries that heavily dependent on the importation of fossil fuels. Renewable energy technologies could minimize price fluctuations and market manipulations which are the main concern to a greater degree (Hari *et al.*, 2015).

2.12.2 Biomass

Biomass is considered as a renewable organic matter. During the process of photosynthesis, plants utilise light energy in order to convert carbon dioxide and water into sugars and oxygen. Biomass can be converted into liquid biofuels i.e. methanol and ethanol through the fermentation process (Demirbaş, 2001). Biofuel is the energy which is derived from renewable plants (Lowe and Hossain, 2008) and animal materials which are produced from biomass (Smith, 2013). These may be useful in the applications such as vehicle fuels, biodiesel, green diesel and biogases (McKendry, 2002). The emission of CO₂ from biofuel is very minimal as compared with fossil fuels. It is evident that biomass is carbon neutral since the amount of CO₂ produced into the atmosphere during the burning of biofuel over time is equal to be equivalent to the amount of CO₂ required when biomass grows through photosynthesis (McKendry, 2002). Biofuel is considered as one of the main emphasis in the development of a sustainable and renewable source of energy in the world (Khan and La Thangue, 2012).

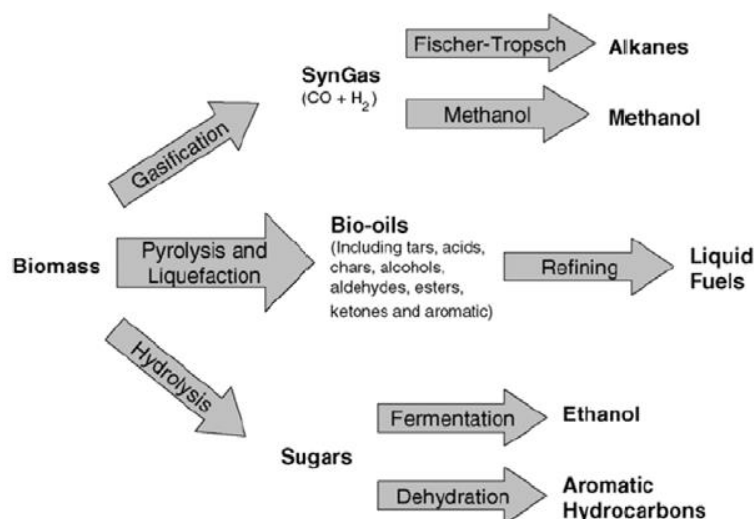


Figure: 2-7 Production of liquid fuels from biomass (Peng, 2012)

Liquid fuels can be produced from biofuels by three processes, the firstly, through gasification of the biomass to produce syngas, which is then followed by the Fischer-tropsch synthesis to produce alkanes. The secondly use of pyrolysis and thermochemical liquefaction for the production of bio-oils, which is then followed by a refined process to produce alkanes. The last process is whereby hydrolysis uses lignocellulose for sugar monomer production, which is converted into ethanol and aromatic hydrocarbons through fermentation and dehydration (Huber and Dumesic, 2006).

2.13 Hydroprocessing reaction

Currently, biodiesel is one of the most useful biofuels, and it manufactured from plant oils and/or animal fats. There have been several types of research which focused on an alternative method for processing plant oils and animal fats into biofuels by utilising a catalyst hydrotreating process similar to the processes in the oil and gas industry (Huber *et al.*, 2007).

Oxygen removal (hydrodeoxygenation), hydroxide carbonylation and hydroxide carboxylation and hydrocracking are main chemical processes or steps that occurs during the conversion of biomass-derived oils into biofuel. The oxygen removal and the breakdown of carbon, double or triple bonds are referred to as hydrotreating while the breaking of large carbon chains into smaller ones is referred to as hydrocracking. Differences between cracking and hydrogenation reaction are described below. Saturated paraffin is cracked to form lower molecular weight olefins and paraffin. Sidechains are normally cracked off small ring aromatics and naphthenes leaving thermally stable polynuclear aromatics however, condensation (dehydrogenation) also takes place if not limited by hydrogenation.

Hydrogenation reactions are exothermic reactions where hydrogen gas is typically used to saturate the molecules from aromatic cracking. Olefins are normally saturated to form light hydrocarbons such as butane. Aromatic rings are hydrogenated to cycloparaffins (naphthenes). Carbon-carbon bond is broken to open aromatic naphthenes ring.

2.14 The emphasis on the production of bio-jet fuel and gasoline

Jet fuel is a high energy density fuel to maximize aircraft distance range and a low freezing point to prevent the formation of crystalline wax particles during the high-altitude flight (Sacia *et al.*, 2015; Wang *et al.*, 2015). Fortunately, cyclic hydrocarbons meet these requirements, and, therefore, these types of fuel are not likely to be displaced for air transportation. Moreover, increasing consumption of jet fuel and anthropogenic CO₂ emissions have resulted in biomass-derived which is presented above in figure 2-8.

Furthermore, linear alkanes produced by these processes requires deep hydrocracking and isomerization to decrease their molecular weight and introduce branching for fuel stability (Kim *et al.*, 2013; Sacia *et al.*, 2015). Additionally, zeolites such as ZSM-5 and Beta are both usually used as the catalysts for aromatization because of their exclusive microporous structure and shape selectivity.

Sorbitol, a key intermediate of biomass derivatives, is easily attained by the hydrogenation process of glucose or even by direct hydrogenation of cellulose. Its molecule consists of high oxygen content, with six hydroxyl groups, resulting in low thermal stability and natural hydrophilicity. Aqueous phase hydrogenation is a catalytic process to eliminate the total or partial oxygenates from water-soluble biomass-derived oxygenates (Dietrich *et al.*, 2012; Kim *et al.*, 2013; Grilc *et al.*, 2015). Recently, it has been widely viewed as a promising option for biomass-derived jet fuel (Kirilin *et al.*, 2012; Kim *et al.*, 2013).

Most companies in Europe and North America use biomass as a feedstock to yield biofuel. Some examples are Arizona biodiesel and Amereco biofuels corp. with both companies utilising waste vegetable oil as their feedstock. These types of companies will in future invest in research to further optimise their production capabilities.

The conventional production process for kerosene or jet fuel (along with other products) from crude oil is shown in Figure 2-9 .

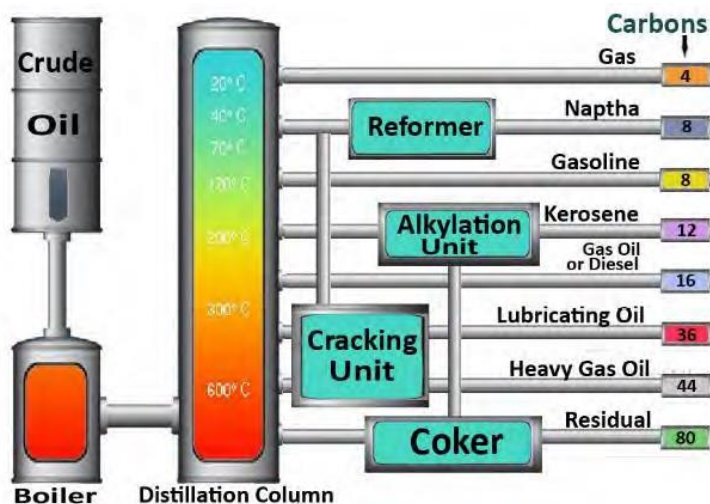


Figure: 2-8 Conventional production process of kerosene and other products

Aviation fuel produced in this conventional production process has decreased air quality by polluting the air due to emissions of CO₂ occurring in both ground and high altitude level from commercial, military and general flights (Dunn, 2001). It has been observed that aircrafts contribute up to 4% of the annual global CO₂ emissions from fossil fuels. For carbon dioxide to be maintained on the earth, petroleum-derived jet fuel should be substituted with biomass and that could result in the decrease of greenhouse emissions of CO₂ causing global warming. Sustainable oils and renewable fuels company reported their effects from a life cycle analysis (LCA) of jet fuel derived from camelina seed invented by the company. The report shows that the decrease in carbon dioxide from the bio-jet fuel emissions is 84% compared to conventional petroleum jet fuel.

2.14.1 Gasoline

Gasoline is typically produced from crude oil. Crude oil consists of a complex mixture of 1000 different compounds. Those compounds are known as hydrocarbons. The compounds that make up crude oil, range from the simplest hydrocarbon molecule (methane) to large, complex molecules which contains many carbon atoms (Barbeira *et al.*, 2007).

Paraffins, aromatics, and naphthenes are categorised as natural constituents of crude oil and produced in numerous refining operations. Olefins usually are not present in crude oil; they are produced in certain refining operations that are devoted mainly to the production of gasoline (Barbeira *et al.*, 2007).

Gasoline is regarded as a complex mixture of around 300 components, mainly volatile hydrocarbon compounds. Gasoline is mixed from several refinery process streams, including any of a number of naphtha streams from the direct distillation of crude oil at atmospheric

pressure, by catalytic and thermal cracking processes (EUCAR, 2003). In some gasoline results, oxygenated compounds are also part of automotive gasoline components.

Table:2-6 Composition by hydrocarbon type of typical automotive gasoline(EUCAR, 2003)

Composition	Ranges
Alkanes	4-8 wt%
Alkenes	2-5 wt%
Isoalkane	25-40 wt%
Cycloalkanes	3-7 wt%
Cycloalkenes	1-4 wt%
Total aromatics	20-50 wt%
Benzene	0.5-25 wt%
paraffins	30-90 vol%
olefins	0-30 vol%
Aromatics	10-50 vol%

2.14.2 Octane rating

The octane rating is defined as a degree of a fuel's ability to avoid or eliminate engine knocking. Knocking takes place when fuel is ignited early in the engine's cylinder. It could result in lower efficiency and damage the engine itself. The fuels consist of oxygenating agents that avoids knocking and these oxygenates are normally referred to as octane rating.

Gasoline is based on its antiknock index (AKI) which is a degree of octane rating. AKI determines the capacity of fuel to repel engine knocking. The AKI is computed as the average of the research octane number (R) and motor octane number (M). A low research octane number has the potential to produce the speed, knock and start-up after the engine has been shut down whereas a low motor octane number may cause engine knock during acceleration in the incline hills (Karpov, 2007). Some properties of typical gasoline are tabulated in Table 2-7.

Table:2-7 Gasoline fuel properties(Eccleston and Cox, 1977)

Property	Value
Energy density	32 MJ L ⁻¹
Water solubility	Negligible
Air-to-fuel ratio	14.6
Energy content	114,000 energy content/Btu/Us gallon
Research octane number	81-89

2.14.3 Benzene, Toluene, Ethylbenzene and Xylene (BTEX) Complex

The BTEX complex is a hydrocarbon mixture of benzene, toluene, ethyl-benzene and xylene. Normally known as gasoline aromatics, these compounds are also advanced from low-octane petroleum products into a high-octane gasoline additive. Though some volume of BTEX produces gasoline, it is also added to final gasoline to boost its octane rating. The total volume of BTEX (aromatics) in final gasoline relies on the desired octane value and other fuel properties (Morrow III *et al.*, 2014)

2.15 Hydroprocessing catalysts

The metallic sites of the catalysts promote hydrogenation and dehydrogenation reactions whereas the acid sites of the catalyst promote isomerization and cracking reactions. This stresses the need to design a catalyst which includes a balance between the metal composition and acidic sites to adapt the product selectivity, catalyst activity and stability (Morel *et al.*, 1997). The main disadvantages of noble metal catalysts are the scarcity and that they are expensive, which results in the economically unfeasible option, and vulnerability to catalyst poisons (Maxwell, 1987). Impurities (such as sulphur, heavy metals and oxygenated compounds) in the feedstock could result in catalyst deactivation (Choudhary and Saraf, 1975). As such, a pre-hydro processing step is required to eliminate impurities from the feedstock which needs additional resources and time.

Iron and nickel are the earliest catalysts which were successfully used and supported on fluorinated montmorillonite and nickel supported on amorphous silica-alumina (Scherzer and Gruia, 1996). After World War II, with the accessibility of crude oil from the Middle East, there was practically no encouragement to convert coal and other fuels to liquid fuels. Newly developed catalytic cracking processes produced or proved more economical for converting heavy petroleum fractions to gasoline (Scherzer and Gruia, 1996).

2.16 Description of hydrocracking technology and its development

Hydrocracking is defined as a catalytic chemical process utilized in petroleum refineries or industries for converting, the high-boiling component, hydrocarbons in petroleum crude oils to produce more valuable lower-boiling yields such as gasoline, kerosene, jet fuel, diesel oil and etc. The process has the potential to occur in a hydrogen-rich atmosphere at high pressures of 200-300 atm and high temperatures of 400°C. The United States made efforts to develop a hydrocracking process with an intention to improve heavier petroleum fractions at the above limitation pressure and temperature (Murphree *et al.*, 1940).

Hydrocracking process was first established in Germany as early as 1915 to deliver liquid fuels resulting from their domestic coal deposits. Leuna, Germany, is where the first plant, which was taken as a commercial hydrocracking unit, began to operate in the year of 1927. Moreover in Britain and France coal was converted to liquid fuels as well, (Porgar and Salehfekr, 2016).

Hydrocracking technology was first established in German for coal conversion between the years of 1915 and 1945. The Germans looked for a steady supply of liquid fuel resultant from domestic deposits of coal and therefore the research and development into hydrocracking reactions and processes began (Scherzer and Gruia, 1996). The first plant which applied hydrogenation of brown coal was established on Leuna, Germany, that implemented the first commercial hydrocracking process. Between the years of 1925 and 1930, a German and an American company worked together to advance a hydrocracking technology considered to convert heavier gas oils into lighter fuels (Heinemann, 1979).

There are many factors that played a vital role in the demand for hydrocracking processes. High performance cars were produced by automobile companies, whose engines required high-octane gasoline which was well attained through the hydrocracking process (Scherzer and Gruia, 1996). Also, the change from steam into diesel engines on trains and in the 1950s, as well as the introduction of commercial jet air crafts increased the demand for diesel fuel and low-freeze-point jet fuel. The degree of development for hydrocracking technologies increased radically as main oil and gas companies such as Chevron Research Company, Unocal and Universal Oil Products all announced new hydrocracking processes during this period. The

catalyst that was used in these processes was Nickel on silica-alumina (Sterba and Watkins 1960). In the mid 1970s, hydrocracking was measured as a mature process but the degree of development became unreasonable due to the high cost of hydrogen, that resulted in the hydrocracking process to be more expensive than catalytic cracking specifically for gasoline production.

There was a crisis between the 1980s to early 1990s when the demand for middle distillates, which is in the carbon range of (C11 – C18 saturated hydrocarbons) increased, that resulted in a steady development for hydrocracking processes around the world. To improve catalyst activity and selectivity, a new catalyst was advanced in such an extent that it was “flexible” to maximise the yield of different products by using the similar catalyst at different operating conditions (Scherzer and Gruia, 1996).

Since hydrocracking has been considered as a mature and advanced technology, substituting the feedstock from crude oil to a sustainable and environmentally friendly alternative to produce biofuels. However replacing the older processes will need large capital costs. That is the main reason in the 21st century, oil and gas companies are investing resources and time into researching sustainable and renewable feedstocks such as vegetable oils and animal fats.

2.17 Biofuel production and process analysis

Some biofuel production processes that are investigated and developed have reached commercialization. Fischer–Tropsch synthesis is one of them which is defined as a set of catalytic processes that can be utilised to yield fuels.

Process analysis

Biomass to Liquid via Fischer–Tropsch (BTL-FT) synthesis is achieved by three important steps (Tijmensen *et al.*, 2002). The first step is whereby biomass is converted into biomass-derived syngas (bio-syngas) through a gasification process. Second step, is whereby a cleaning process is applied to the bio-syngas with an intention to eliminate impurities, resulting in clean bio-syngas which encounters the Fischer–Tropsch synthesis requirements, and third step is where the cleaned bio-syngas is directed into Fischer–Tropsch catalytic reactor to yield green gasoline, jet fuel diesel and other clean biofuels. The flowsheet diagram below indicates the conversion process of Biomass to Liquid via the Fischer–Tropsch Synthesis (BTL-FT) process, (Freerks and Muzzell, 2004).



Figure: 2-9 Flow sheet of the Biomass to Liquid via Fischer–Tropsch Synthesis (BTL-FT) process (Freerks and Muzzell, 2004).

A study on biomass-derived jet-fuel was one of the option which was studied (Li and Huber, 2010; Kirilin *et al.*, 2012; Kim *et al.*, 2013). Here, the aqueous phase hydrogenation of sorbitol was processed in the fixed-bed reactor over the catalyst of Ni-HZSM-5/SBA-15. The catalyst presented a bimodal pore structure that was microporous (HZSM-5, pore width: 0.56nm) and mesoporous (SBA-15, pore width: 8 nm). Moreover, it presented an effective performance in the conversion of biomass large-molecule sorbitol (e.g., sorbitol, diameter: 8.7 nm) into small-molecule hydrocarbons. A maximum yield of 40.4 wt. % of oil product was produced at an elevated temperature (593 K) with aromatic and cyclic-hydrocarbon content of 80.0%.

Biomass is categorised as a renewable material for energy and its content which does not consist of sulphur and nitrogen, is clean. The fast pyrolysis of biomass has received great consideration in recent decades. Though, bio-oil consist of some disadvantages such as high viscosity, thermal instability, corrosiveness and chemical complexity, which results in numerous problems before its full use as a kind of renewable energy. Hydro treatment of bio-oil is one of the upgraded methods which have been widely studied and it was shown that the caloric value and storage stability increased radically. But the process conditions are moderately severe (350–450°C, 5–15 MPa), resulting in the development of substantial amounts of gases. Therefore there is a need to develop alternative ways to operate the process at lower temperatures and hydrogen pressure. Hydrogenation is a method of breaking complex chemical compounds by adding hydrogen gas.

Biomass-derived oils can be achieved from many sources, such as animal fats, plants and microbial plants. Each source consists of advantages and disadvantages in terms of impurities, pre-treatment requirements, potential products, availability and cost. 1st generation feedstocks use crops to produce oil as the feed material for transportation fuels. However, there is economic debate regarding 1st generation feedstocks commonly known as the “food versus fuel” conflict. In the concern of meeting the growing demand for biofuels while not

compromising the value of food, land and water, there is a large emphasis placed on research and process development which utilises 2nd generation feedstocks such as used cooking oil (UCO) (Wang, 2012).

2.18 Vegetable oil as a feedstock

Vegetable oils are a focus on the manufacturing of biodiesel and bio-jet fuel since they are made up of 90 to 98% triglycerides (hydrophobic constituents of vegetable oils and animal fats), which consists of glycerol group that has three fatty acid chains attached to it as seen in Figure 2-11.

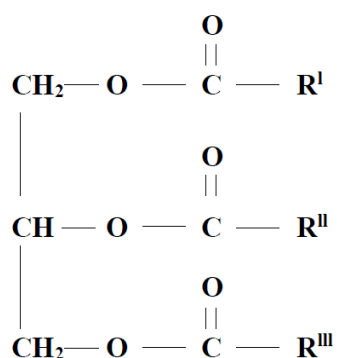


Figure: 2-10 Chemical structure of triglyceride (Wang, 2012)

Triglycerides have differences in chain length and number of double bonds of the fatty acids as shown in Table 2-11. The side chains of triglycerides could be in the form of saturated, monounsaturated or polyunsaturated (Sotelo-Boyás *et al.*, 2012). Fatty acids which are commonly found in vegetable oils are palmitic, stearic, linoleic and linolenic acids (Srivastava and Prasad, 2000).

Table: 2-8 Chemical structure of common fatty acids (Markley, 1960)

Fatty acid	IUPAC name	No. of carbon atoms and double bonds	Chemical formula
Lauric	Dodecanoic	12:0	C ₁₂ H ₂₄ O ₂
Myristic	Tetradecanoic	14:0	C ₁₄ H ₂₈ O ₂
Palmitic	Hexadecanoic	16:0	C ₁₆ H ₃₂ O ₂
Stearic	Octadecanoic	18:0	C ₁₈ H ₃₆ O ₂
Arachidic	Eicosenoic	20:0	C ₂₀ H ₄₀ O ₂
Behenic	Docosenoic	22:0	C ₂₂ H ₄₄ O ₂
Lignoceric	Tetracosenoic	24:0	C ₂₄ H ₄₈ O ₂
Oleic	cis-9-Octadecanoic	18:1	C ₁₈ H ₃₄ O ₂
Linoleic	cis-9,cis-12-Octadecadienoic	18:2	C ₁₈ H ₃₂ O ₂
Linolenic	cis-9,cis-12,cis-15-Octadecatrienoic	18:3	C ₁₈ H ₃₀ O ₂
Erucic	Cis-13-Docosenoic	22:1	C ₂₂ H ₄₂ O ₂

Biofuel is a renewable energy that can be substituted with commercial petroleum products. Currently, many investigators focus on the process of the manufacturing of heavy hydrocarbons from biomass, since there is an increase of demand for clean gasoline, kerosene, diesel, and other biofuel, none producing environmental problems, (Sharma *et al.*, 2008; Al-Sabawi *et al.*, 2012). Raw material such as biomass can be defined as the organic matter derived from vegetable oils or animal fats such as sunflower (Corma *et al.*, 2007), coconut, castor, (Sotelo-Boyas *et al.*, 2008) , soybean, (Sotelo-Boyas *et al.*, 2010) , canola, (Sotelo-Boyas *et al.*, 2010) cotton, (Sebos *et al.*, 2009), jatropha,(Liu *et al.*, 2009), and palm oil (Liu *et al.*, 2009) The choice of these raw materials depends on its availability, cost and climate in country of origin.

Transesterification is a well-known technique for the manufacturing of biofuel from vegetable oil which mostly includes processes of thermal cracking, hydrocracking and catalytic cracking. Transesterification of vegetable oil is a process in which solvents such as methanol and ethanol are used in the presence of a catalyst to break the molecules of vegetable oil into glycerol and esters of the renewable fuel (Zhao *et al.*, 2015a). Mostly, the product from this synthesis process is biodiesel. Thermal cracking can be described as a method used to convert vegetable oil or coconut oil to biofuel at a high temperature and high pressure without the occurrence of the catalyst. The cost of thermal cracking is relatively higher, though, the biofuel yield is relatively low (Li *et al.*, 2009; Zhao *et al.*, 2015b). Related to petroleum-based fuel catalytic cracking is also a method used to convert vegetable oil to biofuel. The decrease of biofuel production cost and the upgrading of product produced can be obtained by developing good selectivity and long lifetime catalysts. Hydrocracking of vegetable oil has the potential to produce high-quality biofuel with a high yield. For the hydrocracking to achieve a high quality of biofuel, high catalyst activity and high hydrogen pressure must be present. Though some transitional metal catalysts have high activity, their high price and limitation of availability does not make them favourable.

The previous study (Yotsomnuk, 2017) which is more relevant to this study focused on determining the optimal conditions for biofuel manufacture from virgin coconut oil containing natural triglycerides. In this research, the result of the reaction temperature (573-673K), at the range of pressure (20-40bar) and reaction time (1-3h) using the catalyst of HZSM-5 in the batch reactor was studied.. HZSM-5 presented the highest product of gasoline and kerosene with corresponding 4% and 35.6% under a temperature of 400°C, initial hydrogen pressure at 40bar and reaction time of 180 minutes. The maximum product of diesel achieved was 70% at a temperature of 350°C, initial hydrogen pressure at 40bar and reaction time of 60 minutes.

The other study (Vieira *et al.*, 2013) used biodiesel as the raw materials for biofuels; Biodiesel is also considered as favourable renewable energy in this century. Also, biodiesel has many advantages compared to petroleum diesel such as lower exhaust emissions, biodegradable, non-toxic, renewable and free of sulfur. Biodiesel is acknowledged in all countries because of its advantage of being environmentally friendly. Biodiesel is generally obtained from cooking vegetable oil. Using high-quality virgin oils causes biodiesel to be more expensive than diesel fuel and it also results in the increase of vegetable oil prices. Therefore low-cost feedstocks are required and should be utilised in the manufacturing of biodiesel. In Turkey, B2 (2% biodiesel,

98% diesel fuel) custom use is tax-free for biodiesel made from waste cooking oil (Shokuhi Rad *et al.*, 2017).

Biodiesel can also be defined as the mono-alkyl esters of long-chain fatty acids that can be taken and prepared from acyl-glycerol (usually triglycerides) in vegetable oil through transesterification with short-chain alcohols. Production of biodiesel is easy yet effective as it is miscible with petroleum-based diesel in all sizes and can be utilised as a fuel either in pure form or mixed with petroleum-based diesel. The mixtures of biodiesel and petrodiesel are regularly coded as B20. The feedstock for biodiesel manufacture can be considered as a lipid feedstock and alcohol feedstock. The lipid feedstock contains vegetable oils, animal fats etc. Coconut oil is one of the lipid feedstock utilised for the synthesis of biodiesel in coastal areas (Kumawat and Meena, 2014).

Table: 2-9 World's oilseed production, average oil price and oil content of various oilseeds (Kumawat and Meena, 2014)

Plant	oil content %	Oil seed production(million metric ton)	Average oil seed price U.S.D/metric	Average oil seed price(U.S.D/metric ton)	Yield kg/ha/yr
rapeseed	35	46.72	375	852	600-1000
Soybean	21	235.77	254	684	300-450
Sunflower seed	44-51	30.15	n/a	n/a	280-700
Palm	40	10.27	n/a	655	2500-4000
Cottonseed	18	46.02	n/a	787	n/a
Penut	36-56	32.36	395	1253	340-440
Copra	65-68	5.28	537	n/a	n/a
Coconut	63	n/a	n/a	8/12	600-1500

Table : 2-10 Fatty Acids (Properties of Coconut Oil) (Organic Facts, 2016)

Name of fatty acid	Percentage%	Remarks	Type of fat
Lauric acid	45-52	Medium chain fatty acid	Saturated
Myristic acid	16-21	Medium chain fatty acid	Saturated
Caprylic acid	5-10	Medium chain fatty acid	Saturated
Capril acid	4-8	medium chain fatty acid	Saturated
Caproic acid	0.5-1	Medium chain fatty acid	Saturated
Palmitic acid	7-10	Medium chain fatty acid	Saturated
Oleic acid	5-8	Medium chain fatty acid	Unsaturated
Palmitoleic acid	in traces	Medium chain fatty acid	Saturated
Linoleic acid	1-3	Medium chain fatty acid Medium chain fatty acid	Unsaturated
Linolenic acid	<0.3	Medium chain fatty acid	Unsaturated
stearic acid	2.4	Medium chain fatty acid	Saturated

2.19 Coconut Oil characteristics

Coconut oil mostly consists of fatty acids, about 94%, which contains more than 60% of medium-chain. Coconut oil performs as any other vegetable oils together with animal fats, it can be considered as a triglyceride, characteristically containing glycerine. It is a lipid feedstock utilised for the manufacturing of biodiesel along with the coastal areas.

Table :2-11 Physico-chemical Characteristics of coconut oil (Parfene *et al.*, 2013)

Appearance odour	Virgin coconut oil from wet coconut colourless coconut smell	Unrefined coconut oil from copra slight brownish coconut smell	Refined coconut oil colourless odourless
Melting point °C	24	24	24
Moisture %	< 0.1	< 0.1	< 0.1
Iodine value(cg 12/g)	12-15	12-15	10-12
Peroxide value(meq.02/kg)	0-1	0-1	0-1
Saponification value(mg KOH/g)	245-255	245-255	250-255
Phospholipids (%)	0.1	0.1	0.0
Unsaponifiable (%)	-	0.42%	0.19%
Tocopherols mg/kg	150 -200	150-200	4-100
Phytosterols(mg/kg)	640	618	20
Saturates	92.0	92.0	92.0
Mono unsaturates	6.0	6.0	6.0
Poly unsaturates	2.0	2.0	2.0

2.20 Catalyst preparation

The main aim when preparing a catalyst for processing is to ensure that it consists of the correct combination of constituents to attain high yield and selectivity while having a reduced degradation and coking rate. Catalyst preparation ensures production of the maximum amount of high quality fuel at a very low time and resources. Normally, the two common techniques utilised for preparing catalysts are a) impregnation technique and b) precipitation technique.

Both techniques require drying, calcining and reduction steps (Satterfield, 1991). The impregnation technique is mostly used in the preparation of hydro processing catalysts. It is a simpler technique, when matched with precipitation technique and is mostly preferred when using an expensive metal component since only a small quantity of it is required to be spread throughout the support. Alternatively, the precipitation technique causes some of the metal ingredients to be bound by other existing materials and is then unable to catalyse the desired reactions (Satterfield, 1991).

There are two types of impregnation techniques which are ‘dry impregnation’ and ‘wet impregnation’. Wet impregnation is used when there is a contact between the precursor and the support, and again when the specific loading of the precursor is low (Pinna, 1998). Specifically in this study wet impregnation is used to prepare the Ni/ZSM-5 catalyst. This technique is often called the ‘sequential wet impregnation’ technique.

2.20.1 Drying

Drying is an essential step in the wet impregnation technique whereby excess water is eliminated. This process generally occurs between the temperature ranges of 80 to 200 °C. The drying temperature is one of the factors that need to be considered as it affects the supply of the active sites, the period of drying and the rate of drying (Pinna, 1998). There are other factors that are difficult to take into consideration which include the rate of nucleation, the degree of liquid saturation, pore size distribution and the degree to which the liquid paths between the pores are connected (Satterfield, 1991).

2.20.2 Calcination

Calcination can be defined as the heat treatment process whereby the catalyst is being heated using air. The calcination temperature is generally slightly higher than the catalytic reaction temperature for which the catalyst is being prepared (Perego and Villa, 1997). Calcination removes chemically bonded water allowing the formation of an active phase metal oxide by decomposition of the precursor (Pinna, 1998).

2.20.3 Catalyst supports

The main aim of the catalyst support varies on the type of catalyst and the reactions taking place. It also provides the acidic sites which promote hydrocracking reactions, the supports also help in giving a platform for the uniform distribution of the metal sites to attain a larger surface area. This helps in preventing coalescing and/or agglomeration of the lower melting point metals (Stiles, 1987). Because of the reasons above the selection of the support is a critical step, as the reaction is dependent on the acid sites on the support.

2.20.4 Catalyst characterisation techniques

Catalyst characterisation techniques are used to determine different properties of the catalyst. It also helps in understanding catalyst's performance and functionality during reactions permitting for optimisation and future catalyst preparations. There are different types of characterisation techniques or methods for catalysts which are commonly used Brunauer, Emmet, and Teller BET, X-ray diffraction (XRD), scanning electron microscope (SEM), Energy-dispersive X-ray spectroscopy (EDS), Gas chromatography (GC), and Gas chromatogram which is coupled with mass spectroscopy (GCMS).

X-Ray Diffraction(XRD) is defined as the characterization technique that used to determine the properties of a material which have a crystal structure and phase composition. Amorphous and crystalline are considered as solid matters. In amorphous materials, atoms are organised randomly as found in liquids whereas, in crystalline materials, atoms are organised in a systematic pattern. It was discovered that most solid materials can be noticeable as crystalline through XRD method. Basically, diffraction pattern is the result of x-rays which act together with crystalline substances.

The BET method offers information on the textural properties of the catalyst used such as the surface area, pore volume and pore width. This method is frequently used in a gas analyser through the physical adsorption of non-polar gases, for example, nitrogen (Pratt and Anderson, 1985). There are many other gases that could be used for the adsorption as presented in Table 2-12 below.

Table: 2-12 Typical adsorption temperatures for gases utilised in surface area measurements (Pratt and Anderson, 1985)

Gas	Typical adsorption temperature (K)
Nitrogen	77
Argon	77
Xenon	90
Methane	90
n-Butane	27
Carbon dioxide	195

It is always vital to remove the gas from the catalyst sample prior into the physical adsorption procedure. The temperature and period of removing the gas process are detailed in the catalyst sample and can be determined experimentally.

The scanning electron microscope (SEM) is a technique that is specifically used for imaging particles together with a high-energy beam of an electron in a raster scan pattern. When the SEM technique is joined with EDS, the mechanism permits the analysis of elemental composition in solid material. In SEM-EDS, an electron visual system to yield an electron probe is needed. Other components used in SEM-EDS is a sample stage to place the sample, a secondary electron sensor for secondary electron collection which is for topographic picture generation (Goldstein and McNeil, 2012).

Gas chromatography (GC) is an analytical technique that is utilised for organic compounds analysis based on their boiling points and molecular weight. This technique is also specialised on uses in the application of chemical mixtures separation to individual components depending on their volatilities. Individual compounds quantified are then followed after the separation process. Joining of gas chromatogram together with mass spectroscopy (GCMS) can result in better identification of individual compounds. GC is known as the very sensitive instrument in such an extent that one microliter or less are introduced into the column. The parts that are much needed in a GC for analysis are the injector ports through where samples are loaded, helium is normally the carrier gas which transports the sample throughout the instrument, a detector and a data processor (Hites *et al.*, 1997).

Samples to be analysed are usually loaded at the injector port, which is then heated to volatilize the sample. Once the sample is in a gas phase, it is injected into a column by the carrier gas (mobile phase). Then again, the application of mass spectroscopy includes the fragmentation of the compound into small ions. These ions are then reorganised based on their mass-to-charge ratios in a mass analyser and collected by a detector to yield mass spectrum. Each molecule has a different mass spectrum and therefore this is used to identify the unknown compounds (Hites *et al.*, 1997).

Energy dispersive X-ray (EDX) analysis uses the X-ray spectrum produced by a solid sample which has been attacked with a focused beam of electrons to achieve a restricted chemical analysis. In principle, all elements considering their atomic number 4 (Be) to 92 (U) can be detected. The qualitative analysis contains the tracks of the lines in the spectrum and is properly direct owing to the modern technology of X-ray spectra. Quantitative analysis needs the measuring line concentrations per each element in the sample and for the same elements in the calibration standards of recognised compositions (Goldstein *et al.*, 1992).

By scanning the beam and showing the strength of a selected X-ray line, element supply images can be formed. Moreover, images formed by electrons attained from the sample disclose surface topography. The scanning electron microscope (SEM) is made mainly for making electron images, but can also be utilised for elemental mapping, and point analysis if an X-ray spectrometer is added (Goldstein *et al.*, 1992).

2.21 Coke formation and regeneration

During the catalytic hydroprocessing reactions, carbonaceous materials within the reactor accumulate on the surface of the catalyst. The accumulated carbonaceous material is called 'coke'. This process takes place based on the mechanism which consists of the initial adsorption of either reactants or products and is subsequently followed by the chemical reaction of the absorbing material to yield surface deposits which consists of lower volatility. These accumulations have a tendency or have the potential to lower the degree of cracking activity of the catalyst. Though, this material can be eliminated sometimes by burning. The formation of coke results in the loss of expected product and following regeneration can be defined as the energy-intensive and for example, factors that results in coke formation are of serious commercial importance (Eberly Jr *et al.*, 1966).

Since an extensive range of reactions takes place in hydroprocessing, a detailed mechanism for the formation of coke is hard to be established, even in systems which use pure compound feedstocks. Though, there are generalisations which are more accurate and are made to offer more understanding and following by the predictability of the process as a whole. The mostly used catalysts in hydroprocessing typically have big surface areas and that leads to the adsorption of hydrocarbons even at high temperatures (Eberly Jr *et al.*, 1966). Highly unsaturated, higher molecular weight hydrocarbons are adsorbed favourably. This result rather accounts for the fact that aromatics have highest trend for the formation of coke (Appleby *et al.*, 1962). Joined with adsorption, aromatics have the potential to experience chemical reactions on the surface, for instance, condensation and hydrogen removal. The hydrogen removal reaction can advance by olefins interacting with the adsorbed aromatics to produce paraffin and hydrogen-deficient coke (Thomas, 1944).

(Voorhies Jr, 1945) performed a study and concluded that the formation of carbon (wt. % on feed) increased exponentially with conversion levels. Also, when stated as weight percent on the catalyst (C), the relevant equation was developed (Voorhies Jr, 1945):

$$C=at^n$$

Where a and n are considered as constants, t for cycle time, and n for a constant value.

(Eberly Jr *et al.*, 1966) discovered that there is a significant difference in the amount of carbon achieved on each particle size range. The experiment results are presented on the table below .

Table : 2-13 Carbon formation as a function of particle size (Eberly Jr *et al.*, 1966)

Particle size range (µm)	990 - 2360	700 - 990	420 - 700	300- 420	250 - 300	150 - 250	75 - 150
Wt. % carbon on catalyst	4.01	4.02	3.78	4.02	4.07	4.0	3.93

The results presented above, show no visible difference in wt. % of carbon on the catalyst. On the whole particle size ranges, indicating that the formation of coke is not reliant on particle size. Moreover, this indicates that there is a constant distribution of coke formation through the internal structure of the catalyst.

2.22 Hydroprocessing operating parameters

The selection of catalyst and operating conditions has the potential to affect hydroprocessing reactions. The main operating parameters of hydroprocessing reactions consist of the reaction temperature, hydrogen partial pressure, hydrogen feed-rate and the liquid hourly space velocity of the feedstock.

2.22.1 Reaction temperature

Catalytic hydro processing reactions have the allowance to operate at the temperature range of between 290-450 °C. The temperature limits are selected based on the kind of catalyst/s and type of feedstock being processed, as well as the desired products. Mostly in industries, during the start-up of the reaction, the temperature is gradually increased until it reaches the selected maximum temperature to overcome the loss of catalyst activity (due to coking and deactivation) especially to maintain both the yield and quality of the expected product (Bezergianni 2013b).

2.22.2 Hydrogen partial pressure

The hydrogen partial pressure is very essential for hydroprocessing reactions and has an effect on the catalyst deactivation. High hydrogen pressure advances a greater degree of hydrocracking that results in a smaller chain hydrocarbons and is then suitable when kerosene and/or gasoline range is needed. Catalyst deactivation can also be inversely proportional to hydrogen partial pressure which permits extended use when smaller chain products are needed. Though, high hydrogen partial pressure does need high operating costs, which increases further when high hydrogen consumption is needed due to saturation reactions as is the case for highly

unsaturated triglycerides. It is then vital to balance hydrogen partial pressure with catalyst performance and life expectation in order to improve the overall process (Bezergianni, 2013b).

2.22.3 Hydrogen feed-rate

The hydrogen feed-rate refers to both heteroatom removal and saturation reaction rates. Though, there is a high operating cost related to high hydrogen practice. As such, renewable energy sources for hydrogen manufacture is being researched as a possible cost improvement (Bezergianni, 2013b) measure.

2.22.4 Liquid hourly space velocity

The liquid hourly space velocity (LHSV) is described as the ratio of the liquid mass feed-rate (g/h) over the catalyst mass (g) and is expressed per hour as presented in the equation below. LHSV is inversely proportional to the residence time of the liquid feed rate to the reactor. This means that, if a high degree of cracking occurs, a low LHSV should be used, that will result in a greater residence time in the reactor. Large LHSV enforces faster degradation of the catalyst, then in industrial applications, the LHSV is sustained in as low values as practically possible (Bezergianni, 2013b).

$$\text{LHSV} = \frac{\text{MASS FLOWRATE OF LIQUID OIL}}{\text{MASS OF CATALYST}} \dots\dots\dots 2.1$$

$$= 0.091$$

CHAPTER 3

3.1 One-Variable-At-A-Time (OVAT) method

The experimental design was designed under the method called One-Variable-At-A-Time (OVAT). In this method, only one variable is varied at a time whereas all other factors are kept constant. If extra factors were being utilised, the OVAT method could not be used since it is applicable to numerous tested factors. Interaction between factors is the result when a factor disturbs the output otherwise at diverse levels of another factor (Antony, 1998). Then, in the case of multiple wide-ranging factors, the results achieved from an OVAT method may possibly not be the optimum results achievable overall, except when all factors are independent of each other (Leardi, 2009).

Table 3-1 Layout for experimental runs

RUN1

Catalyst	Temperature °C	Pressure(Bar)	Liquid oil flowrate(ml/min)	H ₂ gas flowrate(ml/min)
HZSM-5	300	10	0,1	150
	350			
	400			
	450			
Ni/HZSM-5	300	10	0,1	150
	350			
	400			
	450			
without catalyst	300	10	0,1	150
	350			
	400			
	450			

RUN2

Catalyst	Temperature °C	Pressure(Bar)	Liquid oil flowrate(ml/min)	H ₂ gas flowrate(ml/min)
HZSM-5	300	20	0,1	150
	350			
	400			
	450			
Ni/HZSM-5	300	20	0,1	150
	350			
	400			
	450			
without catalyst	300	20	0,1	150
	350			
	400			
	450			

RUN3

Catalyst	Temperature °C	Pressure(Bar)	Liquid oil flowrate(ml/min)	H ₂ gas flowrate(ml/min)
HZSM-5	300	30	0,1	150
	350			
	400			
	450			
Ni/HZSM-5	300	30	0,1	150
	350			
	400			
	450			
without catalyst	300	30	0,1	150
	350			
	400			
	450			

RUN4

Cataslyst	Temperature °C	Pressure(Bar)	Liquid oil flowrate(ml/min)	H ₂ gas flowrate(ml/min)
HZSM-5	300	40	0,1	150
	350			
	400			
	450			
Ni/HZSM-5	300	40	0,1	150
	350			
	400			
	450			
without catalystr	300	40	0,1	150
	350			
	400			
	450			

3.2 Randomisation and replication

Reducing error because of interfering factors during the experimental runs is important, and it improves accuracy of results. Randomisation and replication are strategies that are developed specifically for minimising error.

Randomisation strategy of experimental runs and product analysis techniques are utilised for reducing the systematic error specifically in measurement. Systematic error increases from interfering factors for instance machine wear, air temperature etc. Then, by including the randomisation strategy during experiments runs and analysis, the interfering factors are averaged out and the bias is decreased (DeCoursey, 2003). Also, all products are analysed using the GC-MS machine.

During the experimental runs performance, all raw materials and product analysis techniques were done in triplicates. This guarantees the accuracy of results attained from these analyses.

3.3 Experimental Section

3.3.1 Material description

Zeolite (ZSM-5): Chemical obtained from Zeolyst International (CBV 5524G-1000G), $\text{SiO}_2/\text{Al}_2\text{O}_3 = 50$, was in an ammonium form, consists of white powder of fine particles. This was used as a starting material for HZSM-5 which was the treated catalyst support for metals.

Nickel (II) nitrate hexahydrate: Chemical obtained from Sigma-Aldrich, ACS reagent grade. Consist of green powder with fine particles. Nickel (II) nitrate hexahydrate was considered as a precursor for nickel in preparation of catalyst systems supported on the metal of HZSM-5.

Preparation of the catalyst

Zeolite conversion from ammonium form

ZSM-5 zeolite in ammonium form (CBV 5524G with $\text{SiO}_2/\text{Al}_2\text{O}_3 = 50$) attained from Zeolyst International was calcined in a muffle furnace at the temperature of 600°C in atmospheric environment for 5 hours (Van der Borgh *et al.*, 2015). Ammonia was calcined directly to be zeolite in a protonic form (HZSM-5).

The impregnated catalyst Ni-HZSM-5, were prepared by the method called wet impregnation together with the compound nickel nitrate ($\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$). Initially, suitable amount of carrier (HZSM-5) powder were impregnated with aqueous solution of $\text{Ni}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$. The mixture was mixed into slurry by adding the correct amount of deionized water. Then, the achieved slurry was stirred until it was properly mixed, thereafter it was dried and calcined. It was then dried in the oven overnight at 110°C and it was then calcined again at 823 K for the period of 4 h. The metal Ni loading on the catalysts was 10 wt. %.

3.3.2 Thermal and Catalytic Cracking Experiment

Pre-treatments of catalyst were discovered to be among the effective methods of improving the catalytic performances and catalyst activity. The increase of calcination time had no effect on reaction velocities. It was found out that calcination temperature has a great effect on the catalyst activity (Chen *et al.*, 2005). Calcination is basically the process of exposing a catalyst substance to the action of heat using muffle furnace in an oxygen and fusion absentia for the purpose of changing physical or chemical structure (Al-Fatesh and Fakeeha, 2012). There are

two main common reasons for calcination process (1) drying the moisture presents in the catalyst substance (11) and driving off carbon oxide or any other volatile constituents.

The catalyst activities and density of acid sites rely on and is affected strongly by calcination temperatures.. Calcination is the most vital factor in catalytic properties (Al-Fatesh and Fakeeha, 2012)

Calcination procedure

The catalyst was weighted before and after heating using top balance



Figure: 3-1 Zeolite catalyst (CBV5524G)



Figure:3-2 Top balance

Top balance is a measuring unit that is accurate and easy to use, it measures the weight from 0.01mg up to 220g. The measured catalyst was placed into the crucible and placed inside the muffle furnace.



Figure :3-3 crucibles inside the muffle furnace

The muffle furnace has an extremely heated chamber. There are walls within the muffle furnace for the material being heated so as to be not in contact with a flame. Muffle furnaces are mostly used in laboratories in order to create extremely high temperature atmospheres. They are used to test the characteristics of materials at extremely high temperatures.

Chapter 4

Experimental equipment

4.1(a) The lab-scale hydrocracking set-up

The experimental method is divided into three main sections;

- i) The catalyst preparation
- ii) The catalytic hydrocracking of coconuts oil and,
- iii) The separation and analysis of the products attained from the hydrocracking reactions.

The catalytic hydrocracking of coconuts oil was supported and processed out in a lab-scale packed bed reactor system designed and commissioned as part of the study.

4.1(b) Experimental equipment

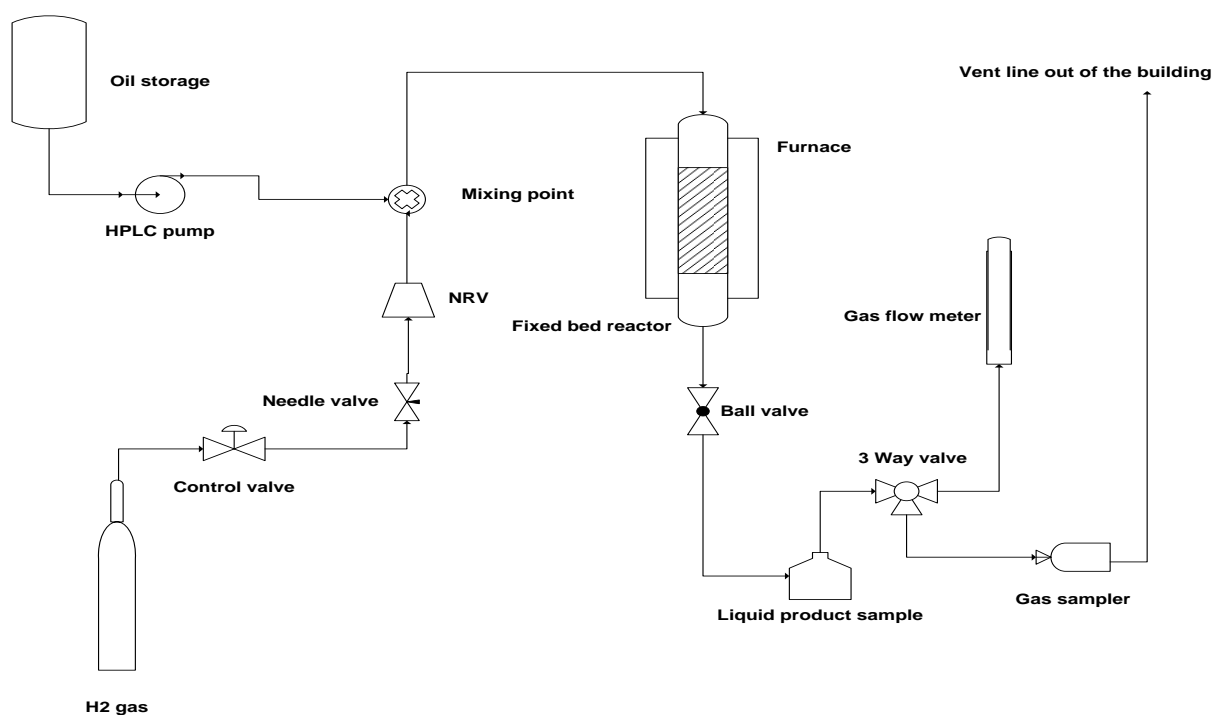


Figure: 4-1 hydrogenation of coconuts oil into bio-jet fuel process flow diagram

4.1.1 Catalyst Tests

All experiments were done and carried out in the packed-bed reactor (PBR). This tubular stainless steel packed-bed reactor has the measurements of (inner diameter of) 10 mm; (length of) 350 mm and an hydrogen gas cylinder of 4 MPa maximum pressure. Just before the reaction took place in the packed-bed reactor, 1.0 g of a catalyst was loaded in the temperature zone of the reactor with quartz wool as the packing materials on the top and for supporting the catalyst in the reactor. Coconut oil (40 wt. %) was pumped into the packed-bed reactor flowing at a rate of 0.1 mL/min by a high pressure liquid pump (HPLC). H₂ gas flow rate (150 mL/min) was introduced into the reactor simultaneously with coconut oil. The packed bed reactor was able to maintain the maximum of H₂ pressure of 4 MPa with the use of pre-pressure controller, and operated in the co-current-flow with liquid oil.

4.1.2 Gas chromatography mass spectroscopy (GC-MS)

The liquid products were analysed and processed using offline gas chromatograph mass spectroscopy (GCM-SQP-2010 Ultra) by Shimadzu, equipped with the capillary column of 30m x 0.25 x 0.25um DB5MS and FID detector. There was approximately one microliter of sample that was introduced into an injector port by a detector temperature of 250 °C and helium at a flowrate of 0.9 ml/ min was used as a carrier gas.

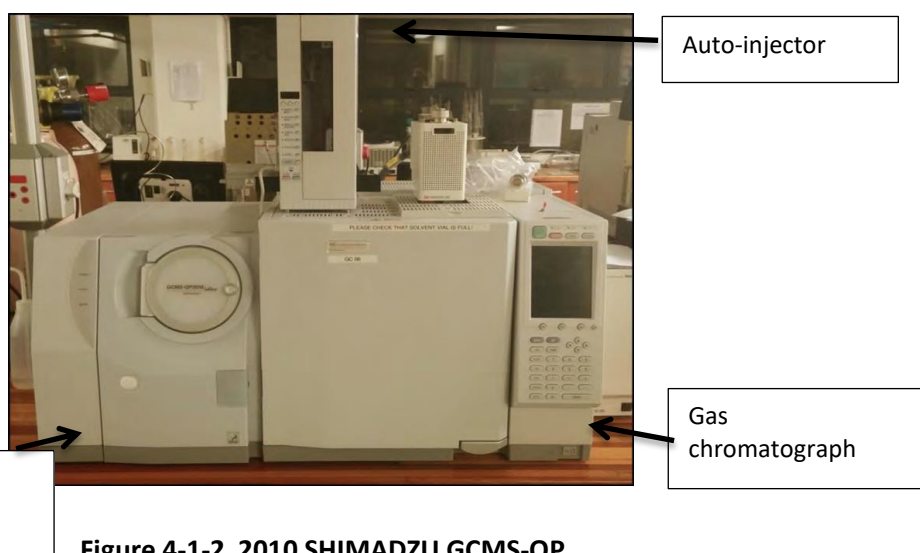


Figure 4-1-2 2010 SHIMADZU GCMS-QP

4.2 The lab-scale hydrocracking apparatus

The lab-scale fixed bed hydrocracking reactor system used in this study consisted of the equipment described below.

4.2.1 Oil feed pump and HPLC pump

The oil from the storage beaker was fed to the reactor via an HPLC pump (Figure 4-2). The coconut oil was pumped at room temperature (25°C). The volumetric flow rate of oil was constantly at 0.1 ml/min. The density of the coconut oil (0.924 g/cm³) was also used to calculate the total mass of coconut oil fed to the reactor over the duration of each experimental run. The HPLC pump had its own non-return valve in order to prevent any oil or gas from flowing back into the pump.

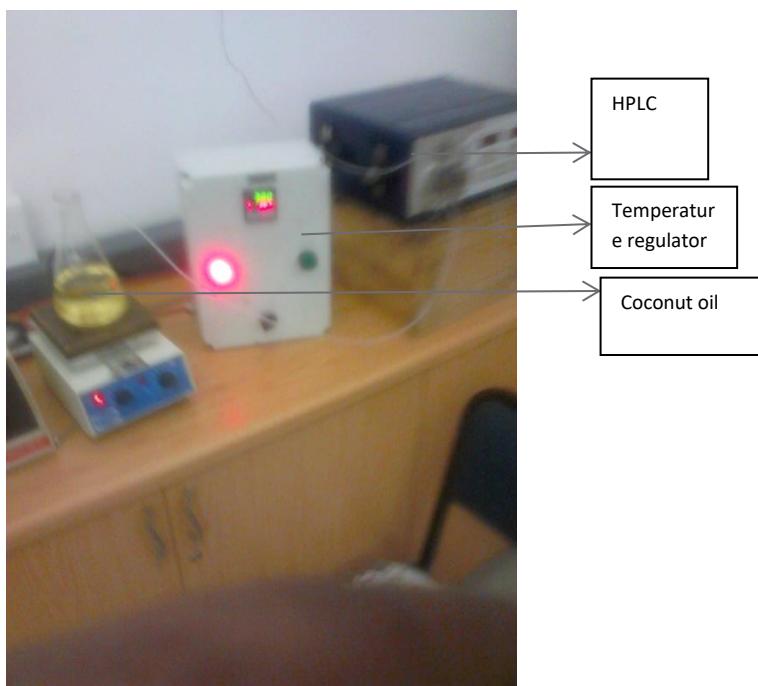


FIGURE: 4-2 Feed beaker and HPLC pump



FIGURE: 4-3 HPLC pump

4.2.2 Reactor and electric furnace

The reactor was made with 316 stainless steel tube (length = 40.4 cm, ID = 1.0 cm and OD = 1.4 cm) fitted with Swagelok tube. The tube was positioned vertically into a clam shell electric furnace designed for heating tubular reactors (Figure 4-4). The vertical arrangements enabled the flow of reactants and products via gravitational force. The feed line to the reactor was installed with a pressure gauge for reading the system pressure over the whole duration of each experimental run. A pressure relief valve was also installed onto the system for safety precaution. The operation of the pressure relief valve is as follows: when the system pressure suddenly increases, the pressure relief valve will open, in order to release the excess pressure to prevent damage to the equipment and possible injuries to the operator.

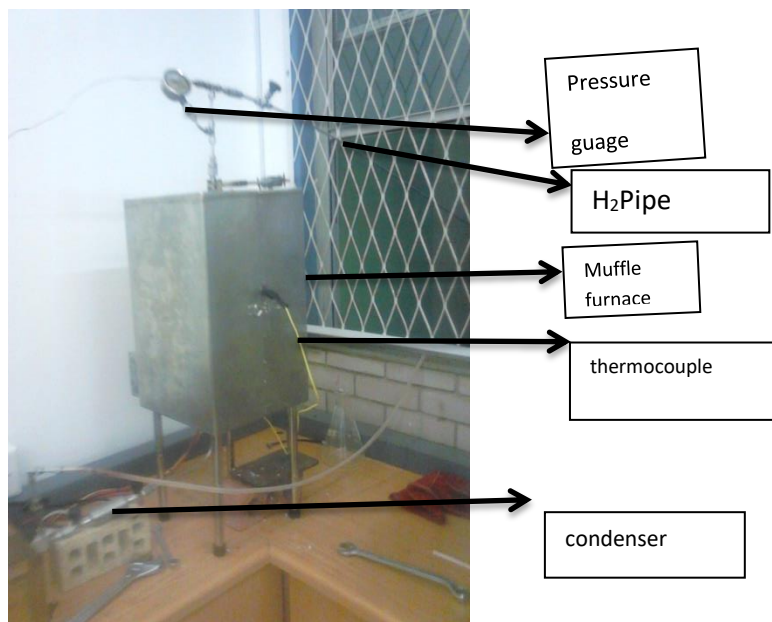


FIGURE:4-4 Reactor and electric furnace

Carbon steel electric arc furnace catalyst is considered as the variable in composition reliable on the steelmaking practice and again the source of scrap utilised in the furnace. In general the particles of catalyst contains significant amounts (> 10%) of nickel. The nickel is generally considered as toxic waste because of the leachability of toxic elements such as lead, cadmium and chromium that are associated with nickel. For this reason, under environmental pressure, the secondary steel industry has been looking for process alternatives for treating the nickel catalyst.

Initial operation conditions were lower temperature range (300-450 °C) and a lower system pressure range of 10-40 Bar. These initial conditions were selected based on a combination of the literature (Hancsók *et al.*, 2014) and obtainable resources at the time. Glass wool was initially selected for the packing material surrounding the catalyst in the tubular reactor. It was expected that the coconut oil would spread better over the entire inner diameter of the reactor tube due to the substantial air spaces in the fabric, therefore permitting the oil to contact all of the catalyst in the fixed bed. All tests were run using the HZSM-5 ,Ni/HZM-5 catalysts and without the catalyst. The tests were carried out at a liquid oil volumetric flow rate of 0.1 ml/min.

4.2.3 Packing material

Though the hydrogen gas maintained the maximum pressure of 40 Bar (with a reaction temperature of 300 °C and 0.03 ml/min) and passed through the system easily, the first problem was experienced when the coconut oil delayed passing through the glass wool packing. It was discovered that there was no product after two hours of run time. It was discovered that upon unpacking the reactor the catalyst bed was completely dry with a portion of the above glass wool soaked with the oil. Other available packing materials were considered, with wire selected as the next best alternative and with a volumetric of 0.1 ml/min. A dry test was performed by passing the coconut oil through the wool and wire inside the reactor tube without the catalyst at room temperature and hydrogen gas. After 5 minutes, drops of oil were present in the tube leading to the product collection vessel. This was an indication that the oil had passed through the system without any problems, thereby validating the choice to use wire in all following experiments. Moreover, upon inspection, it was observed that almost all the surface of the wire had been in contact with the oil, showing a good distribution of the oil over the packing, which recommended a potentially good distribution of the oil over the catalyst bed. This validated the use of wire as the packing material for this study.

4.2.4 System pressure

The second problem that was experienced, was that there was no liquid product in the collection vessel, but only a thick waxy residue formed. This resulted in the exit line from the reactor being completely blocked. It was almost impossible to remove the thick waxy residue from the 1/8" tubing. The exit valve had to be cleaned before re-use. The maximum system pressure of 40 bar was believed to be the reason for no liquid product since higher pressures favoured hydroprocessing reactions and enhancing hydrocracking as well (Bezergianni, 2013a). The pressure of 40 bar was considered as the highest safe operating conditions for the experimental equipment. As an additional safety precaution, a pressure relief valve was fitted to the system and would release any excess pressure above 40 bar. The reaction pressure of 40 bar also helped in reducing the production of waxy residue and subsequent blocking.

4.2.5 Reaction temperature range

Literature (Bezergianni, 2013a) had shown that higher temperatures favoured hydrocracking reactions and enhancing hydrocracking as well, especially in an attempt to minimise the amount of waxy residue being formed, the range of reaction temperatures were increased from 300-450°C. This increased temperature range was also expected to yield more kerosene, gasoline and diesel range products than the initial lower temperature range (since it favoured

hydrocracking). An experiment conducted at 450°C and 40 bar produced the maximum and reasonable amount of liquid relative to the waxy residue than any previous preliminary experiment. Qualitative analysis of this product using GCMS showed gasoline, kerosene and diesel range hydrocarbons to be present in the liquid product. It was then concluded that the higher temperature range which is 450°C would be utilised and studied.

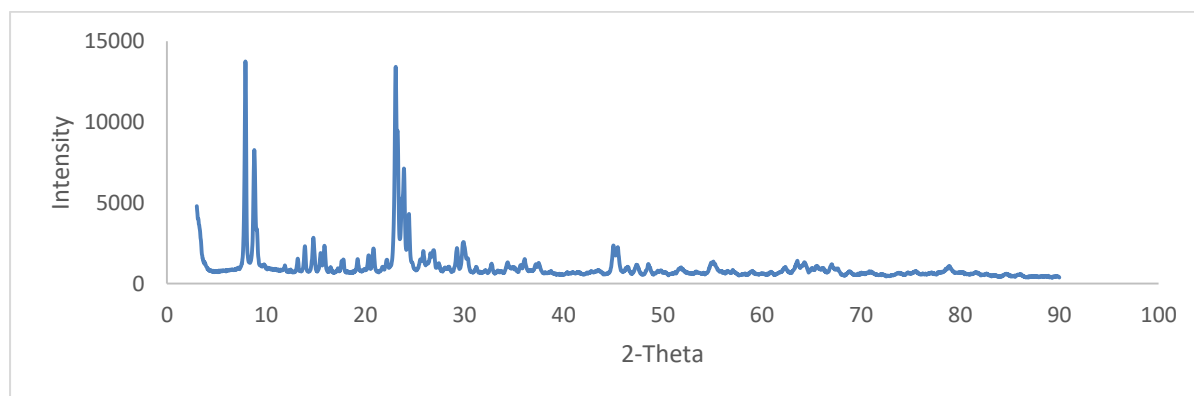
4.2.6 Liquid hourly space velocity

Since lower LHSV results in a greater residence time, which then promotes the degree of hydrocracking taking place. 0.1 ml/min volumetric flow rates were selected to try and improve hydrocracking, and subsequently, the yield of liquid product. Test experiments performed at the 0.1 ml/min indicated a greater yield of liquid products and advance hydroprocessing reactions. As a result, all experiments carried out in this study were performed at 0.1 ml/min.

4.3 Catalyst characterization

4.3.1 X- Ray Diffraction (XRD) - Zeolite transformation from ammonium to hydrogen form

XRD analysis was used to evaluate the crystallinity of the ZSM-5 zeolites used in this study. The XRD Patterns of ZSM-5 received from the supplier in ammonium form and zeolite calcined at 600°C to hydrogen form. It has been found that calcination process did not affect the crystallinity of zeolite. HZSM-5 characteristic peaks in the XRD patterns were found at 2θ diffraction angles of 7.7, 9.1, 14, 14.9, 20.50, 23.3, 24.0, 24.5 and 27 degrees. The 2θ diffraction angles of HZSM-5 were corresponding with the one's for zeolite crystals. This is shown in the figure below.



HZSM-5

Figure :4.5 2 theta (°) vs intensity

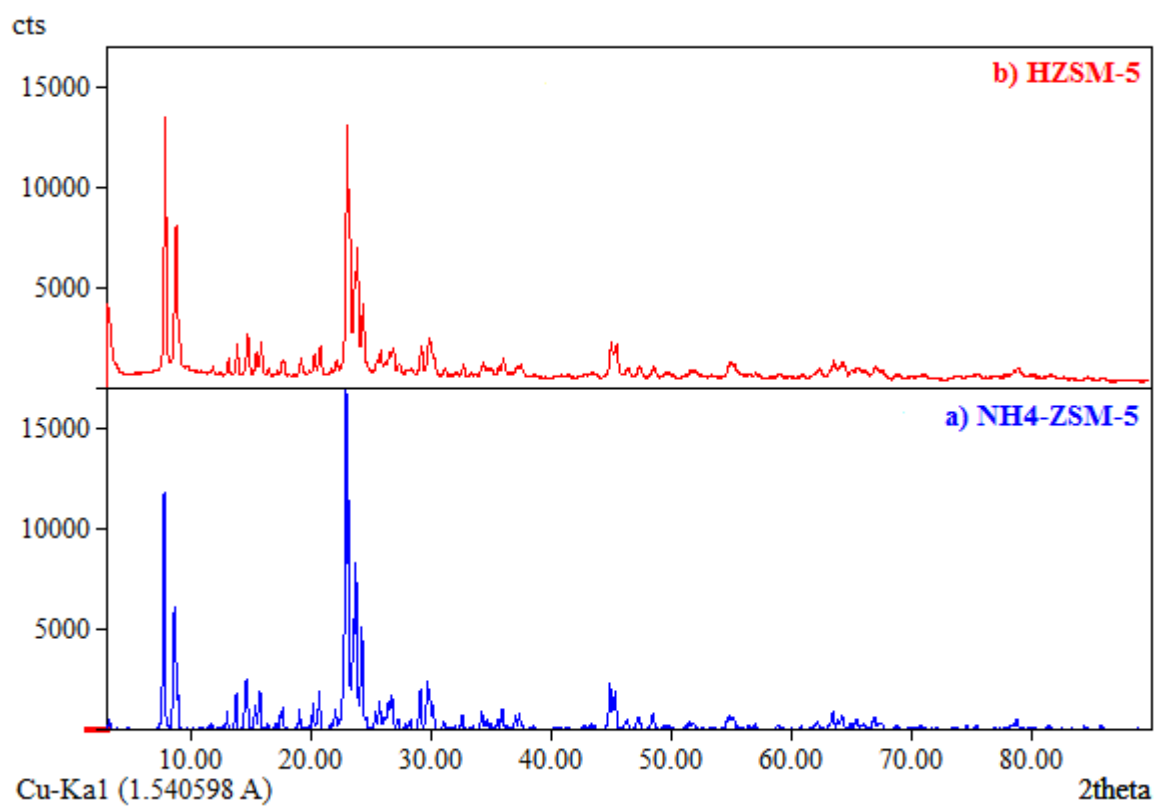


Figure :4.6 XRD Pattern of ZSM-5 a) NH4-ZSM-5 and b) HZSM-5

4.3.2 Zeolite promoted with nickel metal

XRD patterns presented no significant changes in the crystallinity of promoted zeolite. All sample structures of HZSM-5 and Ni/HZSM-5 indicates similar characteristic peaks of 2theta at 7.9, 8.8, 9.1, 9.5, 9.8, 14, 14.5, 15.0, 20.50, 22.2, 23.3, 24.0, 24 degrees with different intensities. Their highest peaks that were achieved are 9.1 and 22.9.

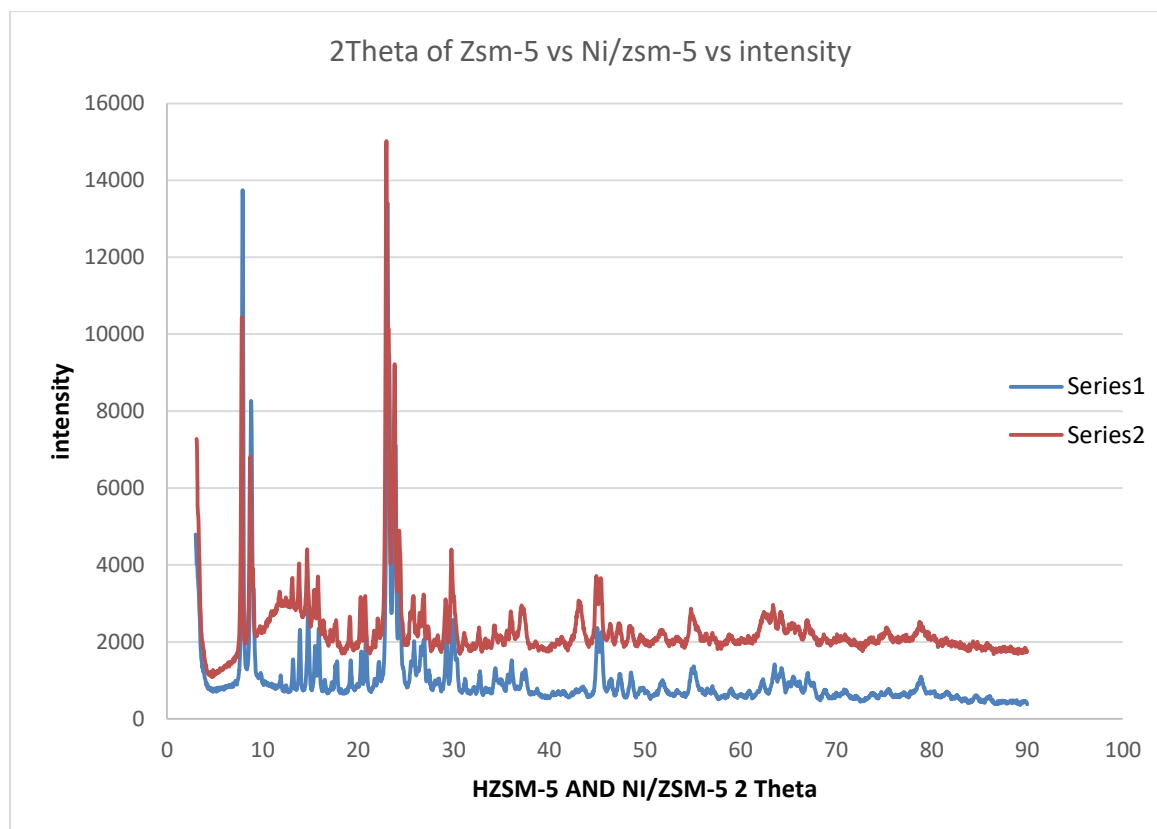


Figure :4.7 2theta(°) of HZSM-5 and Ni/HZSM-5 vs intensity

Series1= HZSM-5, **series2=** Ni/HZSM-5

ZSM-5 Calcined: This is a mother catalyst for HZSM-5 and Ni/HZSM-5 catalysts that were used in this study and was used as a reference for the above catalysts prepared. The particle size of the crystalline was computed to be 29.46 nm, is indicated in the appendix and the catalyst sample was found to have a monoclinic crystal system.

Ni/HZSM-5: is the HZSM-5 impregnated with 10% nickel. The pattern for this catalyst system is shown in the figure above with no change in crystallite structure and the relative crystallinity was 79.8%. The particle size of the crystalline at 2theta of 23° for HZSM-5 presented the highest peak of 5000 intensities and was reduced on its size. The crystal system did not change from monoclinic after nickel impregnation, it remained the same. Nickel was also recognised in a form of NiO crystalline phases.

4.4 Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS).

4.4.1 Zeolite and zeolite promoted metals: Ni

The crystal morphology of zeolite and zeolite promoted metals were examined by SEM analyser as shown in the figure 4.8 and 4.9 below. The SEM images were taken at a magnification of 20 000 times. HZSM-5 was detected to shows irregular shapes, by observing the shape of the size, it can be seen that they are of relative size. It can also be observed that impregnation with nickel has shown the development of particles with irregular shapes stuck together.

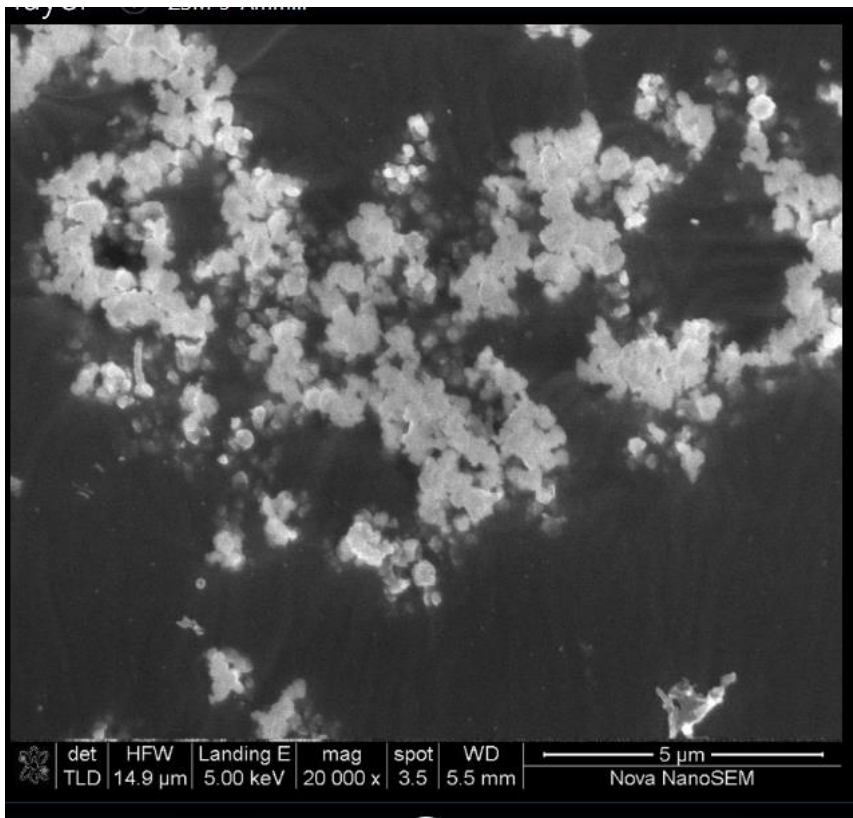


Figure: 4.8 ZSM-5 catalyst

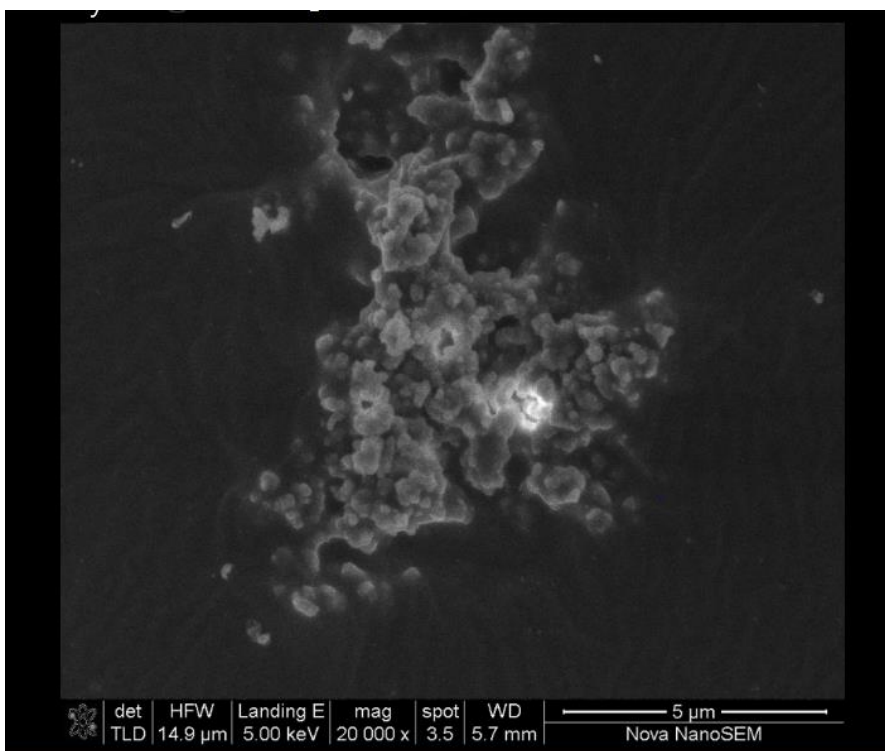


Figure: 4.9 Ni/HZSM-5

Ni/HZSM-5: Shown in Figure 4-10 is nickel supported HZSM-5 catalyst composition. Nickel was detected in the sample verifying the success of metal impregnation. Other elements from zeolite structure such as oxygen, silicon and aluminium were detected as well. Furthermore, carbon detected was from the film. The Ni loading that was computed from these results was 9.77 % which is closer enough to the targeted 10% loading.

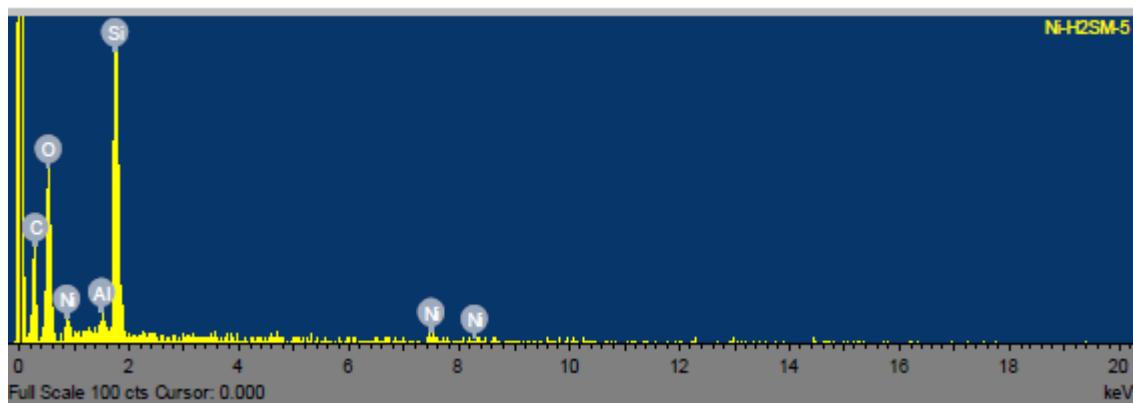


Figure : 4-10 EDS Graph of Ni/HZSM-5 Catalyst

Chapter 5

5. Results and discussion

5.1 Results for the hydroprocessing of coconut oil

The subsequent section consists of the results for the hydroprocessing of coconut oil over Ni/HZSM-5, HZSM-5 and without catalyst. The main focus is a comparative study of the results which were used to evaluate or determined the catalyst, under a specific set of operating conditions (pressure and temperatures), that produced the highest liquid product compositions of the kerosene (jet fuel), gasoline and diesel and also the results regarding the catalyst activity and effectiveness.

5.1.1 The qualitative analysis of GC-MS

Qualitative analysis using the GC-MS indicated that the liquid product contained boiling point range of transportation fuels from C5 to C22 saturated hydrocarbons along with acids which are constituents of the coconuts oil. **In this study the composition of liquids products were equivalent to area percent.**

The following figures show the visual results that were observed for all the experimental runs. The figures will only show one set of three graphs in the same operation conditions (temperature and pressures) with different catalysts of the product collected and catalysts are categorised as one without catalyst, with HZSM-5 and Ni/HZSM-5. All these different catalysts were tested for activity in a high-pressure reactor system using hydrogen gas and coconut oil as the reactants. Mostly, the rate of cracking and the final products depend on the temperature, pressure, reaction time, and presence of catalysts. The production of biofuel under different conditions would be compared to find the best suitable one. This study was achieved in two process reactions which are thermal cracking and catalytic cracking. Thermal cracking and catalytic cracking are defined as the reactions that are used to break down large molecules into smaller compounds. The main difference between processes of thermal cracking and catalytic cracking is that thermal cracking uses heat energy for the breakdown of compounds whereas catalytic cracking involves a catalyst to obtain products.

EFFECT OF REACTION PRESSURE

The hydrogen pressure is one of the vital factors in hydrocracking reaction, so the effect of the initial hydrogen pressure on the reactor was studied. Pressure was regulated on control valve using pressure guage installed on the reactor. To assess and evaluate this effect, numerous experiments were performed at an interval of 10 to 40 bar. Figure 5-1 to figure 5-12 show the yields for the different liquid compositions obtained where HZSM-5, Ni/HZSM-5 and without (thermal cracking) catalysts were used. The figures provide a graphical representation of calculated data based on Tables below.

TABLE 5-1 EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 300 °C FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	1H1	1,60	75,67	15,01	0,00	10,00	300,00
HZSM-5	2H1	9,37	65,47	25,15	0,01	20,00	300,00
HZSM-5	3H1	14,65	52,44	20,85	12,06	30,00	300,00
HZSM-5	4H1	47,71	52,30	0,00	0,00	40,00	300,00

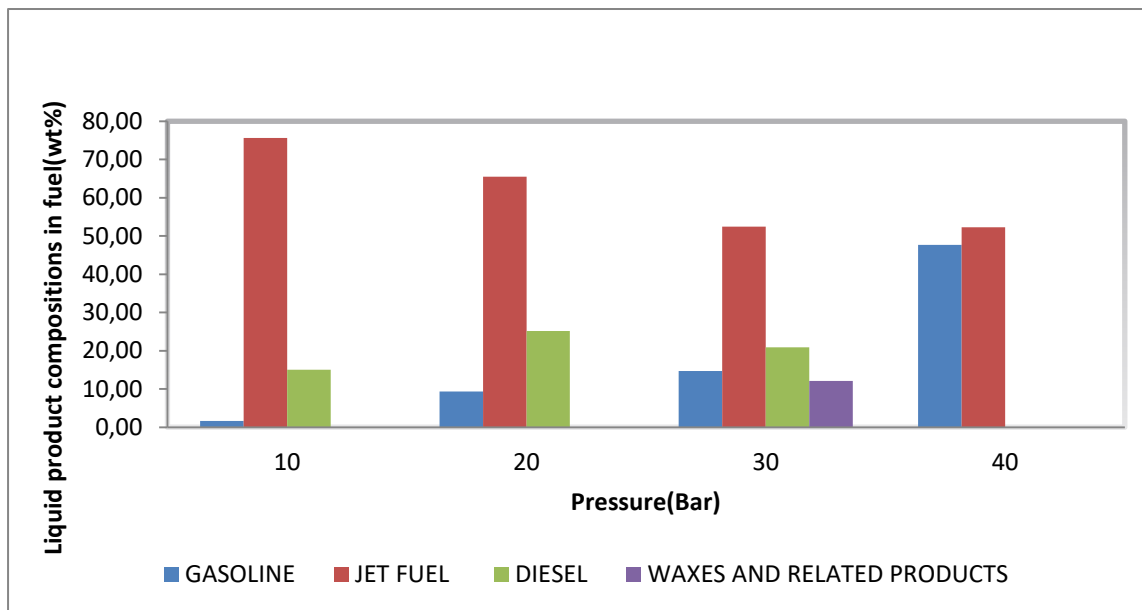


FIGURE:5-1 yield of liquid composition(wt%) vs pressure(bar) at 300°C for HZSM-5.

The figure 5-1 above shows the effect of pressure on the yield of biofuel (gasoline, jet fuel, diesel, waxes and related products range liquid composition) during the hydrocracking of coconut oil using HZSM-5 at the temperature of 300°C and at the reaction pressure range 10-40 bar. The yield of gasoline liquid composition increased with increasing reaction pressure, the yield of kerosene(jet fuel) liquid composition decreased with increasing reaction pressure, the highest yield of diesel liquid composition was achieved at 25% and is more favoured at 20 bar. Waxes compositions are only favourable at 30 bar with the yield of 10%. HZSM-5 produces the highest yield of gasoline and kerosene liquid compositions with corresponding of 47.7% and 52.30.% under a temperature of 300°C. It is found that the decrease of jet fuel range could be due to low temperature and coke which was formed within the reactor. The accumulations of coke have a tendency to lower the degree of cracking activity of the catalyst (Eberly Jr *et al.*, 1966).

TABLE 5-2		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 300 °C FOR WITHOUT CAT					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	1W1	3,49	51,87	16,96	24,98	10	300
WITHOUT CAT	2W1	0	78,72	17,5	3,78	20	300
WITHOUT CAT	3W1	1,95	64,23	17,35	16,46	30	300
WITHOUT CAT	4W1	54,82	2,09	18,18	23,62	40	300

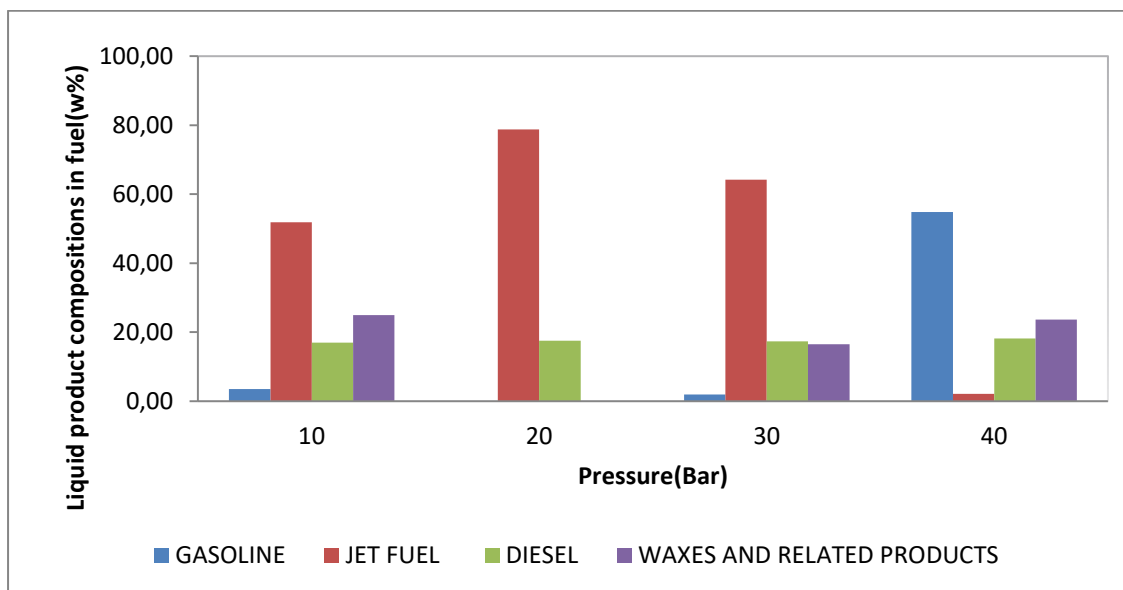


FIGURE:5-2 Yield of liquid composition (wt%) vs pressure(bar) at 300 °C for without catalyst.

Figure 5-2 above shows the effect of reaction pressure on the yield of biofuel during the thermal cracking of coconut oil at 300°C and at 10-40 bar without a catalyst. The yield of gasoline and kerosene (jet-fuel) liquid compositions increased with increasing reaction pressure. Thermal cracking shows the highest yield of gasoline and jet fuel liquid compositions of 55% at 40 bar and 79% at 20 bar respectively. The yield of diesel composition remained constant at around 17% and waxes composition indicated the highest yield at 10 bar.

TABLE 5-3 EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 300 °C FOR Ni/ZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	1N1	11,72	78,73	4,12	5,43	10	300
Ni/HZSM-5	2N1	21,47	54,09	11	8,61	20	300
Ni/HZSM-5	3N1	60,71	18,49	20,86	0	30	300
Ni/HZSM-5	4N1	69,01	15,05	15,94	0	40	300

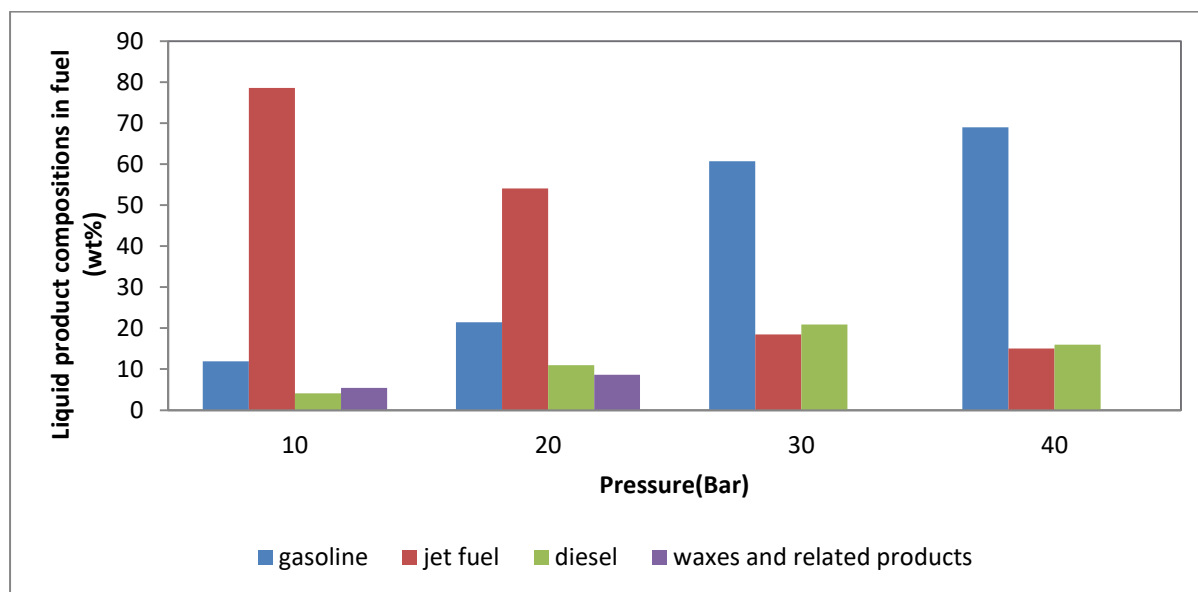


FIGURE:5-3 yield of liquid composition (wt%) vs pressure(bar) at 300 °C for Ni/HZSM-5 catalyst.

Based on data in Figure 5-3 above where HZSM-5 is promoted to Ni/HZSM-5, the increase of hydrocracking pressure, the yield of gasoline and diesel liquid compositions were also increasing while product of jet fuel compositions were decreasing. At higher pressure which is directly proportional to temperature, light hydrocarbon could be cracked more, because thermal cracking was faster than catalytic cracking. It was found that at 40 bar and 300 °C highest yield of the gasoline range composition was achieved 69,01 %, the highest yield of jet fuel range composition of 78,73% was achieved at 10 bar and 300 degrees, highest yield of diesel at 30 bar of 20 %, and highest waxes range at 20 bar of 8,6%.

COMPOSITIONS VS PRESSURES AT CONSTANT TEMPERATURE 350 DEGREES FOR DIFFERENT CATALYSTS.

TABLE 5-4	EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 350 °C FOR WITHOUT CATALYST						
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	1W2	7,46	54,88	15,46	22,21	10	350
WITHOUT CAT	2W2	10,48	49,06	16,45	24,01	20	350
WITHOUT CAT	3W2	15,44	50,15	20,13	14,28	30	350
WITHOUT CAT	4W2	56,07	7,06	23,61	12,09	40	350

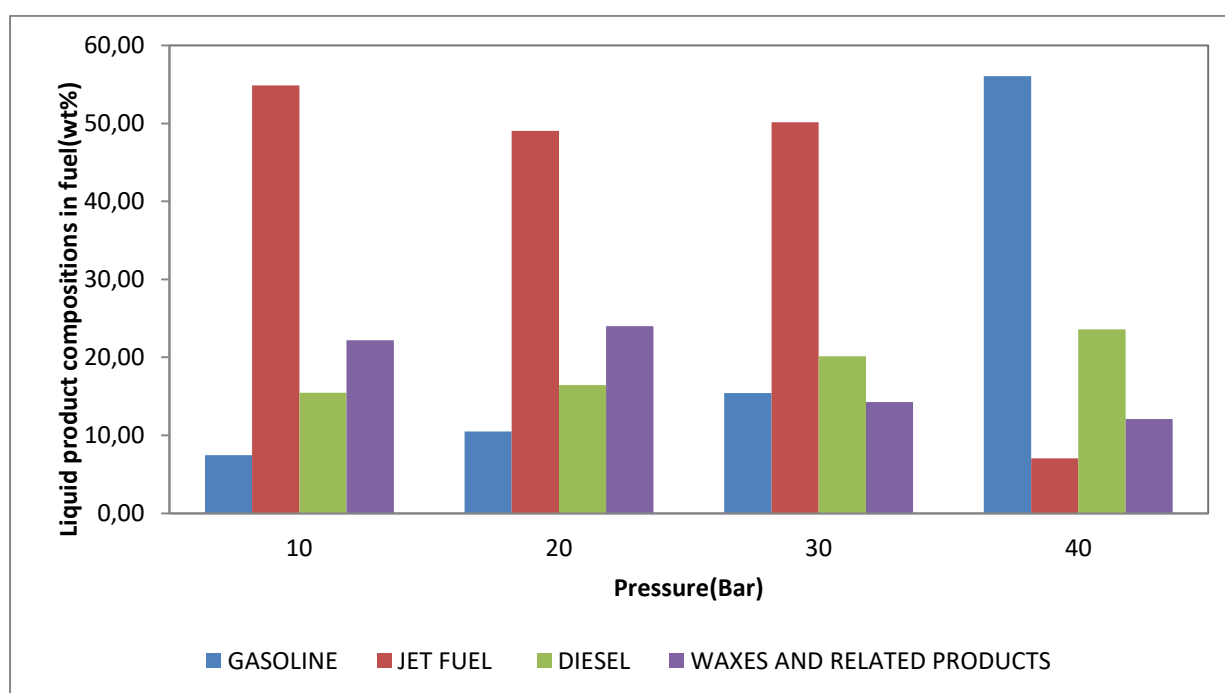


FIGURE: 5-4 Yield of liquid composition (wt%) vs pressure(bar) at 350°C without catalyst.

The Figure 5-4 above shows the effect of reaction pressure on the yield of biofuel (gasoline, kerosene, diesel and waxes) liquid compositions during the thermal cracking of coconut oil at 350°C and at 10-40 bar without a catalyst. The yield of gasoline and diesel liquid compositions increased with increasing reaction pressure. It also shows the decrease of yield of jet-fuel liquid composition with the increase of reaction pressure. It was found that thermal cracking at 350 degrees shows the highest yield of gasoline liquid composition 56,07% at 40 bar, the highest yield of jet fuel liquid composition with 54,88% at 10 bar, the highest yield of diesel

liquid composition with 23,61% at 40 bar, and the highest yield of waxes liquid composition with 24,01% at 20 bar.

TABLE 5-5 EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 350 °C FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	1H2	12,36	50,33	20,74	16,58	10	350
HZSM-5	2H2	26,65	47,59	17,83	7,18	20	350
HZSM-5	3H2	1,93	60,21	14,72	23,15	30	350
HZSM-5	4H2	26,74	45,28	16,38	11,6	40	350

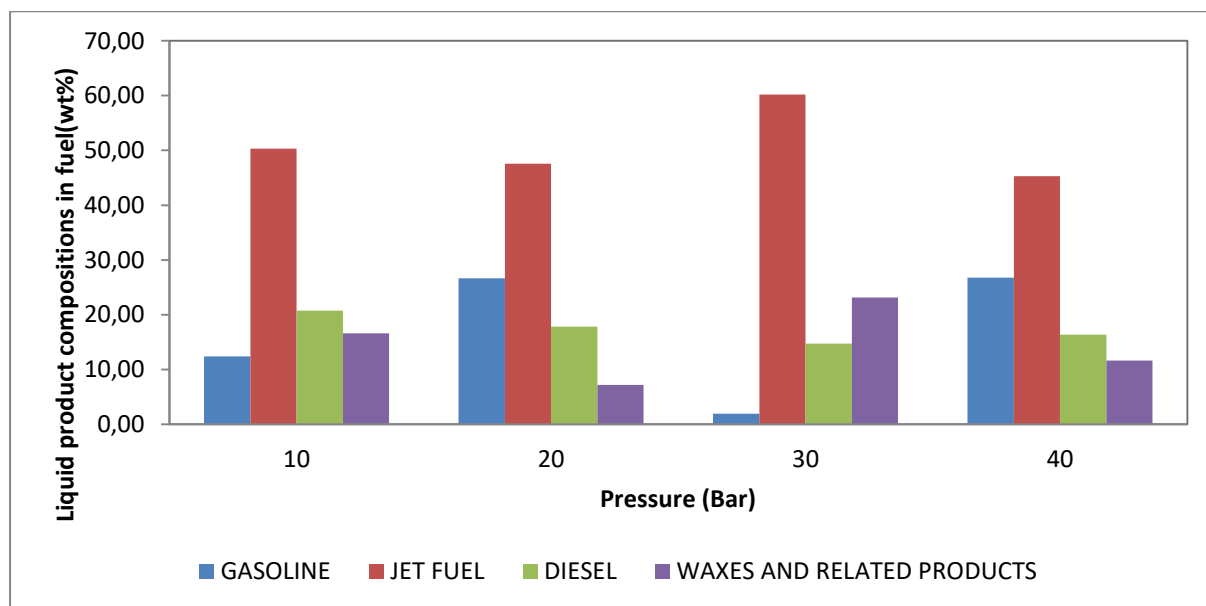


FIGURE: 5-5 yield of liquid composition (wt%) vs pressure(bar) at 350 °C for HZSM-5 catalyst.

In the figure 5-5 above, with the increase of hydrocracking pressure, product of gasoline liquid composition increased while product of diesel liquid composition decreased. Yields of jet-fuel and waxes liquid compositions were fluctuating. It was found that the highest yield of gasoline liquid composition which was obtained at 40 bar was 26,74%, the highest yield of diesel liquid composition at 10 bar was 21 %, the highest yield of jet fuel liquid composition was 60% at 30 bar and the highest yield of waxes liquid composition at 30 bar was 23,15 %.

TABLE 5-6		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 350 °C FOR Ni/HZSM-5					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	1N2	74,07	18,85	7,07	0	10	350
Ni/HZSM-5	2N2	65,16	29,99	4,86	0	20	350
Ni/HZSM-5	3N2	42,56	47,33	10,12	0	30	350
Ni/HZSM-5	4N2	67,04	19,76	12,16	0	40	350

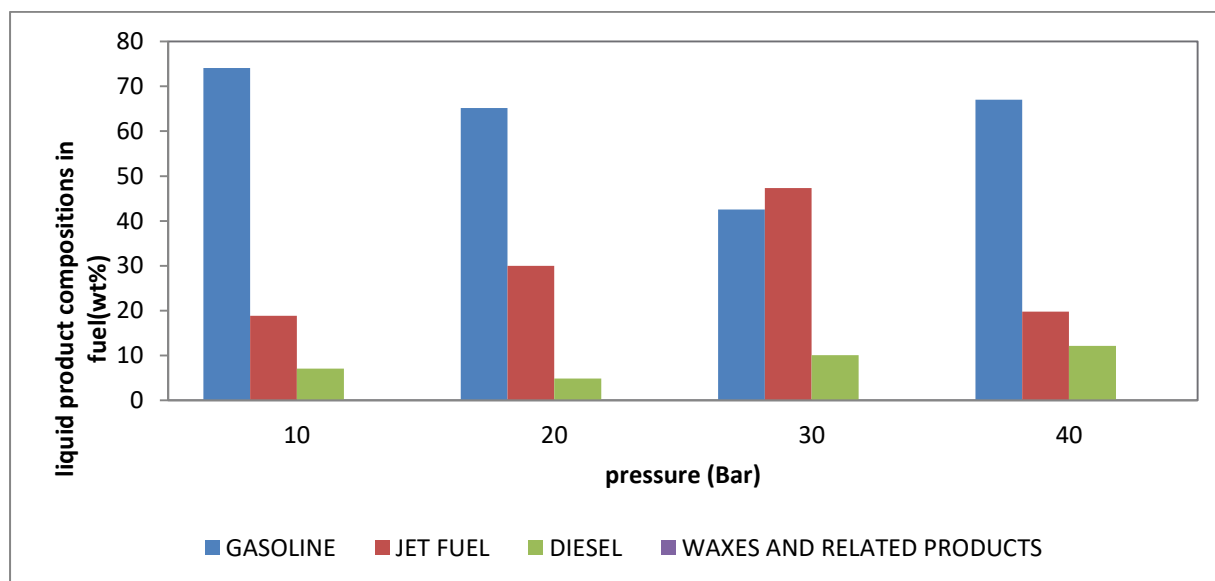


FIGURE:5-6 yield of liquid composition (wt%) vs pressure(bar) at 350 °C for Ni/HZSM-5 catalyst.

In Figure 5-6 above where HZSM-5 is promoted to Ni/HZSM-5. The increase of hydrocracking pressure, the yield of gasoline liquid composition experienced the decrease from 10-30 bar and increased from 30-40 bar, this was an indication that as the temperature increases a delay in increase of gasoline range is taking place. The yield of diesel liquid composition was increasing and the highest product of diesel liquid composition was 11% at 40 bar. Basically, the increase of diesel liquid composition indicates the catalytic cracking of these compounds into heavy hydrocarbons that is more favourable under high reaction pressure. In the interval of 10-40 bar, the yield of jet-fuel liquid composition is slightly affected by the pressure since it varies from 19% to 49% and from 49% to 20%.

COMPOSITIONS VS PRESSURES AT CONSTANT TEMPERATURE 400 °C FOR DIFFERENCE CATALYSTS.

TABLE5-7		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 400 °C FOR WITHOUT CATALYST					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	1W3	16,26	49,26	16,13	17,59	10	400
WITHOUT CAT	2W3	22,53	35,02	20,54	20,81	20	400
WITHOUT CAT	3W3	26,84	28,67	15,54	11,2	30	400
WITHOUT CAT	4W3	20,39	56,37	17,02	6,24	40	400

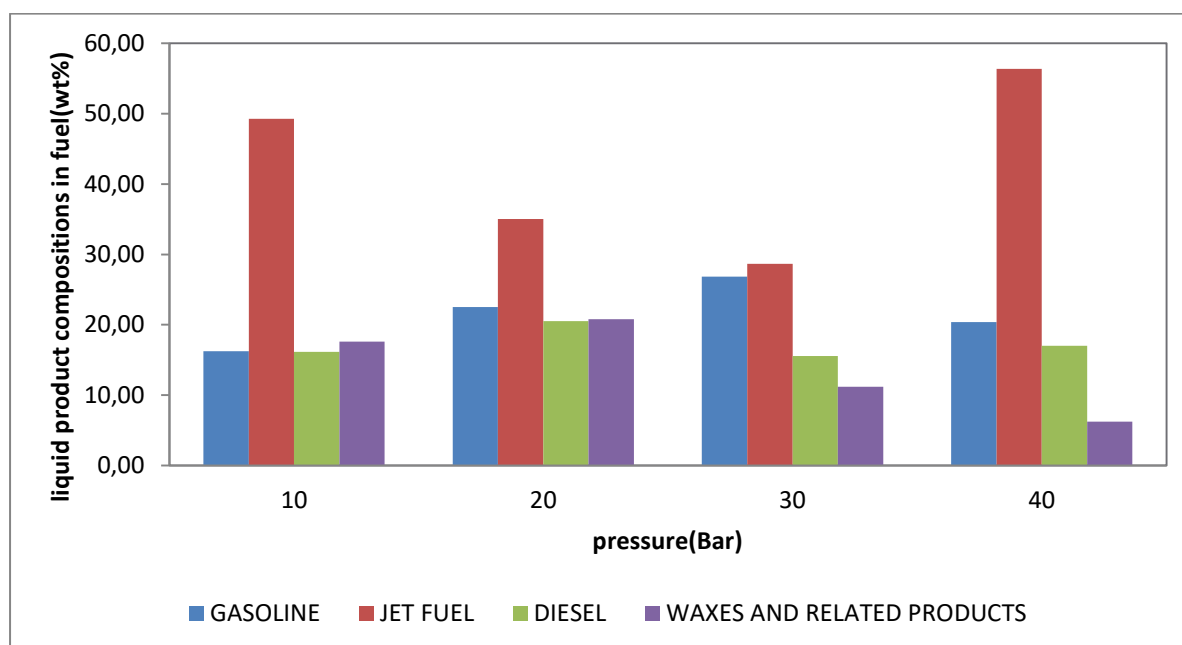


FIGURE:5-7 Yield of liquid composition (wt%) vs pressure(bar) at 400 °C for without catalyst.

The Figure 5-7 above indicates the effect of reaction pressure on the yield of biofuel (gasoline, kerosene, diesel and waxes) liquid compositions during the thermal cracking of coconut oil at 400°C and 10-40 bar without a catalyst. The yield of gasoline and diesel liquid compositions increased with increasing reaction pressure and dropped at 30 bar and 20 bar respectively. It also shows the decrease of the yield of jet- fuel liquid composition from 10-30 bar and indicates the increase from 30-40 bar with the increase of reaction pressure. It was found that thermal cracking at 400°C shows the highest yield of gasoline liquid composition with 28% at 30 bar, the highest yield of jet fuel liquid composition with 57,88% at 40 bar, the highest yield of diesel

liquid composition with 20% at 20bar, and the highest yield of waxes liquid composition with 20% at 20 bar. The highest products that were achieved for figure5-7 are very close to the thermal cracking at 350 °C.

TABLE 5-8 EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 400 °C FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	1H3	78,27	14,81	6,91	0	10	400
HZSM-5	2H3	74,25	13,32	9,67	2,76	20	400
HZSM-5	3H3	68,81	23,28	7,57	0	30	400
HZSM-5	4H3	68,19	22,88	8,97	0	40	400

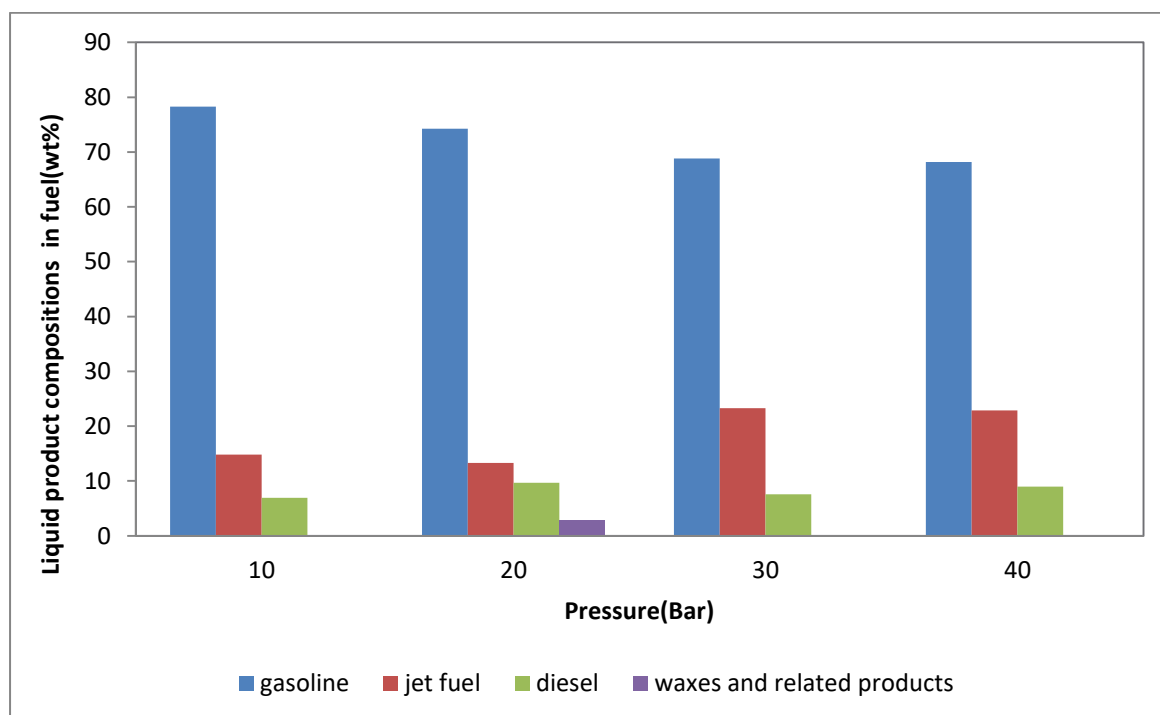


FIGURE:5-8 Yield of liquid composition (wt%) vs pressure(bar) at 400°C for HZSM-5 catalyst.

The figure 5-8 above indicates the effect of pressure on the yield of biofuel (gasoline, jet fuel, diesel, waxes and related products) liquid compositions during the hydrocracking of coconut oil using HZSM-5 at 400°C and 10-40 bar. The yield of gasoline liquid composition decreased with increasing reaction pressure, this trend is contrary from the trends at 300 and 350 degrees where HZSM-5 was used since gasoline liquid composition was increasing at 300 and 350 degrees. The highest yield of gasoline liquid composition was achieved 78% at 10 bar, and it shows that catalytic cracking of these hydrocarbons into lighter hydrocarbons is more favourable at high temperature. The yield of kerosene (jet fuel) liquid composition increased

with increasing reaction pressure which is opposite with the above temperatures again, the highest yield of kerosene liquid composition was achieved 21% and is more favoured at 30 and 40 bar. The yield of diesel liquid composition is slightly affected by the pressure, as it only varies from 6.91% to 8.97%. The yield of waxes liquid composition is only favourable at 20 bar with 2.76%.

TABLE 5-9		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 400 °C FOR Ni/HZSM-5					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	1N3	58,02	28,56	9,25	4,17	10	400
Ni/HZSM-5	2N3	54,98	19,8	24,04	1,14	20	400
Ni/HZSM-5	3N3	16,36	55,47	8,87	18,24	30	400
Ni/HZSM-5	4N3	73,57	12,88	13,69	0	40	400

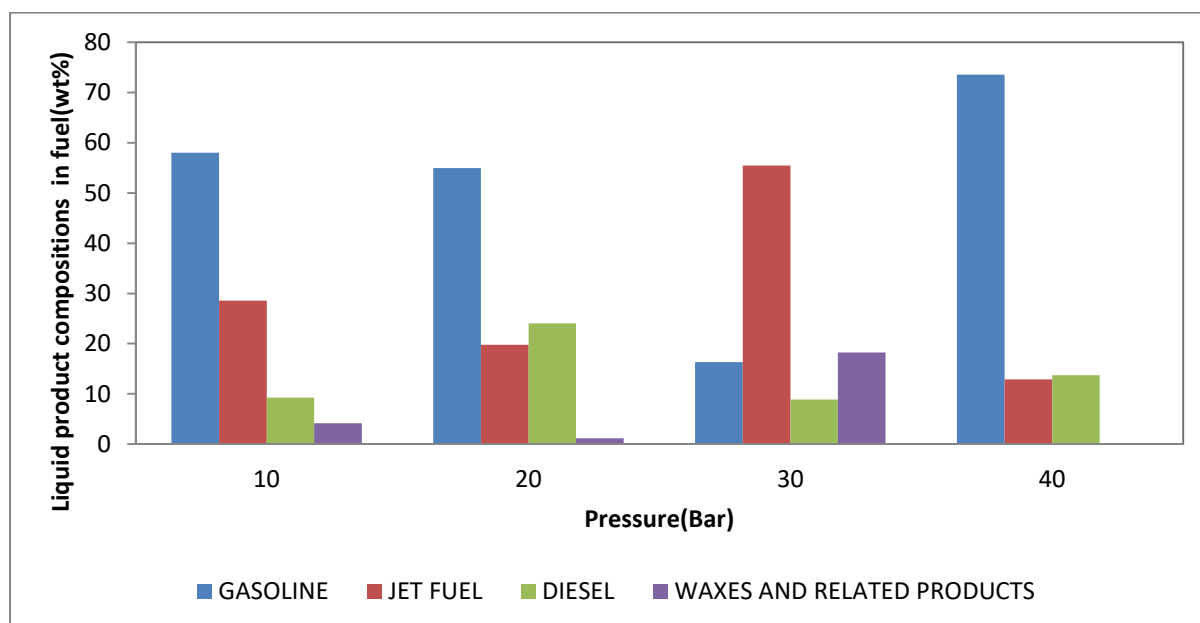


FIGURE:5-9 yield of liquid composition (wt%) vs pressure(bar) at 400 °C for Ni/HZSM-5 catalyst.

In Figure 5-9 above, HZSM-5 is promoted with nickel-metal to Ni/HZSM-5. With the increase of hydrocracking pressure, the yield of gasoline liquid composition experienced the decrease from 10-30 bar and increased from 30-40 bar, this was an indication that as the temperature increases the delay to increase gasoline liquid composition is taking place and its highest yield was achieved 58,02%. The yield of diesel liquid composition was fluctuating and its highest product was 24% at 20 bar, In the interval of 10-40 bar, the yield of jet-fuel liquid composition

is slightly affected by the pressure since it varies from 28,56% to 9,25% this could be due to coke that was formed inside the reactor since it was not regenerated and its highest yield that was achieved was 55,47% at 30 bar. It was observed that the trend is almost the same and as the temperature increases, the highest yield of biofuels (gasoline, jet fuel, diesel and waxes) liquid compositions are also increasing.

COMPOSITIONS VS PRESSURES AT CONSTANT TEMPERATURE 450 °C FOR DIFFERENT CATALYSTS.

TABLE5-10		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 450 °C FOR WITHOUT CATALYST					
Catalyst type	Sample code	Gasoline	Jet fuel	Diese l	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	1W4	49,81	31,08	11,98	7,16	10	450
WITHOUT CAT	2W4	56,66	27,29	13,18	2,82	20	450
WITHOUT CAT	3W4	63,72	24,38	9,22	2,71	30	450
WITHOUT CAT	4W4	65,23	22,38	11,77	0	40	450

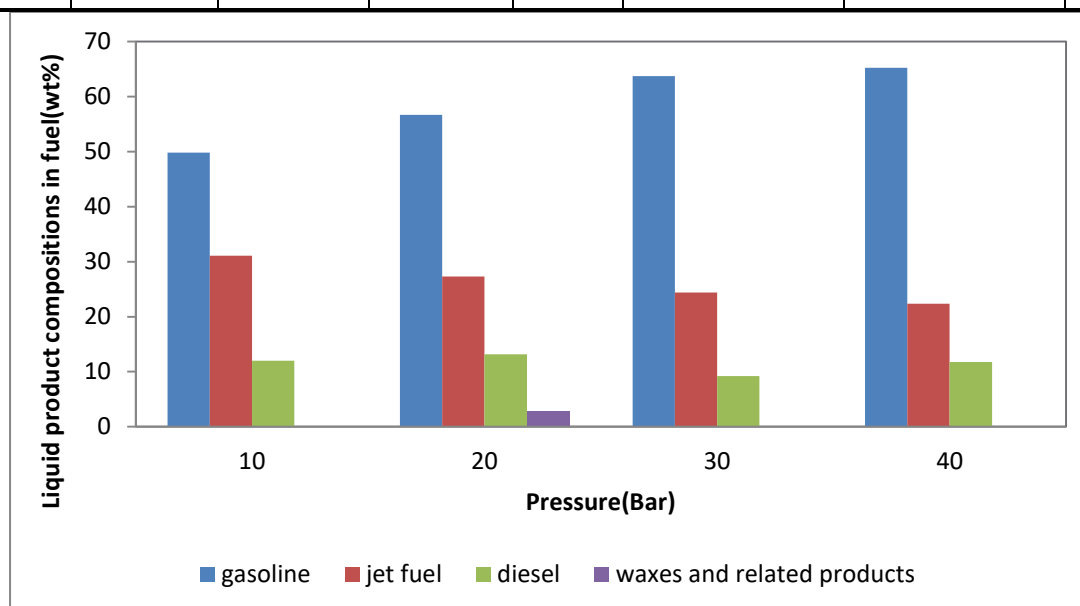


FIGURE:5-10 Yield of liquid composition (wt%) vs pressure(bar) at 450°C for without catalyst.

The figure 5-10 above indicates the effect of reaction pressure on the yield of biofuel (gasoline, kerosene, diesel and waxes) liquid compositions during the thermal cracking of coconut oil at 450°C and 10-40 bar without a catalyst. The yield of gasoline liquid composition increased with increasing reaction pressure. It also shows the decrease of yield of jet-fuel liquid composition with the increase of reaction pressure. It has been observed that the trend at 450 degrees is almost the same with thermal cracking figures at the other temperatures. It was also found that thermal cracking at 450 degrees shows the highest yield of gasoline liquid composition of 65,23% at 40 bar, the highest yield of jet fuel liquid composition of 31,08% at 10 bar. The yield of diesel liquid compositions varied from 11,98% to 11,77% as the reaction pressure increases,

its highest yield was 11,98% at 10 bar. The highest yield of waxes liquid composition that was produced was 7,16% at 10 bar.

TABLE5-11 EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 450 °C FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	1H4	71,6	15,75	11,42	1,21	10	450
HZSM-5	2H4	72,2	16,22	10,55	1,03	20	450
HZSM-5	3H4	83,1	16,9	0	0	30	450
HZSM-5	4H4	83,03	17,56	0,46	0	40	450

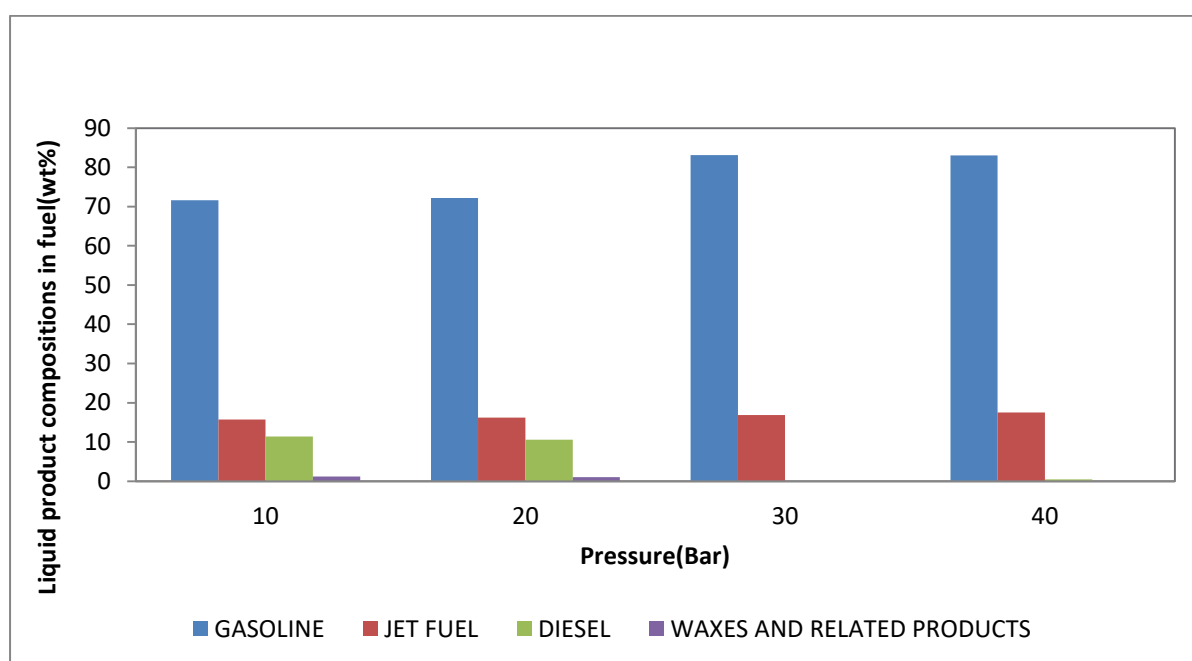


FIGURE:5-11 yield of liquid composition (wt%) vs pressure(bar) at 450°C for HZSM-5 catalyst.

The distribution of the yields of the liquid compositions for the different transportation fuels are seen in Figure 5-11 which shows the expected trend for an increase in pressure (10-40 bar), since the yield of the gasoline and kerosene liquid compositions were increasing. Though, diesel and waxes range compositions were decreasing with an increase in pressure range. The highest yield of gasoline and jet fuel range compositions were achieved at 83.03% at 40 bar and 17.56% at 40bar respectively. The highest yield of diesel liquid composition was achieved 11,42 % at 10 bar.

TABLE5-12		EFFECT OF PRESSURE ON PRODUCT DISTRIBUTION AND AT 450 °C FOR Ni/HZSM-5					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	1N4	62,51	18,03	11,36	8,23	10	450
Ni/HZSM-5	2N4	63,02	19,86	10,02	7,1	20	450
Ni/HZSM-5	3N4	64,42	20,09	14,33	1,16	30	450
Ni/HZSM-5	4N4	70,65	24,05	4,05	0	40	450

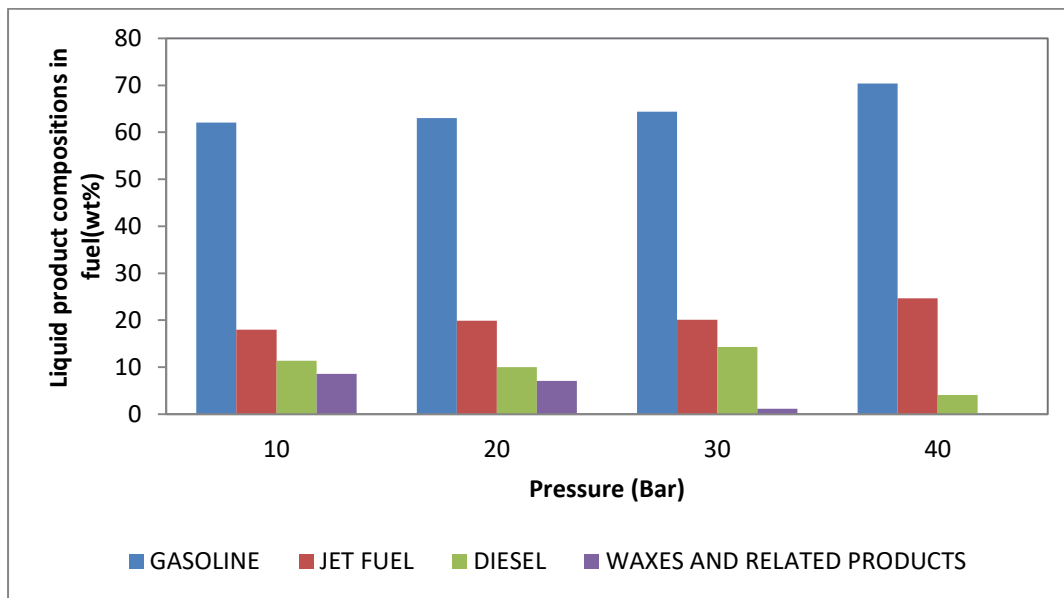


FIGURE:5-12 yield of liquid composition (wt%) vs pressure(bar) at 450 °C for Ni/HZSM-5 catalyst.

In the Figure 5-12 above, where HZSM-5 is promoted with nickel-metal to Ni/HZSM-5 in order to enhance hydrocracking reaction. With the increase of hydrocracking pressure, the yield of gasoline and jet fuel liquid compositions experienced the increase as well. This was an indication that as the temperature increases the yield of gasoline and jet fuel liquid compositions are highly favoured. The decrease of diesel and waxes liquid compositions indicate that catalytic cracking of these compounds into lighter hydrocarbons is more favourable under high reaction pressure. It has been observed that diesel range composition was fluctuating and its highest yield achieved was 11,36% at 10 bar. In the interval of 10-40 bar, the highest yield of jet-fuel and gasoline liquid compositions were achieved 24,05% and 70,65% respectively, and both yields were obtained at a maximum pressure of 40 bar and the highest yield of waxes liquid composition that was achieved 8,23% at 10 bar.

5.1.3 Observation at the effect of reaction pressure

Hydrocracking coconut oil under Ni/HZSM-5 catalysts was favorable and produced the highest yield of jet fuel liquid compositions 78.73% at the operation conditions of constant temperature 300°C, and pressure of 10 bar, this was due to less coke that was formed within a reactor and less energy of 300°C was used to produce highest jet fuel in figure:5-3. Temperature and the reaction pressure had a direct effect on yields of gasoline and jet fuel liquid compositions. The increased reaction pressure where HZSM-5 and Ni/HZSM-5 were used had a slight effect on the increase of yield of liquid biofuel. The best yield and performance of gasoline liquid composition 83.03% was obtained from the reaction pressure figure 5-11 at the temperature of 450 °C in 40bar where HZSM-5 catalysts was used. The highest yield of diesel liquid composition 24.04% occurred at constant temperature of 400°C at 20 bar where Ni/HZSM-5 was used in figure:5-9. It was found that hydrocracking coconut oil has the potential to produce high-quality biofuel with a high yield if there was catalyst activity and high hydrogen pressure.

5.2 Effect of reaction temperature.

The temperature has been identified as a key factor for catalyst effectiveness and catalyst life (Scherzer and Gruia, 1996). Increasing temperature within the reactor produced the increase of catalyst activity. This study on product yields and quality were achieved on hydrocracking of coconut oil at four different reactor temperatures, i.e. 300, 350, 400, 450°C. The operating conditions were hydrocracking conditions with pressure at the range of 10-40 bar, and different catalysts (HZSM-5, Ni/HZSM-5). The following figures provide a graphical representation of calculated data based on Tables below.

5.2.1 Compositions vs temperature at constant pressure 10 bar for different catalysts.

TABLE5-13		EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 10 BAR FOR Ni/HZSM-5					
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	1N1	55,05	25,36	11,36	8,23	10	300
Ni/HZSM-5	1N2	58,02	28,56	9,25	4,17	10	350
Ni/HZSM-5	1N3	74,07	18,85	7,07	0	10	400
Ni/HZSM-5	1N4	78,56	11,89	4,12	5,43	10	450

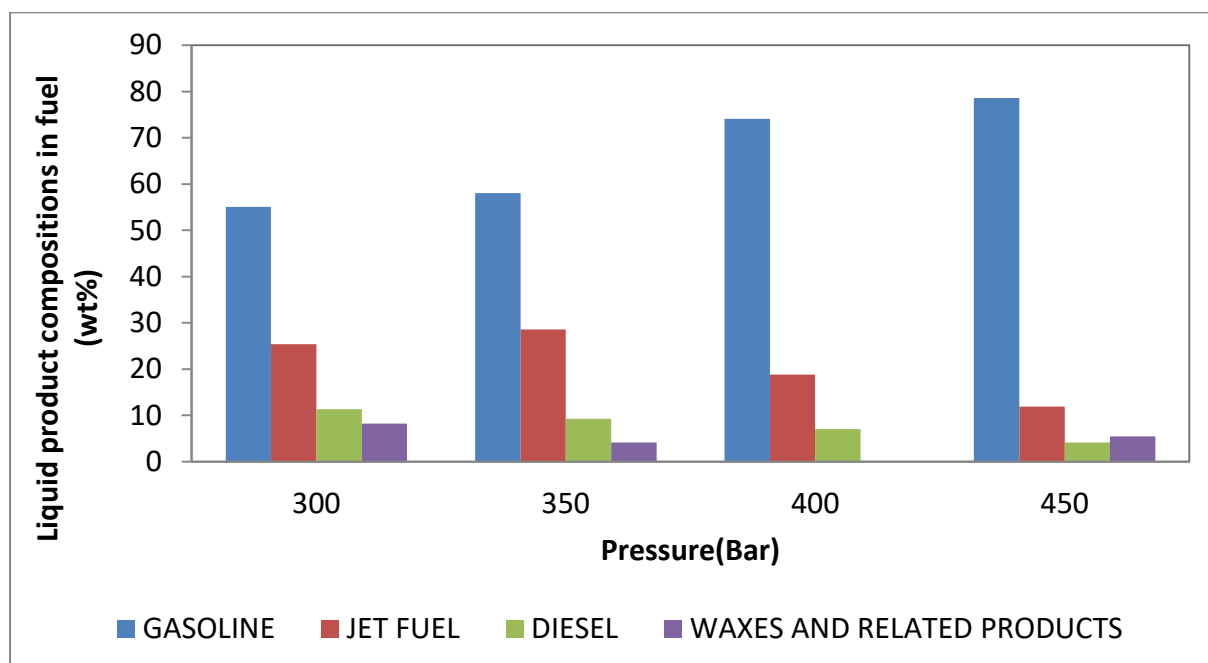


FIGURE:5-13 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 10 bar for NI/HZSM-5 catalyst.

Based on figure 5-13 above, where HZSM-5 is promoted to Ni/HZSM-5. An increase of hydrocracking temperature occurred, as a result the product of gasoline liquid composition increased while products of diesel, jet fuel and waxes liquid compositions were decreasing. This could be due to low pressure and coke that was formed within the reactor. The highest yield of gasoline liquid composition that was achieved is 78,56% at 300°C. The highest yield of jet fuel, diesel and waxes liquid compositions that were achieved are 25.36% at 350, 11.36% at 300°C and 8.23% at 300°C respectively.

TABLE5-14 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 10 BAR FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	1H1	71,6	15,75	11,42	1,21	10	300
HZSM-5	1H2	78,27	14,81	6,91	0	10	350
HZSM-5	1H3	12,36	50,33	20,74	16,58	10	400
HZSM-5	1H4	1,60	75,67	15,01	0	10	450

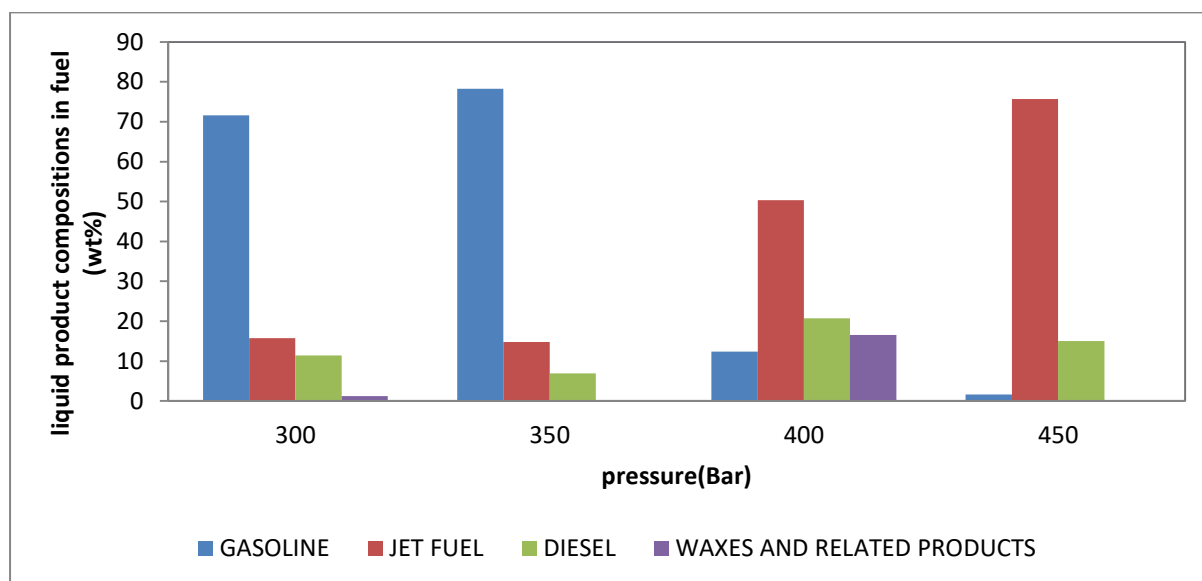


FIGURE:5-14 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 10bar for HZSM-5 catalyst.

Based on the data in Figure 5-14, the increase of hydrocracking temperature occurred. As the result products of jet fuel range composition show the very positive performance by increasing while products of diesel, gasoline, and waxes liquid compositions were fluctuating. The highest yield of jet fuel range liquid composition was produced 71,6 % at 450 degree. The highest yield of diesel and gasoline liquid compositions attained were 20,74% at 400°C , and 78.27% at 350°C respectively. It was found that increasing temperature causes more intensive cracking consequently not only heavier molecules but also some diesel molecules are further cracked into lighter molecules (Bezergianni and Kalogianni, 2009).

TABLE5-15 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 10 BAR FOR WITHOUT CATALYST							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	1W1	31,08	31,08	11,98	7,16	10	300
WITHOUT CAT	1W2	49,26	49,26	16,13	17,59	10	350
WITHOUT CAT	1W3	54,88	54,88	15,46	22,21	10	400
WITHOUT CAT	1W4	51,87	51,87	16,96	24,98	10	450

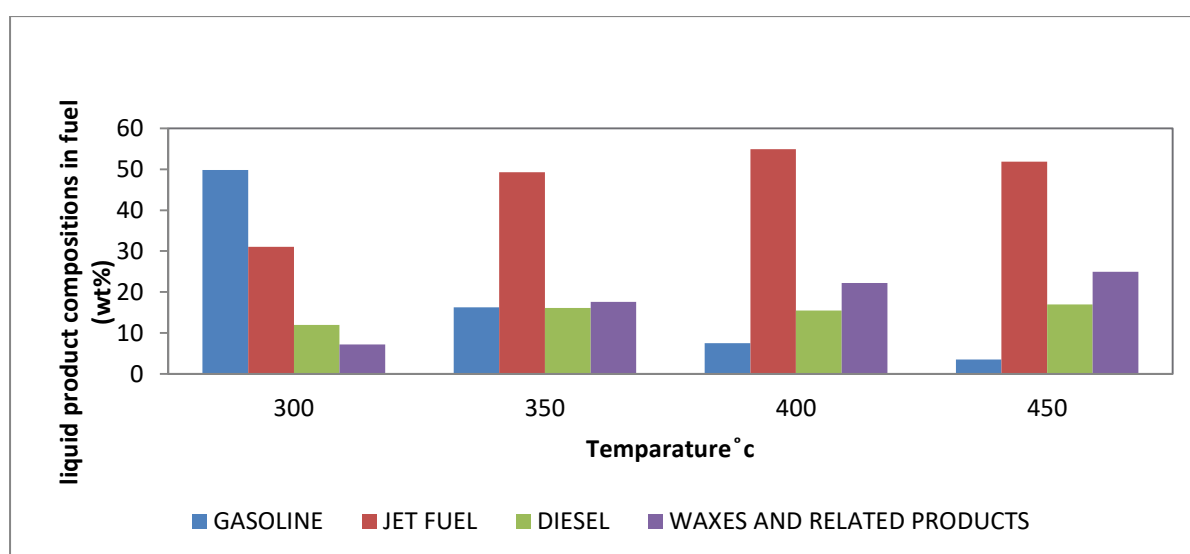


FIGURE:5-15 yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 10bar for without catalyst.

Based on the data in Figure 5-15 where thermal cracking occurred. It has been observed that its trend or performance is in contrast to the Figures above at 10bar where HZSM-5 and Ni/HZSM-5 catalysts were used. As the thermal cracking temperature increases, the yield of diesel and waxes liquid compositions were also increased, their highest yield were achieved are 16.96% at 450°C and 24,98% at 450 °C respectively. The yield of jet fuel liquid composition was varied from 31,08% to 51,87% and the yield of gasoline liquid composition was decreasing and its highest yield was 49,81% at 300 °C. All these performances could be due to the finding which says the cost of thermal cracking is relatively higher, however, the biofuel yield is relatively low (Li *et al.*, 2009; Zhao *et al.*, 2015b).

5.2.2 Composition vs temperatures at constant pressure 20 bar for difference catalyst.

EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 20 BAR FOR Ni/HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	2N1	78,06	19,86	2,07	0	20	300
Ni/HZSM-5	2N2	54,98	19,80	24,04	1,14	20	350
Ni/HZSM-5	2N3	65,16	29,99	4,86	0	20	400
Ni/HZSM-5	2N4	21,47	54,09	11,00	8,61	20	450

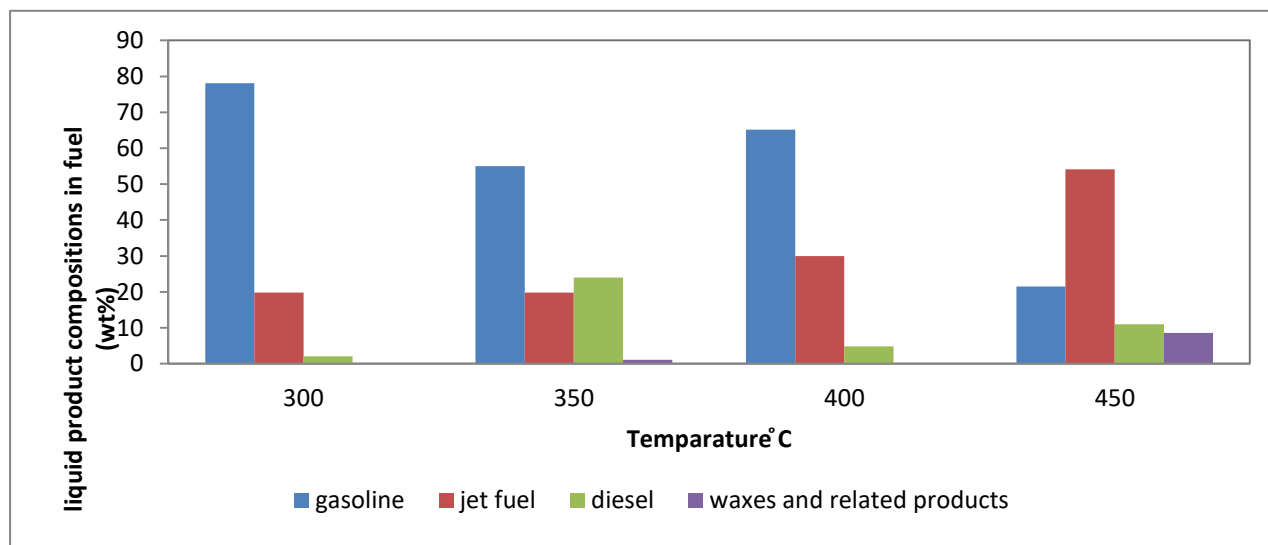


FIGURE:5-16 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 20bar for Ni/HZSM-5 catalyst.

Based on data in Figure 5-16, where HZSM-5 is promoted to Ni/HZSM-5. The increase of hydrocracking temperature, the yield of jet fuel liquid composition shows very positive performance since it is increasing to the highest yield of 54,09% at 450 °C. The yield of gasoline and diesel liquid compositions were fluctuating which could be due to the coke which was formed within the reactor and low hydrogen pressure was applied, their highest yield were 78,06% at 300°C and 24,04% at 350°C respectively.

TABLE5-17 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 20 BAR FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	2H1	27,80	37,22	10,55	23,19	20	300
HZSM-5	2H2	27,02	45,52	15,25	12,21	20	350
HZSM-5	2H3	26,65	47,59	17,83	7,18	20	400
HZSM-5	2H4	9,37	65,47	25,15	0,01	20	450

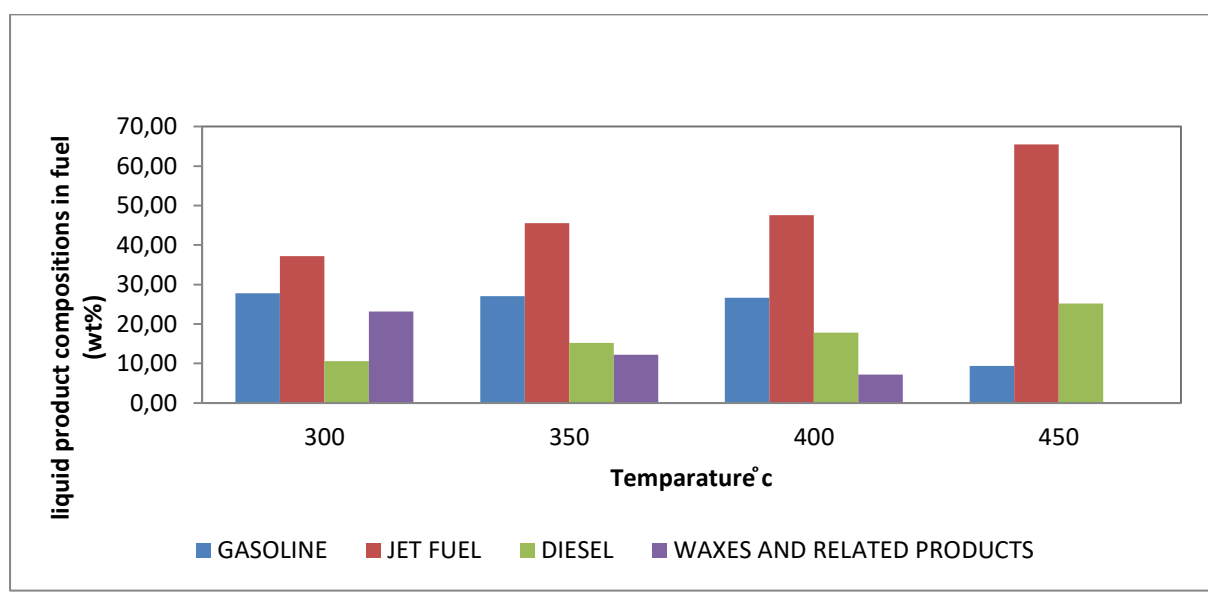


FIGURE:5-17 yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 20bar for HZSM-5 catalyst.

Based on data in Figure 5-17, where HZSM-5 catalyst has been used. The increase of hydrocracking temperature indicates a very positive performance on the yield of jet fuel and diesel liquid compositions since they were also increasing, though the yield of gasoline and waxes liquid compositions were decreasing. The highest yield of jet fuel and diesel liquid compositions that were achieved are 65,47% at 450 °C, and 25,15% at 450 °C respectively. And the highest yield of gasoline and waxes liquid compositions were achieved are 27,80 at 300 °C, and 65,47 % at 300 °C respectively. It was found that at a higher temperature, light hydrocarbon could be cracked more because thermal cracking was faster than catalytic cracking in this set of constant pressure at 20 bar.

TABLE5-18 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 20 BAR FOR WITHOUT CATALYST							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	2W1	56,66	27,29	13,18	2,82	20	300
WITHOUT CAT	2W2	22,53	35,02	20,54	20,81	20	350
WITHOUT CAT	2W3	10,48	49,06	16,45	24,01	20	400
WITHOUT CAT	2W4	0	78,72	17,50	3,78	20	450

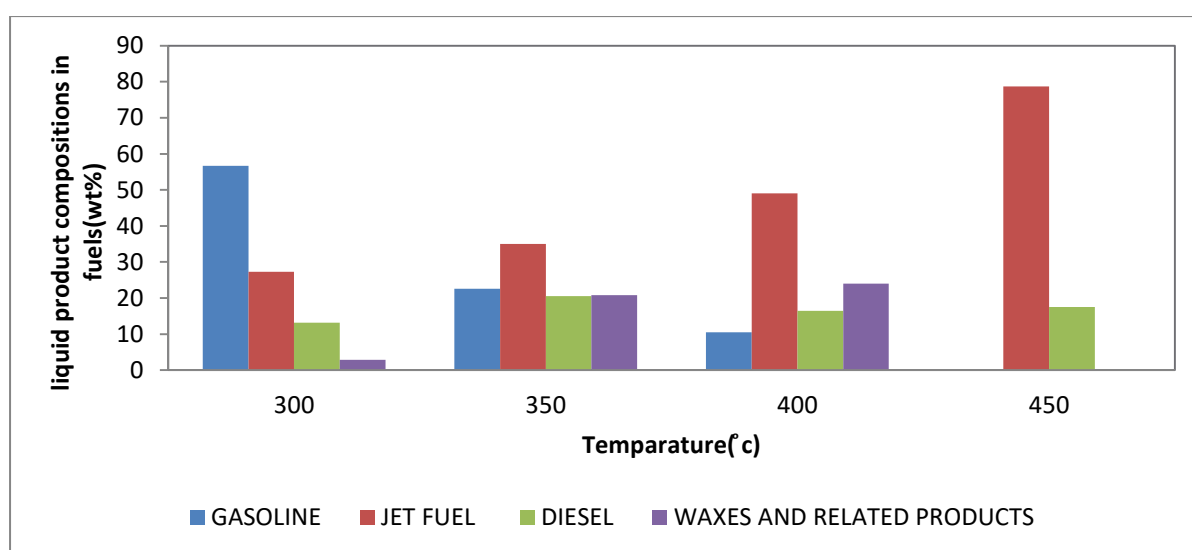


FIGURE:5-18 yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 20bar for WITHOUT catalyst.

Based on data in Figure5-18, where thermal cracking has been utilised at a constant pressure of 20 bar. the yield of jet fuel liquid composition indicates a positive performance since it was increasing as the thermal cracking reaction temperature increases and its highest yield was 78,72% at 450 °C. The yield of gasoline liquid composition was decreasing whereas diesel and waxes liquid compositions fluctuated with the increase of reaction temperature, all trends could be due to absence of catalyst in the reactor. The highest yield of gasoline liquid composition was achieved is 56,66% at 300 °C.

5.2.3 Composition vs temperatures at constant pressure 30 bar for difference catalyst.

TABLE5-19 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 30 BAR FOR Ni/HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	3N1	64,42	20,09	14,33	1,16	30	300
Ni/HZSM-5	3N2	16,36	55,47	8,87	18,24	30	350
Ni/HZSM-5	3N3	42,56	47,33	10,12	0	30	400
Ni/HZSM-5	3N4	60,70	18,49	20,86	0	30	450

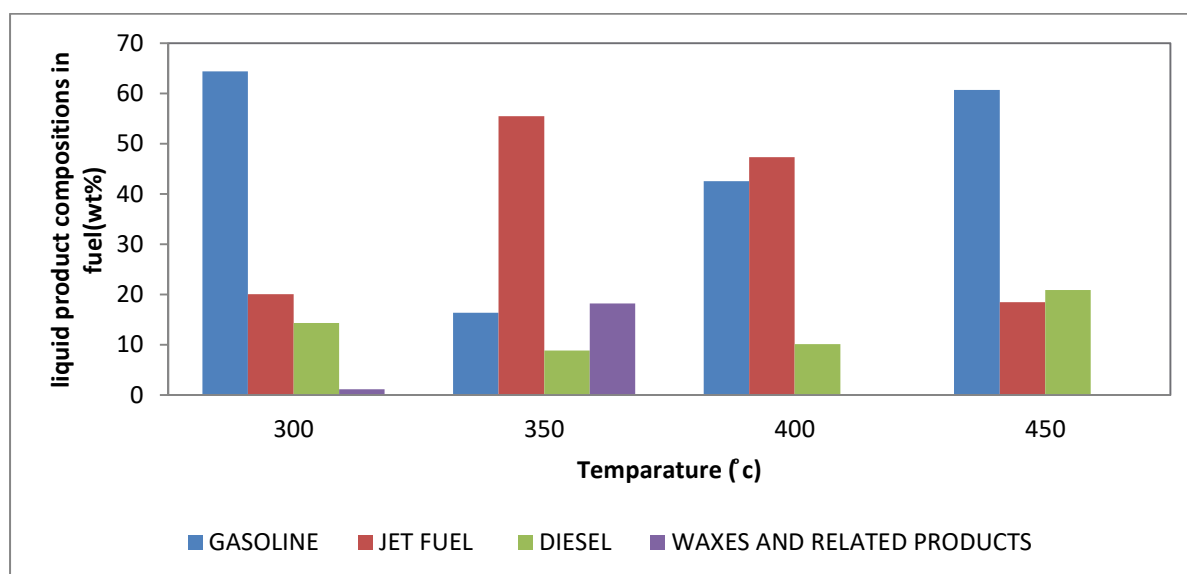


FIGURE:5-19 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 30bar for Ni/HZSM-5 catalyst.

Based on data in Figure 5-19, where HZSM-5 is promoted to Ni/HZSM-5. With the increase of hydrocracking temperature, all biofuels (gasoline, jet fuel, diesel, and waxes) liquid compositions presented on the graph were fluctuating but at the high range of products which could be due to coke that was formed within the reactor, this indicates that as pressure increases, range of yield fraction are also increasing even if they are varied. The yield of gasoline liquid composition shows better performance even though it delayed to increase from 350°C to 450°C. The highest yield of gasoline liquid composition that was achieved 64,42% at 300°C. The highest yield of jet fuel, diesel and waxes liquid compositions were 55.47% at 350°C, 20.86% at 450°C, and 18.24% at 350°C respectively.

TABLE5-20 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 30 BAR FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	3H1	82,10	17,88	0	0	30	300
HZSM-5	3H2	68,81	23,28	7,57	0	30	350
HZSM-5	3H3	14,93	50,21	14,72	20,14	30	400
HZSM-5	3H4	14,65	52,44	20,85	12,06	30	450

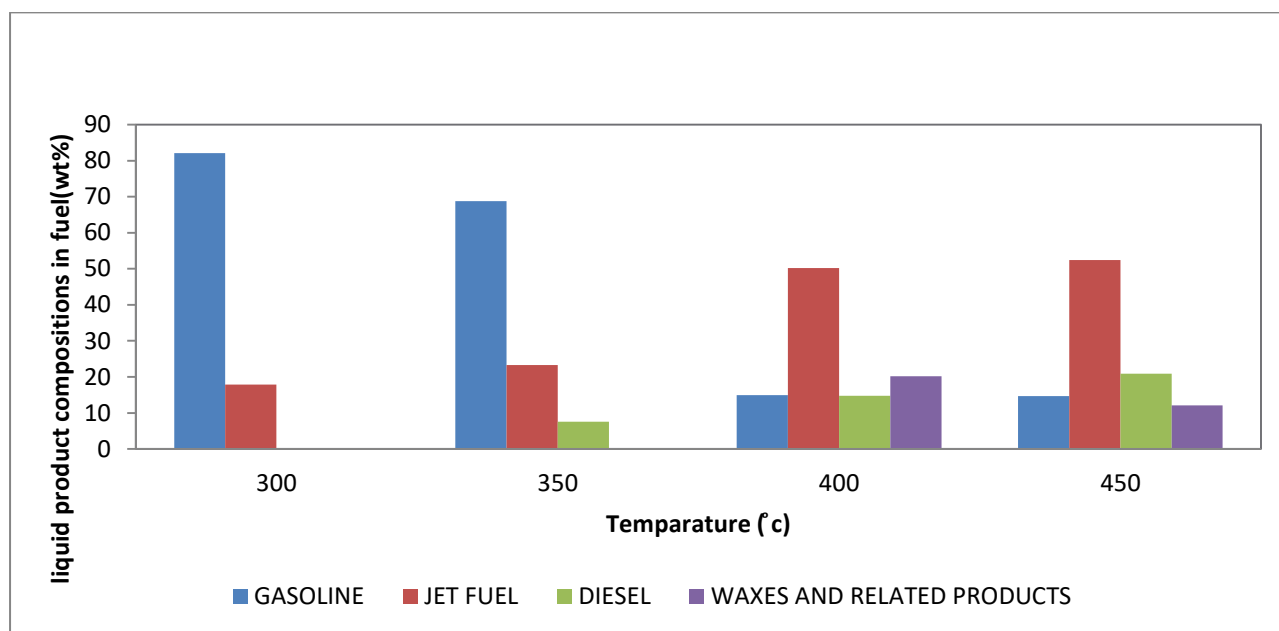


FIGURE:5-20 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 30bar for HZSM-5 catalyst.

Based on data in Figure5-20, where HZSM-5 catalyst has been used. The effect of increasing hydrocracking temperature indicates a very positive performance on the yield of jet fuel and diesel liquid compositions since they increased as the reaction temperature increases, highest yield of jet fuel and diesel liquid compositions were achieved are 52.44% at 450 °C , 20.85% at 450 °C respectively. The yield of gasoline liquid composition decreased as the hydrocracking temperature increased, its highest yield that was achieved 82.1% at 300 °C, and highest yield of waxes 20.14% at 400 °C. It was found that as the pressure increases hydrocracking reaction is favoured.

TABLE5-21 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 30 BAR FOR WITHOUT CATALYST							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	3W1	63,72	24,38	9,22	2,71	30	300
WITHOUT CAT	3W2	26,84	28,67	15,54	11,2	30	350
WITHOUT CAT	3W3	15,44	50,15	20,13	14,28	30	400
WITHOUT CAT	3W4	1,95	64,23	17,35	16,46	30	450

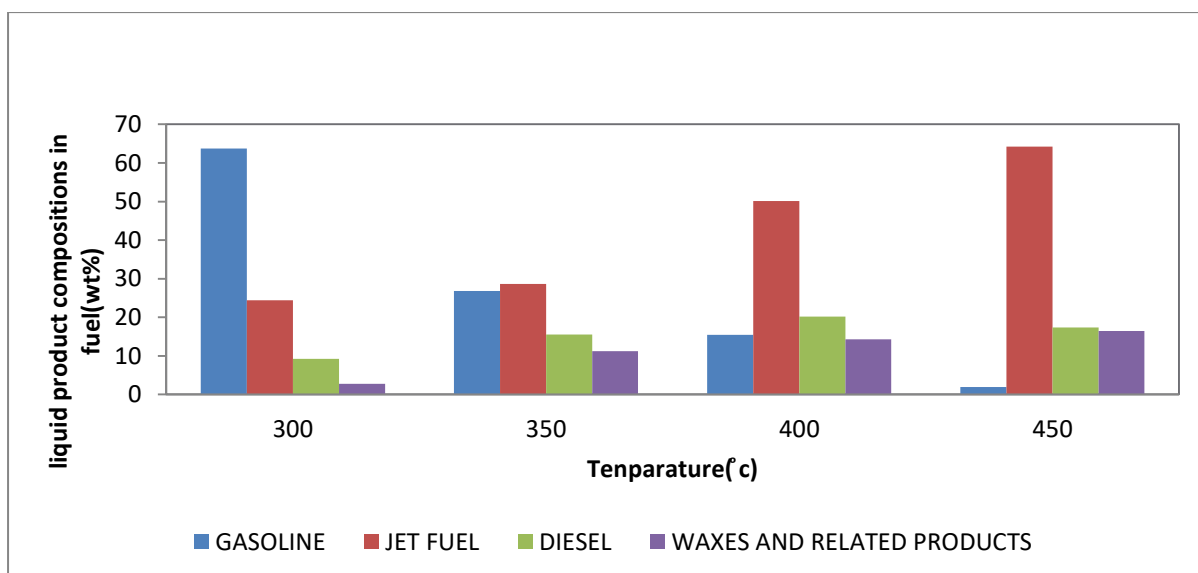


FIGURE: 5-21 yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 30bar for without catalyst.

Based on data in Figure 5-21, where thermal cracking was used at a constant pressure of 30 bar. The yield of jet fuel and waxes liquid compositions indicate a very positive performance since they were increasing as the thermal cracking reaction temperature increases, their highest yield were 64.23% at 450 °C, and 16.46% at 450 °C respectively. The yield of gasoline liquid composition was decreasing as the reaction temperature increases, its highest yield that was achieved 63.72% at 300 °C and diesel liquid composition varied from 9.22% to 17.35%. It was found that at higher temperature and pressure, light hydrocarbon could be cracked more because thermal cracking was faster than catalytic cracking.

5.2.4 Composition vs temperatures at constant pressure 40 bar for difference catalyst.

TABLE5-22 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 40 BAR FOR Ni/HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
Ni/HZSM-5	4N1	82,25	13,69	4,05	0	40	300
Ni/HZSM-5	4N2	73,57	12,88	13,69	0	40	350
Ni/HZSM-5	4N3	67,04	15,02	13,01	4,66	40	400
Ni/HZSM-5	4N4	69,01	15,05	15,94	0	40	450

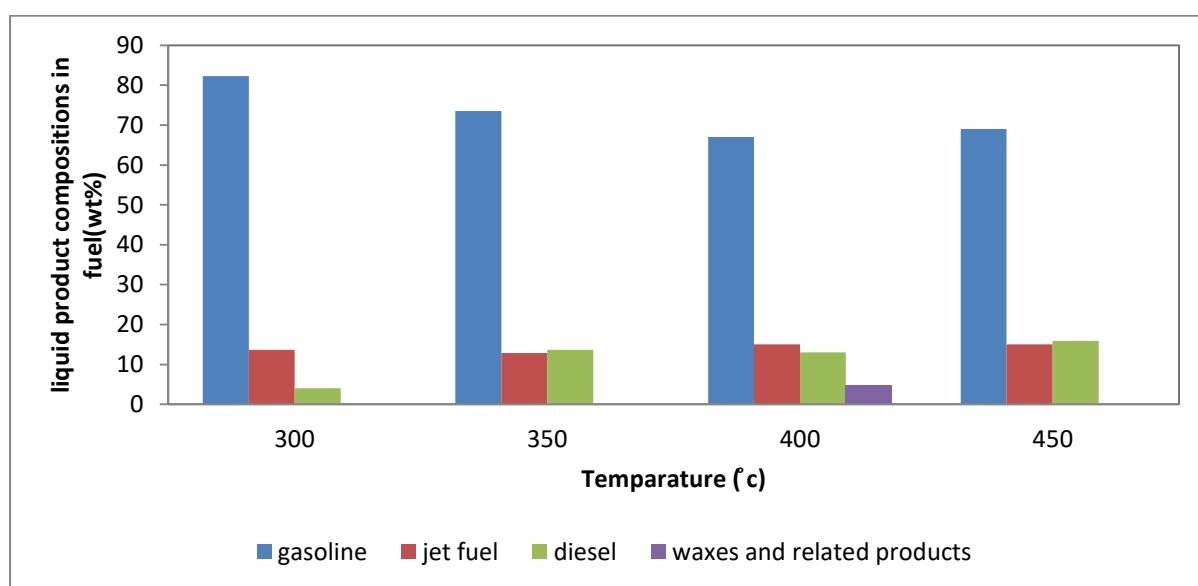


FIGURE:5-22 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 40bar for Ni/HZSM-5 catalyst.

Based on Figure 5-22 above, where HZSM-5 is promoted to Ni/HZSM-5. The increase of hydrocracking temperature, produced the best performance of jet fuel and diesel liquid compositions since they were increasing while products of gasoline liquid composition decreased. It was found that as the pressure and temperature increases hydrocracking was highly favoured and the amount of waxy was minimised. The highest yield of jet fuel and diesel liquid compositions that were achieved are 15,05% at 450 °C and 15,94% at 450 °C respectively.

TABLE5-23 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 40 BAR FOR HZSM-5							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
HZSM-5	4H1	69,69	28,43	0,64	1,23	40	300
HZSM-5	4H2	68,19	22,88	8,97	0	40	350
HZSM-5	4H3	26,74	45,28	16,38	11,6	40	400
HZSM-5	4H4	47,71	52,30	0	0	40	450

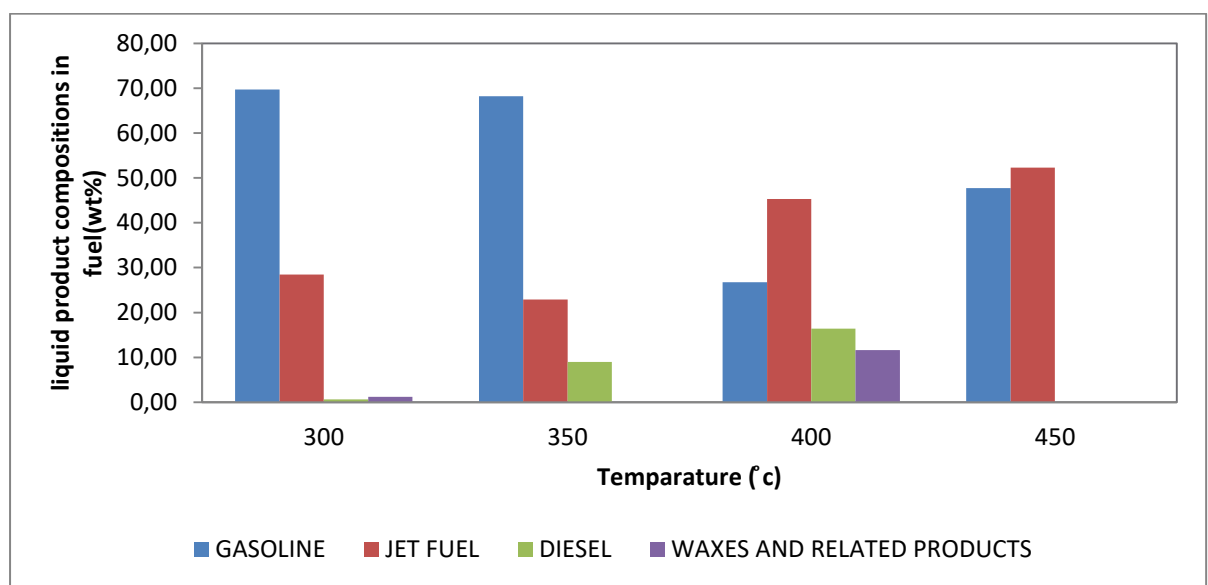


FIGURE:5-23 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 40bar for HZSM-5 catalyst.

Based on data in Figure 5-23, where HZSM-5 catalyst has been used. The effect of increasing hydrocracking temperature indicates a very positive performance on the yield of jet fuel liquid composition since it was increasing as well. However, it started to increase from 350 °C to a maximum temperature of 450 °C. The highest yield of jet fuel liquid composition that was achieved is 52.30% at 450 °C. The yield of gasoline liquid composition was varied from 69.69% to 47.71 %. The yield of diesel and waxes liquid compositions were affected since they were fluctuating as the hydrocracking temperature increases.

TABLE5-24 EFFECT OF TEMPERATURE ON PRODUCT DISTRIBUTION AND AT 40 BAR FOR WITHOUT CATALYST							
Catalyst type	Sample code	Gasoline	Jet fuel	Diesel	Waxes and related products	Pressure(Bar)	Temperature °C
WITHOUT CAT	4W1	65,23	22,38	12,38	0	40	300
WITHOUT CAT	4W2	20,39	56,37	17,02	6,24	40	350
WITHOUT CAT	4W3	56,07	7,06	23,61	12,09	40	400
WITHOUT CAT	4W4	54,84	2,09	18,18	23,62	40	450

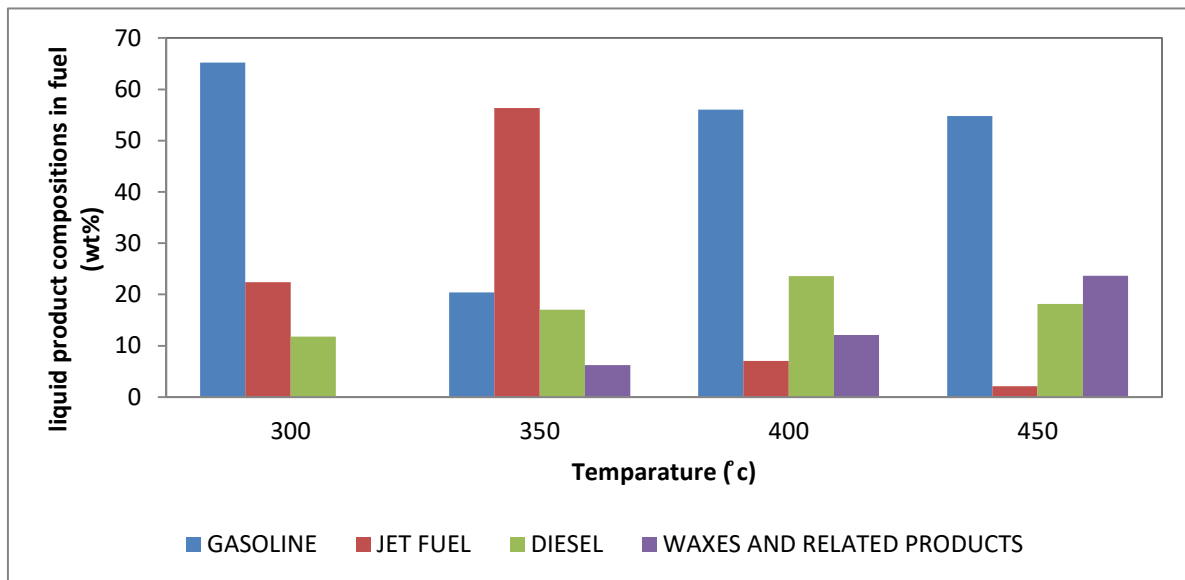


FIGURE:5-24 Yield of liquid composition (wt%) vs temperature(°C) at constant pressure of 40bar for WITHOUT catalyst.

Based on data in Figure5-24, where thermal cracking was used at a constant pressure of 40 bar. The yield of jet fuel liquid composition started to increase from 300 °C with 22,38 % to 350 °C with 56,37% and decreased to 450 °C with 2,09% . Gasoline liquid composition had a highest yield at 300 °C with 65,23% and fluctuated along the graph . The fluctuation of Gasoline , jet fuel , diesel and waxes liquid compositions could be due to the coke that was formed within the reactor.

5.2.5 Observation at the effect of reaction temperature

An increase in temperature resulted in a slight increase in the yield of the liquid composition. It has been found that hydrocracking and the thermal cracking of coconuts oil can produce high-quality biofuel with a high yield. It requires high catalyst activity and high hydrogen pressure and temperature. The best and highest yield of gasoline liquid composition 82.25% was produced at constant pressure of 40 bar in 300°C where promoted catalyst(Ni/HZSM-5) was used, this occurred in figure: 5-22 . The best and highest yield of jet fuel liquid composition 75.67% was produced at constant pressure of 10 bar at maximum temperature of 450° C, this was due to less coke that was formed within a reactor and occurred in figure:5-14 where HZSM-5 was used. The best and highest yield of diesel liquid composition 25.15% was produced at 20 bar in 450°C, this occurred in figure:5-17.

In a paper by (Huber *et al.*, 2007) a consecutive reaction mechanism was proposed for the conversion of triglycerides to alkanes. The coconut oil is first hydrogenated to produce diglycerides, monoglycerides and waxes. These species subsequently go through decarboxylation, decarbonylation and hydrogenation to yield diesel liquid composition.

Based on the results of this study attained above, it is clear that the first hydrogenation to wax products can be achieved over a low activity catalyst at relatively low reaction temperatures. Though, the higher activation energies demand a higher reaction temperature and a more active catalyst. Metal catalyst produces a surface phase that is many times more active and selective than the original oxide state.

CHAPTER 6

Overall conclusion

The performance of Ni/HZSM-5, HZSM-5, and without catalyst were investigated for the hydroprocessing of coconut oil to yield biofuel (bio-jet fuel and high-value low molecule hydrocarbons) range in a laboratory-scale, using a packed-bed tubular reactor at the operating parameters with a temperature range of 300-450 °C, operating pressure of 10-40 bar and a liquid oil volumetric flow rate of 0.1 ml/min. Moreover, wire as well as glass wool were found to be a more efficient form of packing material compared to only glass wool inside the reactor. It was found that an increase in the reaction temperature resulted in an increase in oil conversion, which indicates that hydrocracking and thermal reaction were favoured at higher temperatures. The reduced wax yield is additional proof that hydrotreating reactions are favoured at higher temperatures as well.

Hydrocracking of coconut oil with HZSM-5 and Ni/HZSM-5 catalysts produced the highest yield of gasoline and kerosene at the condition of temperature at 450°C with the pressure of 40 bar. The temperature had a direct effect on yields of gasoline and kerosene. An increase in oil conversion and liquid compositions with an increase in reaction temperature for all tested catalysts indicate that hydroprocessing (thermal and hydrocracking) reactions are favoured at higher temperatures and high pressures. Moreover, impregnating the catalysts was found to greatly increase the catalyst activity.

The best yield and performance of gasoline liquid composition 83.03% was obtained from the reaction pressure figure 5-11 at constant temperature of 450°C in 40bar where HZSM-5 catalysts was used, the yield of gasoline liquid composition 82.25% was also produced at constant pressure of 40 bar in 300°C where promoted catalyst(Ni/HZSM-5) was used, this occurred in figure: 5-22.

Hydrocracking coconut oil under Ni/HZSM-5 catalysts produced the best and highest yield of jet fuel liquid compositions 78.73% at constant temperature 300°C, and pressure of 10 bar, this was due to less coke that was formed within a reactor and less temperature of 300°C. Best yield of jet fuel liquid composition 75.67% was also produced at constant pressure of 10 bar at maximum temperature of 450°C, this was also due to less coke that was formed within a reactor where HZSM-5 was used because of less pressure applied, this occurred in figure: 5-14.

For the highest yield of diesel liquid composition 24.04%, constant temperature at 400°C of 20 bar where Ni/HZSM-5 was used in figure:5-9 and the highest yield of diesel liquid composition 25.15% was also produced at constant pressure of 20 bar in 450°C where HZSM-5 was used, this occurred in figure:5-17.

Metal Ni which was impregnated to ZSM-5 was prepared and characterized through XRD, SEM and BET analysis. Through XRD, it was confirmed that catalyst synthesis was successful. The transformation process of zeolite from ammonium form to hydrogen form by the calcination process did not affect the crystallinity and crystal system of the zeolite. And again it was found that metal impregnation on HZSM-5 did affect crystallinity and crystal system of the zeolite. It was found that crystallinity of impregnated with Ni metals decreased compared to the crystallinity of ZSM-5 which is the parent catalyst. Metal loading had an impact on the size of the catalyst systems by decreasing the particle size of the crystalline as evaluated at 2theta between 23° to 25°.

Recommendation

Raw materials of coconut oil and Hydrogen gas have shown positive results in production of hydrocarbons through metals supported Ni/HZSM-5 and HZSM-5, hydrocracking of coconut oil with HZSM-5 and Ni/HZSM-5 catalysts produced the highest yield of gasoline and kerosene at the condition of temperature at 450°C with the pressure of 40 bar . It is recommend that other metal support and other oils be investigated as well.

According to the performance of the above set of figures, in order to produce more and the best yield of gasoline, it is recommended to use the condition of temperature at 450°C with the pressure of 40 bar where HZSM-5 catalyst was used in figure: 5-11. For the best and highest yield of jet fuel liquid compositions 78.73%, it is recommended to use constant temperature of 300°C, and pressure of 10 bar.

For the best yield of diesel, it is recommended to use constant pressure of 20 bar in 450°C where HZSM-5 was used, this occurred in figure:5-17.

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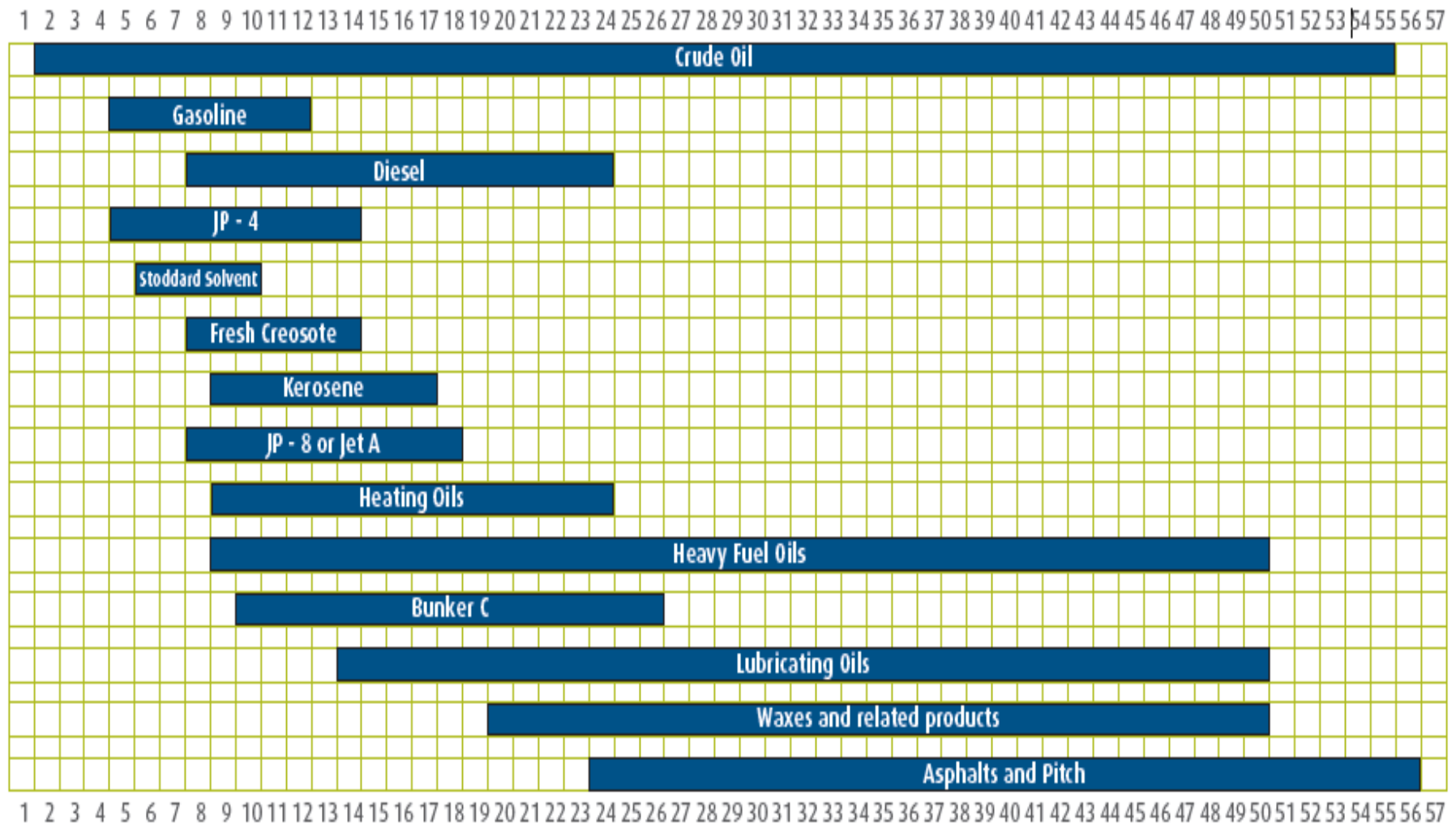
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Appendix

Petroleum Fractions by Carbon Range

Number of Carbons



	Sample Information											
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Analyzed	: 2018-06-09 04:17:54 AM											
Sample Type	: Unknown											
Level #	: 1											
Sample Name	: 4N4 40bah NI/HZSM-5 AT 450 DEGREESE											
Sample ID	: 4N4											
IS Amount	: [1]=1											
Sample Amount	: 1											
Dilution Factor	: 1											
Vial #	: 15											
Injection Volume	: 0.10											
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	TIC											
	20 729 197											
	10,0 20,0 30,0											
	min											
	Peak Report TIC											
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	product	chemical formula
1	3,568	3,490	3,645	53511140	31,47	20128937	28,51	2,66		Toluene	gasoline	C7H8
2	5,273	5,235	5,330	3260354	1,92	1850388	2,62	1,76		Ethylbenzene	gasoline	C8H10
3	5,489	5,330	5,565	46576197	27,39	14233073	20,16	3,27	V	Benzene, 1,3-d	gasoline	C8H10
4	5,921	5,865	5,970	14033478	8,25	8255340	11,69	1,70		Benzene, 1,3-d	gasoline	C8H10
5	6,548	6,525	6,590	189432	0,11	113016	0,16	1,68		Benzene, (1-m	gasoline	C9H12

6	7,270	7,225	7,325	428494	0,25	217886	0,31	1,97		Benzene, propy	gasoline	C9H12
7	7,471	7,420	7,515	3574050	2,10	1798855	2,55	1,99		Benzene, 1-eth	diesel	C15H17
8	7,554	7,515	7,605	1648402	0,97	808144	1,14	2,04	V	Benzene, 1-eth	diesel	C15H17
9	7,709	7,605	7,770	2457647	1,45	1208447	1,71	2,03	V	Benzene, 1,2,3	gasoline	C9H12
10	7,959	7,915	8,005	653723	0,38	299474	0,42	2,18		Benzene, 1-eth	diesel	C15H17
11	8,478	8,400	8,535	9497700	5,59	3769965	5,34	2,52		Benzene, 1,2,3	gasoline	C9H12
12	9,315	9,285	9,335	156026	0,09	69995	0,10	2,23		Benzene, 1,2,3	gasoline	C9H12
13	9,374	9,335	9,440	1011114	0,59	403807	0,57	2,50	V	Benzene, (1-m	gasoline	C9H12
14	9,804	9,755	9,860	458000	0,27	188587	0,27	2,43		Indane	gasoline	C10H12
15	10,183	10,155	10,220	161522	0,09	87937	0,12	1,84		Indane	gasoline	C10H12
16	10,284	10,250	10,335	403174	0,24	198864	0,28	2,03		Indane	gasoline	C10H12
17	10,426	10,390	10,450	393726	0,23	188701	0,27	2,09		Indane	gasoline	C10H12
18	10,471	10,450	10,515	434270	0,26	212792	0,30	2,04	V	o-Cymene	gasoline	C10H14
19	10,982	10,945	11,020	252937	0,15	131745	0,19	1,92		o-Cymene	gasoline	C10H14
20	11,053	11,020	11,095	262858	0,15	124991	0,18	2,10		o-Cymene	gasoline	C10H14
21	11,127	11,095	11,165	215379	0,13	110282	0,16	1,95	V	1H-Indene, 2,3	jet fuel	C11H12
22	11,216	11,165	11,280	867053	0,51	346745	0,49	2,50	V	o-Cymene	gasoline	C10H14
23	12,019	11,985	12,060	154022	0,09	90226	0,13	1,71		o-Cymene	gasoline	C10H14
24	12,100	12,070	12,140	211034	0,12	113641	0,16	1,86		Benzene, 1,2,3	gasoline	C9H12
25	12,425	12,410	12,525	50252	0,03	19111	0,03	2,63		Benzene, 1,2,3	gasoline	C9H12
26	12,553	12,525	12,605	477202	0,28	253103	0,36	1,89	V	Benzene, 1-eth	diesel	C15H17
27	12,749	12,715	12,775	184582	0,11	97048	0,14	1,90		Benzene, 1-eth	diesel	C15H17
28	12,819	12,775	12,850	133419	0,08	67563	0,10	1,97	V	Benzene, 1-eth	diesel	C15H17
29	13,284	13,260	13,310	54082	0,03	36737	0,05	1,47		Benzene, 1-eth	diesel	C15H17
30	13,533	13,490	13,560	163352	0,10	83342	0,12	1,96		Benzene, 1-eth	diesel	C15H17
31	13,620	13,560	13,675	5099395	3,00	2419599	3,43	2,11		Naphthalene	gasoline	C10H8
32	16,645	16,570	16,700	8945336	5,26	3620300	5,13	2,47		Naphthalene, 1	jet fuel	C11H10
33	16,970	16,920	17,025	3228654	1,90	1737546	2,46	1,86		Naphthalene, 2	jet fuel	C11H12
34	18,341	18,315	18,415	714601	0,42	375123	0,53	1,90		Naphthalene, 1	jet fuel	C11H10
35	18,506	18,455	18,515	1657121	0,97	1167774	1,65	1,42		Naphthalene, 2	jet fuel	C11H12
36	18,530	18,515	18,580	1911353	1,12	1508524	2,14	1,27	V	Naphthalene, 2	jet fuel	C11H12

37	18,679	18,580	18,710	2353221	1,38	1572195	2,23	1,50	V	Naphthalene, 1	jet fuel	C11H10
38	18,735	18,710	18,780	1367657	0,80	1043438	1,48	1,31	V	Naphthalene, 2	jet fuel	C11H12
39	18,935	18,890	18,990	690630	0,41	287174	0,41	2,40		Naphthalene, 1	jet fuel	C11H10
40	19,101	19,075	19,145	172864	0,10	137628	0,19	1,26		Naphthalene, 1	jet fuel	C11H10
41	19,458	19,445	19,475	42092	0,02	39449	0,06	1,07		Naphthalene, 1	jet fuel	C11H10
42	19,510	19,495	19,525	29551	0,02	33164	0,05	0,89		Naphthalene, 1	jet fuel	C11H10
43	19,617	19,590	19,665	618130	0,36	298271	0,42	2,07		Naphthalene, 2	jet fuel	C11H12
44	19,682	19,665	19,740	135559	0,08	66844	0,09	2,03	V	Naphthalene, 2	jet fuel	C11H12
45	19,813	19,760	19,845	370562	0,22	210748	0,30	1,76		Naphthalene, 2	jet fuel	C11H12
46	19,878	19,845	19,915	287051	0,17	197312	0,28	1,45	V	Naphthalene, 2	jet fuel	C11H12
47	20,007	19,915	20,035	214910	0,13	139071	0,20	1,55	V	Naphthalene, 2	jet fuel	C11H12
48	20,061	20,040	20,095	187723	0,11	148716	0,21	1,26		Naphthalene, 2	jet fuel	C11H12
49	20,170	20,135	20,190	113088	0,07	64738	0,09	1,75		Naphthalene, 2	jet fuel	C11H12
50	20,405	20,380	20,475	33289	0,02	32059	0,05	1,04		Naphthalene, 2	jet fuel	C11H12
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	min											
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Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	product	chemical formula
1	3,541	3,495	3,635	14665150	22,36	7991472	24,86	1,84	V	Toluene	gasoline	C7H8
2	4,060	4,030	4,125	195318	0,30	86123	0,27	2,27		Toluene	gasoline	C7H8
3	5,269	5,235	5,335	2948591	4,50	1773091	5,52	1,66		Ethylbenzene	gasoline	C8H10
4	5,462	5,335	5,545	15522357	23,67	5621817	17,49	2,76	V	Benzene, 1,3-d	gasoline	C8H10
5	5,904	5,870	5,960	3713274	5,66	2478576	7,71	1,50		Benzene, 1,3-d	gasoline	C8H10

6	6,013	5,960	6,050	380853	0,58	227591	0,71	1,67	V	Nonane	gasoline	C9H20
7	6,546	6,515	6,590	210731	0,32	118449	0,37	1,78		Nonane	gasoline	C9H20
8	7,267	7,230	7,315	599505	0,91	300700	0,94	1,99		Benzene, propy	gasoline	C9H12
9	7,471	7,415	7,515	3990001	6,08	2008065	6,25	1,99		Benzene, 1-eth	diesel	C15H17
10	7,554	7,515	7,610	2806956	4,28	1442804	4,49	1,95	V	Benzene, 1-eth	diesel	C15H17
11	7,705	7,610	7,750	224934	0,34	108321	0,34	2,08	V	Mesitylene	gasoline	C9H12
12	7,956	7,925	8,020	368833	0,56	156774	0,49	2,35		Benzene, (1-m	gasoline	C9H12
13	8,458	8,405	8,530	3695974	5,64	1554316	4,84	2,38		Benzene, 1,2,3	gasoline	C9H12
14	9,323	9,280	9,355	184735	0,28	75504	0,23	2,45		Benzene, 1,2,3	gasoline	C9H12
15	9,390	9,355	9,415	95048	0,14	31848	0,10	2,98	V	Benzene, 1,2,3	gasoline	C9H12
16	9,493	9,415	9,525	151134	0,23	67104	0,21	2,25	V	Benzene, 1,2,3	gasoline	C9H12
17	9,802	9,760	9,840	213524	0,33	101718	0,32	2,10		Indane	gasoline	C10H12
18	10,180	10,140	10,230	440461	0,67	223063	0,69	1,97		Benzene, 1,2-d	gasoline	C10H14
19	10,280	10,240	10,330	667976	1,02	323781	1,01	2,06		Benzene, 1-me	gasoline	C10H14
20	10,425	10,385	10,470	1332352	2,03	606255	1,89	2,20		Benzene, 1-me	gasoline	C10H14
21	10,981	10,950	11,015	134996	0,21	73536	0,23	1,84		Benzene, 1-me	gasoline	C10H14
22	11,052	11,015	11,090	182725	0,28	91306	0,28	2,00	V	Benzene, 1-me	gasoline	C10H14
23	11,124	11,090	11,170	155681	0,24	82685	0,26	1,88	V	Benzene, 1-me	gasoline	C10H14
24	11,214	11,175	11,270	965965	1,47	407790	1,27	2,37		Benzene, 4-eth	gasoline	C10H14
25	11,594	11,540	11,670	1488400	2,27	791623	2,46	1,88		Undecane	jet fuel	C11H24
26	12,437	12,405	12,480	175734	0,27	98011	0,30	1,79		Undecane	jet fuel	C11H24
27	12,547	12,520	12,605	350984	0,54	188653	0,59	1,86		Benzene, 1-eth	diesel	C15H17
28	12,689	12,605	12,720	189655	0,29	112969	0,35	1,68	V	Benzene, 1-eth	diesel	C15H17
29	12,820	12,795	12,860	178554	0,27	111173	0,35	1,61		Benzene, 1-eth	diesel	C15H17
30	12,954	12,930	12,995	222434	0,34	105454	0,33	2,11	V	Benzene, 1-eth	diesel	C15H17
31	13,288	13,255	13,320	127432	0,19	70884	0,22	1,80		Benzene, 1-eth	diesel	C15H17
32	13,524	13,490	13,550	212102	0,32	103141	0,32	2,06		Benzene, 1-eth	diesel	C15H17
33	13,614	13,550	13,680	1199417	1,83	441722	1,37	2,72	V	Azulene	gasoline	C10H8
34	16,623	16,555	16,705	2737811	4,17	1090441	3,39	2,51		Naphthalene, 2	jet fuel	C11H12
35	16,966	16,925	17,020	332623	0,51	158729	0,49	2,10		Naphthalene, 2	jet fuel	C11H12
36	17,100	17,020	17,135	100935	0,15	54012	0,17	1,87	V	Naphthalene, 2	jet fuel	C11H12

37	18,341	18,305	18,410	382360	0,58	217855	0,68	1,76		Naphthalene, 1	jet fuel	C11H10
38	18,505	18,410	18,515	799324	1,22	525472	1,63	1,52	V	Naphthalene, 1	jet fuel	C11H10
39	18,528	18,515	18,580	823745	1,26	615309	1,91	1,34	V	Naphthalene, 1	jet fuel	C11H10
40	18,677	18,640	18,710	395289	0,60	246530	0,77	1,60		Naphthalene, 1	jet fuel	C11H10
41	18,738	18,710	18,775	235735	0,36	161873	0,50	1,46	V	Naphthalene, 1	jet fuel	C11H10
42	18,948	18,910	18,975	92136	0,14	49861	0,16	1,85		Naphthalene, 1	jet fuel	C11H10
43	19,427	19,400	19,440	171866	0,26	139499	0,43	1,23		Naphthalene, 1	jet fuel	C11H10
44	19,452	19,440	19,495	223932	0,34	182927	0,57	1,22	V	Naphthalene, 1	jet fuel	C11H10
45	19,620	19,590	19,660	493275	0,75	266301	0,83	1,85		Naphthalene, 2	jet fuel	C11H12
46	19,680	19,660	19,715	160351	0,24	135438	0,42	1,18	V	Dodecanoic acid	diesel	C12H24O2
47	20,170	20,120	20,200	267619	0,41	117631	0,37	2,28		Dodecanoic acid	diesel	C12H24O2
48	20,285	20,200	20,315	146403	0,22	68654	0,21	2,13	V	Dodecanoic acid	diesel	C12H24O2
49	20,489	20,460	20,505	105836	0,16	64755	0,20	1,63		Dodecanoic acid	diesel	C12H24O2
50	21,255	21,225	21,280	119561	0,18	74602	0,23	1,60		Dodecanoic acid	diesel	C12H24O2
				65580587	100,00	32146208	100,00					

0 Sample Information													
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Analyzed	: 2018-06-09 11:36:33 AM												
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Level #	: 1												
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Sample ID	: 4N2												
IS Amount	: [1]=1												
Sample Amou	: 1												
Dilution Facto	: 1												
Vial #	: 25												
Injection Volu	: 0.10												
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Modified	: 2018-06-09 08:45:38 PM												
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10,0 20,0 30,0													
min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical form	
1	3,044	3,010	3,080	92447	0,05	48236	0,06	1,92	MI	Toluene	gasoline	C7H8	
2	3,131	3,080	3,185	190276	0,10	71246	0,09	2,67	MI	Toluene	gasoline	C7H8	
3	3,286	3,245	3,320	129103	0,07	88686	0,11	1,46	MI	Toluene	gasoline	C7H8	
4	3,474	3,405	3,500	267637	0,15	93593	0,11	2,86	MI	Toluene	gasoline	C7H8	
5	3,558	3,500	3,640	36303946	19,82	17128738	20,76	2,12	V	Toluene	gasoline	C7H8	

6	3,913	3,865	3,965	168352	0,09	59097	0,07	2,85	MI	Toluene	gasoline	C7H8
7	3,988	3,965	4,020	72918	0,04	45450	0,06	1,60	MI	Toluene	gasoline	C7H8
8	4,064	4,030	4,125	333868	0,18	128775	0,16	2,59		Toluene	gasoline	C7H8
9	4,229	4,195	4,290	261296	0,14	112476	0,14	2,32	MI	Toluene	gasoline	C7H8
10	4,593	4,570	4,615	44447	0,02	33552	0,04	1,32	MI	Toluene	gasoline	C7H8
11	4,653	4,615	4,680	105979	0,06	55796	0,07	1,90	MI	Toluene	gasoline	C7H8
12	4,950	4,880	4,995	151314	0,08	41238	0,05	3,67	MI	Toluene	gasoline	C7H8
13	5,278	5,230	5,355	7931941	4,33	4434293	5,37	1,79		Ethylbenzene	gasoline	C8H10
14	5,488	5,355	5,545	40534147	22,13	12246169	14,84	3,31	V	Benzene, 1,3-	gasoline	C8H10
15	5,750	5,710	5,800	134803	0,07	63886	0,08	2,11	MI	Benzene, 1,3-	gasoline	C8H10
16	5,917	5,870	5,965	10028282	5,48	6054672	7,34	1,66		Benzene, 1,3-	gasoline	C8H10
17	6,018	5,965	6,070	466314	0,25	234039	0,28	1,99	V	Decane	gasoline	C10H22
18	6,141	6,090	6,195	149519	0,08	49554	0,06	3,02	MI	Decane	gasoline	C10H22
19	6,549	6,515	6,585	438032	0,24	275005	0,33	1,59		Benzene, (1-r	gasoline	C9H12
20	7,274	7,230	7,335	1609784	0,88	816096	0,99	1,97		Benzene, prop	gasoline	C9H12
21	7,490	7,420	7,525	10549703	5,76	4630574	5,61	2,28		Benzene, 1-et	diesel	C15H17
22	7,576	7,525	7,620	8477979	4,63	4275213	5,18	1,98	V	Benzene, 1-et	diesel	C15H17
23	7,712	7,620	7,765	905810	0,49	429057	0,52	2,11	V	Benzene, 1,2,	gasoline	C9H12
24	7,963	7,925	8,020	754471	0,41	348403	0,42	2,17		Benzene, 1-et	diesel	C15H17
25	8,483	8,410	8,545	9720380	5,31	3778986	4,58	2,57		Benzene, 1,2,	gasoline	C9H12
26	8,606	8,570	8,655	114691	0,06	59281	0,07	1,93	MI	Benzene, 1,2,	gasoline	C9H12
27	8,961	8,935	9,030	181175	0,10	67631	0,08	2,68	MI	Benzene, 1,2,	gasoline	C9H12
28	9,325	9,290	9,355	321677	0,18	145268	0,18	2,21		o-Cymene	gasoline	C10H14
29	9,381	9,355	9,430	340437	0,19	156744	0,19	2,17	V	Benzene, 1-et	diesel	C15H17
30	9,495	9,450	9,545	416825	0,23	187766	0,23	2,22		Benzene, 1-n	gasoline	C10H14
31	9,806	9,765	9,870	667243	0,36	286579	0,35	2,33		Indane	gasoline	C10H12
32	10,185	10,145	10,235	1111718	0,61	538963	0,65	2,06		Benzene, 1,2-	gasoline	C10H14
33	10,290	10,245	10,345	1996595	1,09	982221	1,19	2,03		Benzene, 1-n	gasoline	C10H14
34	10,439	10,385	10,535	4560920	2,49	2064498	2,50	2,21		Benzene, 1-n	gasoline	C10H14
35	10,696	10,615	10,730	124613	0,07	52581	0,06	2,37	MI	Benzene, 1-n	gasoline	C10H14
36	10,986	10,955	11,025	287425	0,16	153787	0,19	1,87		Benzene, 2-et	gasoline	C10H14

37	11,057	11,025	11,100	400950	0,22	208762	0,25	1,92	V	1,3,8-p-Mentl	gasoline	C10H14
38	11,130	11,100	11,175	462158	0,25	231282	0,28	2,00	V	Benzene, 1-e	diesel	C15H17
39	11,221	11,175	11,290	2304238	1,26	1031996	1,25	2,23	V	Benzene, 1-e	diesel	C15H17
40	11,400	11,370	11,435	129838	0,07	66167	0,08	1,96	MI	Benzene, 1-e	diesel	C15H17
41	11,600	11,560	11,675	1274702	0,70	630361	0,76	2,02		Undecane	jet fuel	C11H24
42	11,846	11,780	11,895	160624	0,09	70131	0,08	2,29	MI	Undecane	jet fuel	C11H24
43	11,980	11,945	12,000	165650	0,09	79897	0,10	2,07	MI	Undecane	jet fuel	C11H24
44	12,020	12,000	12,060	279154	0,15	159921	0,19	1,75	MI	o-Cymene	gasoline	C10H14
45	12,105	12,070	12,150	117728	0,06	64411	0,08	1,83	MI	o-Cymene	gasoline	C10H14
46	12,440	12,405	12,480	507570	0,28	294468	0,36	1,72		Benzene, (1,1	jet fuel	C11H16
47	12,554	12,480	12,615	1119298	0,61	584432	0,71	1,92		Benzene, 1-e	diesel	C15H17
48	12,693	12,615	12,725	821299	0,45	475269	0,58	1,73	V	Benzene, (1,1	jet fuel	C11H16
49	12,822	12,795	12,870	803607	0,44	440465	0,53	1,82	V	Benzeneprop	gasoline	C10H12O
50	12,957	12,880	13,010	1088852	0,59	382967	0,46	2,84		Benzene, (1,2	jet fuel	C11H16
51	13,038	13,010	13,070	137203	0,07	81865	0,10	1,68	MI	Benzene, (1,2	jet fuel	C11H16
52	13,133	13,105	13,175	135744	0,07	72564	0,09	1,87	MI	Benzene, (1,2	jet fuel	C11H16
53	13,287	13,250	13,340	373176	0,20	204994	0,25	1,82		Benzene, (1,1	jet fuel	C11H16
54	13,534	13,500	13,565	540890	0,30	293102	0,36	1,85		1H-Indene, 2,	jet fuel	C11H14
55	13,618	13,565	13,690	3587944	1,96	1571527	1,90	2,28	V	Naphthalene	jet fuel	C11H14
56	13,791	13,755	13,910	395445	0,22	83515	0,10	4,74	MI	Naphthalene	jet fuel	C11H14
57	14,334	14,280	14,380	125215	0,07	50172	0,06	2,50	MI	Naphthalene	jet fuel	C11H14
58	14,447	14,400	14,475	90468	0,05	45552	0,06	1,99	MI	Naphthalene	jet fuel	C11H14
59	14,722	14,680	14,750	223796	0,12	108496	0,13	2,06	MI	Naphthalene	jet fuel	C11H14
60	14,781	14,755	14,860	371534	0,20	93183	0,11	3,99	V	Naphthalene	jet fuel	C11H14
61	15,177	15,135	15,205	316234	0,17	140457	0,17	2,25		Naphthalene	jet fuel	C11H14
62	15,232	15,210	15,280	268495	0,15	117833	0,14	2,28	MI	Naphthalene	jet fuel	C11H14
63	15,464	15,425	15,510	334588	0,18	143848	0,17	2,33		Benzene, (1-r	gasoline	C9H12
64	15,611	15,535	15,650	317738	0,17	70436	0,09	4,51		Benzene, (1-r	gasoline	C9H12
65	15,708	15,665	15,785	401097	0,22	112491	0,14	3,57	MI	Naphthalene,	jet fuel	C11H10
66	15,945	15,885	16,025	173629	0,09	45258	0,05	3,84	MI	Naphthalene,	jet fuel	C11H10
67	16,646	16,560	16,710	8348615	4,56	3327359	4,03	2,51		Naphthalene,	jet fuel	C13H14
68	16,967	16,920	17,015	1539869	0,84	769674	0,93	2,00		Naphthalene,	jet fuel	C13H14
69	17,096	17,060	17,130	198383	0,11	112188	0,14	1,77	MI	Naphthalene,	jet fuel	C13H14
70	17,314	17,280	17,345	80452	0,04	40553	0,05	1,98	MI	Naphthalene,	jet fuel	C13H14
71	17,425	17,380	17,455	124166	0,07	76515	0,09	1,62	MI	Naphthalene,	jet fuel	C13H14
72	17,598	17,570	17,620	79208	0,04	51296	0,06	1,54	MI	Naphthalene,	jet fuel	C13H14

73	17,651	17,630	17,680	94589	0,05	58710	0,07	1,61	MI	Naphthalene,	jet fuel	C13H14
74	17,769	17,740	17,815	161038	0,09	56638	0,07	2,84	MI	Naphthalene,	jet fuel	C13H14
75	18,011	17,940	18,070	297679	0,16	90296	0,11	3,30	MI	Naphthalene,	jet fuel	C13H14
76	18,344	18,305	18,425	1096767	0,60	637387	0,77	1,72		Naphthalene,	jet fuel	C13H14
77	18,505	18,460	18,520	2171373	1,19	1375044	1,67	1,58		Naphthalene,	jet fuel	C13H14
78	18,534	18,520	18,575	2610269	1,43	2119548	2,57	1,23	V	Naphthalene,	jet fuel	C11H10
79	18,680	18,575	18,710	1390249	0,76	931679	1,13	1,49	V	Naphthalene,	jet fuel	C11H10
80	18,736	18,710	18,770	848499	0,46	626173	0,76	1,36	V	Naphthalene,	jet fuel	C11H10
81	18,937	18,900	18,975	384491	0,21	207250	0,25	1,86		Naphthalene,	jet fuel	C11H10
82	19,104	19,060	19,145	164202	0,09	70453	0,09	2,33	MI	Naphthalene,	jet fuel	C11H10
83	19,158	19,145	19,185	66697	0,04	43444	0,05	1,54	MI	Naphthalene,	jet fuel	C11H10
84	19,426	19,400	19,445	377974	0,21	296673	0,36	1,27		2-Dodecanon	gasoline	C10H20O
85	19,460	19,445	19,490	327728	0,18	291532	0,35	1,12	V	2-Dodecanon	gasoline	C10H20O
86	19,510	19,495	19,545	37509	0,02	43914	0,05	0.85	MI	2-Dodecanon	gasoline	C10H20O
87	19,620	19,585	19,665	1417281	0,77	839421	1,02	1,69		Naphthalene,	jet fuel	C13H14
88	19,683	19,665	19,730	119972	0,07	62299	0,08	1.93	MI	Naphthalene,	jet fuel	C13H14
89	19,814	19,750	19,850	358104	0,20	177990	0,22	2,01	MI	Naphthalene,	jet fuel	C13H14
90	19,882	19,855	19,905	223768	0,12	182710	0,22	1.22	MI	Naphthalene,	jet fuel	C13H14
91	20,012	19,980	20,030	186980	0,10	122179	0,15	1.53	MI	Naphthalene,	jet fuel	C13H14
92	20,061	20,040	20,095	281463	0,15	233778	0,28	1,20	MI	Naphthalene,	jet fuel	C13H14
93	20,176	20,090	20,235	730055	0,40	225053	0,27	3,24		Naphthalene,	jet fuel	C13H14
94	20,285	20,250	20,320	197627	0,11	150361	0,18	1.31	MI	3-Tetradecan	jet fuel	C13H26O
95	20,488	20,455	20,540	425683	0,23	197199	0,24	2,16		3-Tetradecan	jet fuel	C13H26O
96	20,942	20,890	20,955	115133	0,06	57518	0,07	2.00	MI	3-Tetradecan	jet fuel	C13H26O
97	21,049	21,020	21,070	86178	0,05	68261	0,08	1.26	MI	3-Tetradecan	jet fuel	C13H26O
98	21,259	21,225	21,285	193580	0,11	122643	0,15	1.58	MI	3-Tetradecan	jet fuel	C13H26O
99	23,030	23,000	23,070	120503	0,07	70090	0,08	1.72	MI	3-Tetradecan	jet fuel	C13H26O
100	23,145	23,115	23,175	110914	0,06	87602	0,11	1.27	MI	3-Tetradecan	jet fuel	C13H26O
101	23,200	23,175	23,245	82157	0,04	63199	0,08	1.30	MI	3-Tetradecan	jet fuel	C13H26O
102	23,295	23,265	23,330	95078	0,05	62119	0,08	1.53	MI	3-Tetradecan	jet fuel	C13H26O
103	23,785	23,750	23,815	86044	0,05	49598	0,06	1.73	MI	3-Tetradecan	jet fuel	C13H26O
104	23,897	23,855	23,930	98718	0,05	62383	0,08	1.58	MI	3-Tetradecan	jet fuel	C13H26O
105	23,996	23,965	24,025	90641	0,05	63213	0,08	1.43	MI	3-Tetradecan	jet fuel	C13H26O
106	24,611	24,575	24,670	201629	0,11	76726	0,09	2.63	MI	3-Tetradecan	jet fuel	C13H26O
107	27,763	27,735	27,795	149720	0,08	114318	0,14	1.31	MI	3-Tetradecan	jet fuel	C13H26O
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	Sample Information											
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Analyzed	: 2018-06-09 01:51:46 AM											
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Level #	: 1											
Sample Name	: 4N1											
Sample ID	: 4N1 40 Bar NICKEL AT 300 DEGREESE											
IS Amount	: [1]=1											
Sample Amount	: 1											
Dilution Factor	: 1											
Vial #	: 12											
Injection Volume	: 0.10											
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min												
Peak Report TIC												
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical formula
1	3,544	3,495	3,635	23537163	21,82	12552059	24,23	1,88	V	Toluene	gasoline	C7H8
2	5,269	5,230	5,335	5708599	5,29	3459222	6,68	1,65		Ethylbenzene	gasoline	C8H10
3	5,467	5,335	5,545	24183796	22,42	8307904	16,03	2,91	V	Benzene, 1,3-d	gasoline	C8H10
4	5,905	5,865	5,955	5951526	5,52	3921095	7,57	1,52		Benzene, 1,3-d	gasoline	C8H10
5	6,541	6,510	6,580	440055	0,41	273190	0,53	1,61		Benzene, (1-m	gasoline	C9H12

6	7,264	7,220	7,320	1047411	0,97	533642	1,03	1,96		Benzene, propy	gasoline	C9H12
7	7,476	7,415	7,515	8377013	7,77	3947277	7,62	2,12		Benzene, 1-eth	diesel	C15H17
8	7,558	7,515	7,615	4674712	4,33	2450823	4,73	1,91	V	Benzene, 1-eth	diesel	C15H17
9	7,705	7,615	7,745	193895	0,18	104072	0,20	1,86	V	Mesitylene	gasoline	C8H80
10	7,951	7,910	8,000	789082	0,73	374372	0,72	2,11		Benzene, 1-eth	diesel	C15H17
11	8,461	8,400	8,520	5473730	5,08	2323050	4,48	2,36		Benzene, 1,2,3	gasoline	C9H12
12	9,313	9,270	9,355	340691	0,32	149497	0,29	2,28		1,3,8-p-Mentha	gasoline	C10H14
13	9,480	9,440	9,530	328443	0,30	147348	0,28	2,23		o-Cymene	gasoline	C10H14
14	9,798	9,755	9,840	403574	0,37	180649	0,35	2,23		Indane	gasoline	C10H12
15	10,176	10,135	10,230	991902	0,92	470930	0,91	2,11		Benzene, 1,2-d	gasoline	C10H14
16	10,279	10,230	10,330	1454032	1,35	736210	1,42	1,98		Benzene, 1-me	gasoline	C10H14
17	10,423	10,330	10,520	2209392	2,05	909632	1,76	2,43	V	Benzene, 1-me	gasoline	C10H14
18	10,977	10,940	11,015	283450	0,26	146425	0,28	1,94		Benzene, 2-eth	gasoline	C10H14
19	11,047	11,015	11,090	379931	0,35	192080	0,37	1,98	V	Benzene, 1-eth	diesel	C15H17
20	11,121	11,090	11,165	250643	0,23	133447	0,26	1,88	V	Benzene, 1-eth	diesel	C15H17
21	11,213	11,165	11,270	2011284	1,86	833793	1,61	2,41		Benzene, 1-eth	diesel	C15H17
22	11,590	11,550	11,615	541886	0,50	289364	0,56	1,87		Undecane	jet fuel	C11H24
23	11,630	11,615	11,670	211018	0,20	119598	0,23	1,76	V	Undecane	jet fuel	C11H24
24	12,431	12,395	12,475	361924	0,34	225052	0,43	1,61		Benzene, (1,1-	jet fuel	C11H16
25	12,546	12,510	12,595	719635	0,67	373221	0,72	1,93		Benzene, 1-eth	diesel	C15H17
26	12,685	12,595	12,720	297508	0,28	168743	0,33	1,76	V	Benzene, (1,1-	jet fuel	C11H16
27	12,816	12,720	12,860	441517	0,41	206836	0,40	2,13	V	Benzene, (1,1-	jet fuel	C11H16
28	12,955	12,885	13,000	462861	0,43	155126	0,30	2,98		Benzene, (1,1-	jet fuel	C11H16
29	13,123	13,055	13,160	181376	0,17	74872	0,14	2,42	V	Benzene, (1,1-	jet fuel	C11H16
30	13,281	13,245	13,315	255328	0,24	151517	0,29	1,69		Benzene, 1,1'-(jet fuel	C11H16
31	13,521	13,485	13,550	385979	0,36	207704	0,40	1,86		1H-Indene, 2,3	jet fuel	C11H14
32	13,609	13,550	13,665	1917180	1,78	701316	1,35	2,73	V	1H-Indene, 2,3	jet fuel	C11H14
33	13,690	13,665	13,730	191492	0,18	86247	0,17	2,22	V	1H-Indene, 2,3	jet fuel	C11H14
34	15,699	15,655	15,760	297704	0,28	93002	0,18	3,20		Naphthalene, 1	jet fuel	C11H10
35	16,624	16,555	16,695	3905007	3,62	1673534	3,23	2,33		Naphthalene, 2	jet fuel	C13H14
36	16,961	16,925	17,010	321274	0,30	150809	0,29	2,13		Naphthalene, 2	jet fuel	C13H14

37	17,090	17,010	17,130	253140	0,23	122605	0,24	2,06	V	Naphthalene, 2	jet fuel	C13H14
38	18,339	18,305	18,400	766991	0,71	472074	0,91	1,62		Naphthalene, 2	jet fuel	C13H14
39	18,500	18,400	18,515	1602654	1,49	937806	1,81	1,71	V	Naphthalene, 1	jet fuel	C11H10
40	18,526	18,515	18,585	1578386	1,46	1299769	2,51	1,21	V	Naphthalene, 1	jet fuel	C11H10
41	18,671	18,585	18,710	435608	0,40	308070	0,59	1,41	V	Naphthalene, 1	jet fuel	C11H10
42	18,733	18,710	18,765	277737	0,26	190234	0,37	1,46	V	Naphthalene, 1	jet fuel	C11H10
43	19,454	19,440	19,480	182590	0,17	165226	0,32	1,11	V	Naphthalene, 1	jet fuel	C11H10
44	19,616	19,585	19,670	1185980	1,10	662515	1,28	1,79		Naphthalene, 2	jet fuel	C13H14
45	20,059	20,040	20,095	155923	0,14	124251	0,24	1,25		Naphthalene, 2	jet fuel	C13H14
46	20,193	20,095	20,240	842727	0,78	247254	0,48	3,41		Dodecanoic ac	gasoline	C10H20O2
47	20,282	20,240	20,310	204123	0,19	107163	0,21	1,90	V	Dodecanoic ac	gasoline	C10H20O2
48	20,484	20,460	20,505	269178	0,25	152598	0,29	1,76		Dodecanoic ac	gasoline	C10H20O2
49	29,655	29,630	29,675	153153	0,14	65289	0,13	2,35		Dodecanoic ac	gasoline	C10H20O2
50	29,688	29,675	29,775	424900	0,39	135147	0,26	3,14	V	Dodecanoic ac	gasoline	C10H20O2
				#####	100,00	51813659	100,00					

	Sample Information												
Analyzed by	: Neal												
Analyzed	: 2018-06-09 12:02:14 AM												
Sample Type	: Unknown												
Level #	: 1												
Sample Name	: 3N4 30 Bar NI/HZSM-5 AT 450 DEGREESE												
Sample ID	: 3N4												
IS Amount	: [1]=1												
Sample Amount	: 1												
Dilution Factor	: 1												
Vial #	: 9												
Injection Volume	: 0.10												
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Report File	:												
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt												
Modified by	: Neal												
Modified	: 2018-06-09 08:14:15 PM												
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10,0	20,0	30,0											
	min												
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	product	chemical formula	
1	3,531	3,490	3,615	7892183	20,53	4477928	22,37	1,76		Toluene	gasoline	C7H8	
2	5,263	5,225	5,315	1590502	4,14	984505	4,92	1,62		Ethylbenzene	gasoline	C8H10	
3	5,448	5,405	5,530	7876989	20,49	3257786	16,27	2,42		Benzene, 1,3-d	gasoline	C8H10	
4	5,896	5,855	5,950	1975732	5,14	1247009	6,23	1,58		Benzene, 1,3-d	gasoline	C8H10	
5	6,006	5,980	6,035	87606	0,23	63505	0,32	1,38		Benzene, 1,3-d	gasoline	C8H10	

6	6,537	6,510	6,580	102010	0,27	55724	0,28	1,83		Benzene, 1,3-d	gasoline	C8H10
7	7,262	7,225	7,305	292888	0,76	150978	0,75	1,94		Benzene, propy	gasoline	C9H12
8	7,459	7,415	7,505	2239457	5,83	1157961	5,78	1,93		Benzene, 1-eth	diesel	C15H17
9	7,544	7,505	7,595	1561781	4,06	784490	3,92	1,99	V	Benzene, 1-eth	diesel	C15H17
10	7,697	7,595	7,745	219850	0,57	91962	0,46	2,39	V	Benzene, 1-eth	diesel	C15H17
11	7,947	7,915	7,990	206954	0,54	92457	0,46	2,24		Benzene, 1-eth	diesel	C15H17
12	8,446	8,390	8,505	1970477	5,13	848195	4,24	2,32		Benzene, 1,2,3	gasoline	C9H12
13	9,795	9,760	9,840	167540	0,44	77762	0,39	2,15		Benzene, 1,2,3	gasoline	C9H12
14	10,174	10,140	10,215	211839	0,55	117421	0,59	1,80		Benzene, 1,2-d	gasoline	C10H14
15	10,272	10,230	10,310	335509	0,87	161610	0,81	2,08		Benzene, 1-me	gasoline	C9H12
16	10,417	10,370	10,450	682368	1,78	323731	1,62	2,11		Benzene, 1-me	gasoline	C9H12
17	10,475	10,450	10,500	107497	0,28	53765	0,27	2,00	V	Benzene, 1-me	gasoline	C9H12
18	10,980	10,955	11,010	67087	0,17	42258	0,21	1,59		Benzene, 1-me	gasoline	C9H12
19	11,046	11,010	11,075	102175	0,27	60016	0,30	1,70		Benzene, 1-me	gasoline	C9H12
20	11,121	11,090	11,165	140889	0,37	70982	0,35	1,98		Benzene, 1-me	gasoline	C9H12
21	11,207	11,165	11,280	561066	1,46	221991	1,11	2,53		Benzene, 1-eth	diesel	C15H17
22	11,585	11,550	11,625	403322	1,05	242569	1,21	1,66		Undecane	jet fuel	C11H24
23	12,425	12,400	12,520	109175	0,28	45522	0,23	2,40		Undecane	jet fuel	C11H24
24	12,544	12,520	12,595	283947	0,74	148602	0,74	1,91	V	Benzene, 1-eth	diesel	C15H17
25	12,684	12,595	12,715	122912	0,32	62241	0,31	1,97	V	Benzene, 1-eth	diesel	C15H17
26	12,816	12,785	12,840	88440	0,23	57240	0,29	1,55		Benzene, 1-eth	diesel	C15H17
27	12,950	12,915	13,000	122639	0,32	58950	0,29	2,08		Benzene, 1-eth	diesel	C15H17
28	13,522	13,490	13,540	101796	0,26	60341	0,30	1,69		Benzene, 1-eth	diesel	C15H17
29	13,607	13,540	13,640	964646	2,51	379372	1,90	2,54	V	Naphthalene	gasoline	C10H8
30	13,660	13,640	13,690	188291	0,49	101696	0,51	1,85	V	Naphthalene	gasoline	C10H8
31	16,615	16,555	16,690	1983669	5,16	845086	4,22	2,35		Naphthalene, 2	jet fuel	C11H12
32	16,956	16,920	17,015	410764	1,07	201282	1,01	2,04		Naphthalene, 2	jet fuel	C11H12
33	17,095	17,015	17,120	69113	0,18	44392	0,22	1,56	V	Naphthalene, 2	jet fuel	C11H12
34	18,340	18,305	18,395	256202	0,67	132218	0,66	1,94		Naphthalene, 2	jet fuel	C11H12
35	18,500	18,470	18,510	477474	1,24	346923	1,73	1,38		Naphthalene, 2	jet fuel	C11H12
36	18,522	18,510	18,565	531341	1,38	408611	2,04	1,30	V	Naphthalene, 1	jet fuel	C11H10

37	18,671	18,645	18,710	450212	1,17	290851	1,45	1,55		Naphthalene, 1	jet fuel	C11H10
38	18,731	18,710	18,775	277254	0,72	186171	0,93	1,49	V	Naphthalene, 1	jet fuel	C11H10
39	19,421	19,400	19,440	197279	0,51	151591	0,76	1,30		2-Tridecanone	jet fuel	C13H26O
40	19,450	19,440	19,485	114161	0,30	123502	0,62	0,92	V	2-Tridecanone	jet fuel	C13H26O
41	19,618	19,580	19,655	341328	0,89	172410	0,86	1,98		Naphthalene, 2	jet fuel	C11H12
42	19,676	19,655	19,725	636176	1,66	591306	2,95	1,08	V	Dodecanoic ac	jet fuel	C12H24O2
43	20,190	20,095	20,260	865020	2,25	244584	1,22	3,54		Undecanoic ac	jet fuel	C11H22O2
44	20,283	20,260	20,305	89791	0,23	60088	0,30	1,49	V	Undecanoic ac	jet fuel	C11H22O2
45	21,251	21,230	21,285	92388	0,24	62048	0,31	1,49		Undecanoic ac	jet fuel	C11H22O2
46	21,491	21,465	21,520	223088	0,58	155258	0,78	1,44		Undecanoic ac	jet fuel	C11H22O2
47	23,471	23,445	23,505	112832	0,29	94161	0,47	1,20		Undecanoic ac	jet fuel	C11H22O2
48	24,612	24,590	24,630	82874	0,22	66963	0,33	1,24		Undecanoic ac	jet fuel	C11H22O2
49	27,758	27,725	27,790	287537	0,75	217487	1,09	1,32		12-Tricosanone	waxes and related products	C23H46O
50	28,889	28,865	28,935	159339	0,41	126128	0,63	1,26		12-Tricosanone	waxes and related products	C23H46O
				38435409	100,00	20019629	100,00					

Sample Information													
Analyzed by	: Neal												
Analyzed	: 2018-06-09 06:39:15 PM												
Sample Type	: Unknown												
Level #	: 1												
Sample Name	: 3N3 rpt 1 30 Bar in NI/HZSM-5 AT 400 DEGREESE												
Sample ID	: 3N3 rpt 1												
IS Amount	: [1]=1												
Sample Amount	: 1												
Dilution Factor	: 1												
Vial #	: 16												
Injection Volume	: 1.00												
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Modified by	: Neal												
Modified	: 2018-06-09 08:13:26 PM												
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6 641 952													
10,0 20,0 30,0													
min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical formula	
1	3,532	3,495	3,625	6245341	3,69	3434518	7,43	1,82		Toluene	gasoline	C7H8	
2	4,054	4,020	4,135	318957	0,19	133563	0,29	2,39	MI	Hexane, 2,4-di	gasoline	C8H18	
3	5,270	5,240	5,315	1284462	0,76	790702	1,71	1,62		Ethylbenzene	gasoline	C8H10	
4	5,454	5,410	5,525	5277798	3,12	2144153	4,64	2,46		Benzene, 1,3-d	gasoline	C8H10	
5	5,906	5,875	5,945	1285138	0,76	784072	1,70	1,64		o-Xylene	gasoline	C8H10	

6	6,013	5,945	6,050	669787	0,40	372973	0,81	1,80	V	Nonane	gasoline	C9H20
7	6,129	6,080	6,160	81149	0,05	43022	0,09	1,89	MI	Nonane	gasoline	C9H20
8	6,550	6,515	6,600	97169	0,06	50828	0,11	1,91	MI	Nonane	gasoline	C9H20
9	7,274	7,235	7,345	270008	0,16	138936	0,30	1,94	MI	Nonane	gasoline	C9H20
10	7,474	7,430	7,520	1720727	1,02	883132	1,91	1,95		Benzene, 1-eth	diesel	C15H17
11	7,558	7,520	7,605	1114110	0,66	559531	1,21	1,99	V	Benzene, 1-eth	diesel	C15H17
12	7,718	7,670	7,760	105501	0,06	50302	0,11	2,10	MI	Benzene, 1-eth	diesel	C15H17
13	7,967	7,915	8,015	221944	0,13	95504	0,21	2,32	MI	Benzene, 1-eth	diesel	C15H17
14	8,329	8,275	8,360	79280	0,05	37457	0,08	2,12	MI	Benzene, 1-eth	diesel	C15H17
15	8,465	8,420	8,535	1179914	0,70	463448	1,00	2,55		Benzene, 1,2,3	gasoline	C9H12
16	8,606	8,535	8,650	453251	0,27	197701	0,43	2,29	V	Decane	gasoline	C10H22
17	8,789	8,735	8,885	548875	0,32	112843	0,24	4,86	MI	Decane	gasoline	C10H22
18	9,816	9,780	9,875	187770	0,11	87471	0,19	2,15	MI	Decane	gasoline	C10H22
19	10,191	10,125	10,230	245316	0,15	112670	0,24	2,18	MI	Decane	gasoline	C10H22
20	10,293	10,250	10,345	362383	0,21	164349	0,36	2,20	MI	Benzene, 1-me	gasoline	C9H12
21	10,435	10,385	10,475	552266	0,33	286878	0,62	1,93		Benzene, 1-me	gasoline	C9H12
22	11,134	11,095	11,175	283871	0,17	140125	0,30	2,03	MI	Benzene, 1-eth	gasoline	C9H12
23	11,227	11,185	11,290	542167	0,32	197447	0,43	2,75		o-Cymene	gasoline	C10H14
24	11,394	11,290	11,450	509061	0,30	164827	0,36	3,09	V	2-Undecene, (Z	jet fuel	C11H22
25	11,610	11,560	11,660	3478881	2,06	2032537	4,40	1,71		Undecane	jet fuel	C11H24
26	12,442	12,405	12,480	103473	0,06	53033	0,11	1,95	MI	Undecane	jet fuel	C11H24
27	12,561	12,525	12,595	217458	0,13	124682	0,27	1,74	MI	Benzene, 1-eth	gasoline	C9H12
28	12,696	12,670	12,730	104456	0,06	67277	0,15	1,55	MI	Benzene, 1-eth	gasoline	C9H12
29	12,758	12,730	12,795	73172	0,04	37495	0,08	1,95	MI	Benzene, 1-eth	gasoline	C9H12
30	12,829	12,790	12,890	117163	0,07	68850	0,15	1,70	MI	Benzene, 1-eth	gasoline	C9H12
31	12,960	12,895	13,020	212226	0,13	66277	0,14	3,20	MI	Benzene, 1-eth	gasoline	C9H12
32	13,625	13,555	13,700	819256	0,48	290580	0,63	2,82		Naphthalene	gasoline	C10H8
33	13,861	13,830	13,900	350792	0,21	187676	0,41	1,87	MI	Undecane	jet fuel	C11H24
34	14,045	14,010	14,140	910412	0,54	100650	0,22	9,05		Undecane	jet fuel	C11H24
35	14,200	14,140	14,200	965013	0,57	309462	0,67	3,12	MI	Undecane	jet fuel	C11H24
36	14,323	14,200	14,370	3263509	1,93	540326	1,17	6,04	MI	Octanoic acid	gasoline	C8H16O

37	16,612	16,560	16,695	3364648	1,99	1103110	2,39	3,05		Tridecane	jet fuel	C13H28
38	16,974	16,935	17,030	298398	0,18	155889	0,34	1,91	MI	Naphthalene, 2	jet fuel	C11H12
39	18,150	18,080	18,170	1174225	0,69	300348	0,65	3,91	V	Naphthalene, 2	jet fuel	C11H12
40	18,261	18,170	18,265	2589166	1,53	616741	1,33	4,20	MI	Naphthalene, 2	jet fuel	C11H12
41	18,300	18,265	18,320	1788696	1,06	643788	1,39	2,78	V	n-Decanoic aci	gasoline	C10H20O2
42	18,333	18,320	18,425	1175255	0,69	307990	0,67	3,82	MI	n-Decanoic aci	gasoline	C10H20O2
43	18,475	18,425	18,495	695955	0,41	431436	0,93	1,61	V	Dodecanal	jet fuel	C12H24O
44	18,510	18,495	18,525	599219	0,35	401703	0,87	1,49	V	Naphthalene, 1	jet fuel	C11H10
45	18,535	18,525	18,580	601786	0,36	445842	0,96	1,35	V	Naphthalene, 1	jet fuel	C11H10
46	18,685	18,650	18,715	411115	0,24	249710	0,54	1,65	MI	Naphthalene, 1	jet fuel	C11H10
47	18,742	18,725	18,775	197045	0,12	136126	0,29	1,45	MI	Naphthalene, 2	jet fuel	C11H12
48	19,226	19,190	19,285	193371	0,11	114066	0,25	1,70	MI	Naphthalene, 2	jet fuel	C11H12
49	19,384	19,340	19,400	115781	0,07	80913	0,17	1,43	MI	Naphthalene, 2	jet fuel	C11H12
50	19,432	19,400	19,445	805751	0,48	696391	1,51	1,16	V	2-Tridecanone	jet fuel	C13H26O
51	19,461	19,445	19,490	1089876	0,64	1088727	2,35	1,00	V	Tetradecane	jet fuel	C13H28
52	19,624	19,600	19,665	404548	0,24	207282	0,45	1,95	V	Naphthalene, 2	jet fuel	C11H12
53	19,686	19,670	19,720	368034	0,22	345109	0,75	1,07	MI	Hexadecanoic	diesel	C16H32O2
54	20,290	20,125	20,305	5803801	3,43	1434938	3,10	4,04	V	3-Tetradecanon	diesel	C14H28O
55	20,505	20,305	21,010	68260648	40,36	5624857	12,17	12,14	V	Dodecanoic ac	jet fuel	C12H24O2
56	21,038	21,010	21,150	3231251	1,91	587980	1,27	5,50	V	Dodecanoic ac	jet fuel	C12H24O2
57	21,180	21,150	21,240	1303926	0,77	280859	0,61	4,64	V	Dodecanoic ac	jet fuel	C12H24O2
58	21,270	21,240	21,380	1788898	1,06	541182	1,17	3,31	V	Hexadecane	diesel	C16H34
59	21,510	21,380	21,580	676365	0,40	112596	0,24	6,01	V	Hexadecane	diesel	C16H34
60	22,194	22,050	22,420	2662100	1,57	280720	0,61	9,48		Tetradecanoic a	diesel	C14H28O2
61	22,796	22,755	22,835	333857	0,20	212233	0,46	1,57	MI	Dodecanoic ac	jet fuel	C12H24O2
62	23,062	23,000	23,140	662364	0,39	213669	0,46	3,10		Decanoic acid,	jet fuel	C12H24O2
63	23,206	23,190	23,245	220088	0,13	149638	0,32	1,47	MI	Decanoic acid,	jet fuel	C12H24O2
64	23,308	23,285	23,350	296846	0,18	208240	0,45	1,43	MI	2-Heptadecano	jet fuel	C13H26O
65	24,073	23,860	24,140	642437	0,38	106406	0,23	6,04		2-Heptadecano	jet fuel	C13H26O
66	24,630	24,530	24,680	1765249	1,04	1123022	2,43	1,57		8-Pentadecano	diesel	C15H30O
67	25,584	25,480	25,670	485589	0,29	116568	0,25	4,17		8-Pentadecano	diesel	C15H30O
68	26,197	26,160	26,260	1627667	0,96	856159	1,85	1,90		12-Tricosanone	waxes and related products	C23H46O
69	27,779	27,670	27,860	6040670	3,57	4175218	9,03	1,45		12-Tricosanone	waxes and related products	C23H46O
70	28,003	27,900	28,090	795202	0,47	176180	0,38	4,51		12-Tricosanone	waxes and related products	C23H46O
71	28,791	28,660	28,880	3876523	2,29	417124	0,90	9,29	V	12-Tricosanone	waxes and related products	C23H46O
72	28,910	28,880	28,950	5307049	3,14	3691149	7,98	1,44	V	12-Tricosanone	waxes and related products	C23H46O
73	29,029	28,950	29,350	7176694	4,24	599431	1,30	11,97	V	12-Tricosanone	waxes and related products	C23H46O
74	29,919	29,830	30,010	2461920	1,46	544620	1,18	4,52		12-Tricosanone	waxes and related products	C23H46O
75	30,098	30,020	30,230	3571581	2,11	2133492	4,61	1,67		12-Tricosanone	waxes and related products	C23H46O
				#####	100,00	46236749	100,00					

3N2= 30 BAR IN NI/HZSM-5 AT 350 DEGREESE

1	4,481	4,450	4,610	1973358	2,17	682040	2,43	2,89	C8H10		Ethylbenzene
2	4,646	4,610	4,880	14956193	16,42	5456530	19,42	2,74	C8H10	V	o-Xylene
3	5,100	5,045	5,300	5332444	5,85	2283805	8,13	2,33	C8H10	S	Benzene, 1,3-
4	6,354	6,320	6,420	398023	0,44	124078	0,44	3,21	C9H12		Benzene, propyl-
5	6,485	6,445	6,530	3544367	3,89	1540284	5,48	2,30	C15H17	V	Benzene, 1-ethyl-4-
6	6,556	6,530	6,650	2585121	2,84	757221	2,70	3,41	C15H17	V	Benzene, 1-ethyl-4-
7	6,687	6,650	6,800	1421505	1,56	378369	1,35	3,76	C8H80	V	Mesitylene
8	6,904	6,825	6,990	690784	0,76	182007	0,65	3,80	C15H17	V	Benzene, 1-ethyl-4-
9	7,279	7,220	7,580	6481890	7,11	2089288	7,44	3,10	C9H10	SV	Benzene, 1,2,3-
10	8,068	8,025	8,130	409615	0,45	103770	0,37	3,95	C9H10	V	Benzene, 1,2,3-
11	8,934	8,880	8,990	275295	0,30	70324	0,25	3,91	C9H10		Benzene, 1,2,3-
12	9,042	8,990	9,125	482443	0,53	100807	0,36	4,79	C9H10	V	Benzene, 1,2,3-
13	9,215	9,150	9,240	365995	0,40	118080	0,42	3,10	C9H10		Benzene, 1,2,3-
14	9,259	9,240	9,360	573032	0,63	152119	0,54	3,77	C9H10	V	Benzene, 1,2,3-
15	9,865	9,820	9,895	220596	0,24	72555	0,26	3,04	C9H10		Benzene, 1,2,3-
16	9,949	9,895	9,970	270225	0,30	85089	0,30	3,18	C9H10	V	Benzene, 1,2,3-
17	10,014	9,970	10,080	301619	0,33	81580	0,29	3,70	C9H10	V	Benzene, 1,2,3-
18	10,122	10,080	10,210	890766	0,98	245499	0,87	3,63	C15H17	V	Benzene, 1-ethyl-
19	10,581	10,535	10,655	341349	0,37	94661	0,34	3,61	C15H17		Benzene, 1-ethyl-
20	11,129	10,995	11,145	255908	0,28	45664	0,16	5,60	C15H17		Benzene, 1-ethyl-
21	11,594	11,555	11,665	672786	0,74	173114	0,62	3,89	C15H17	V	Benzene, 1-ethenyl-
22	12,578	12,545	12,605	235039	0,26	105555	0,38	2,23	C15H17		Benzene, 1-ethenyl-
23	12,637	12,605	12,820	5028646	5,52	1196621	4,26	4,20	C10H8	V	Naphthalene
24	12,845	12,820	12,885	284003	0,31	92795	0,33	3,06	C10H8	V	Naphthalene
25	15,239	15,185	15,530	10596801	11,63	2297497	8,18	4,61	C11H10	S	Naphthalene, 1-
26	15,705	15,655	15,850	2157815	2,37	452372	1,61	4,77	C11H10		Naphthalene, 1-
27	17,607	17,570	17,725	1384208	1,52	321361	1,14	4,31	C11H10		Naphthalene, 1-
28	17,761	17,725	17,770	1498844	1,65	1041587	3,71	1,44	C11H12	V	Naphthalene, 2,6-
29	17,789	17,770	17,925	4322529	4,74	1153262	4,11	3,75	C11H12	V	Naphthalene, 2,6-
30	17,955	17,925	18,010	2616617	2,87	976431	3,48	2,68	C11H10	V	Naphthalene, 1,2-

31	18,038	18,010	18,210	2157267	2,37	496958	1,77	4,34	C11H10	SV	Naphthalene, 1,6-
32	18,290	18,210	18,385	616207	0,68	155528	0,55	3,96	C11H10	V	Naphthalene, 1,3-
33	18,874	18,840	18,900	380778	0,42	179767	0,64	2,12	C12H26		Dodecane, 2-
34	19,025	18,980	19,105	1328964	1,46	381577	1,36	3,48	C11H12	V	Naphthalene, 2-(1-
35	19,130	19,105	19,175	411236	0,45	180830	0,64	2,27	C11H12	V	Naphthalene, 2-(1-
36	19,227	19,175	19,280	541739	0,59	161677	0,58	3,35	C11H12	V	Naphthalene, 2,3,6-
37	19,305	19,280	19,355	341971	0,38	119983	0,43	2,85	C11H12	V	Naphthalene, 2,3,6-
38	19,608	19,545	19,730	4660671	5,12	1593336	5,67	2,93	C12H24O2	V	Dodecanoic acid
39	19,760	19,730	19,805	667416	0,73	202980	0,72	3,29	C12H24O2	V	Dodecanoic acid
40	19,855	19,825	19,875	220370	0,24	84295	0,30	2,61	C12H24O2	V	Dodecanoic acid
41	19,933	19,875	20,015	784982	0,86	190920	0,68	4,11	C12H24O2	V	Dodecanoic acid
42	21,245	21,200	21,295	502887	0,55	120550	0,43	4,17	C12H24O2		Dodecanoic acid
43	27,105	27,075	27,170	229477	0,25	105502	0,38	2,18	C12H24O2		Dodecanoic acid
44	32,055	31,975	32,090	954744	1,05	186703	0,66	5,11	C12H24O2	V	Dodecanoic acid
45	32,135	32,090	32,245	1030123	1,13	183729	0,65	5,61	C12H24O2	V	Dodecanoic acid
46	33,960	33,845	33,975	1593930	1,75	317092	1,13	5,03	C12H24O2	V	Dodecanoic acid
47	34,022	33,975	34,090	2327584	2,55	375838	1,34	6,19	C12H24O2	V	Dodecanoic acid
48	34,115	34,090	34,130	621880	0,68	265406	0,94	2,34	C12H24O2	V	Dodecanoic acid
49	34,140	34,130	34,210	845288	0,93	229343	0,82	3,69	C12H24O2	V	Dodecanoic acid
50	34,255	34,210	34,270	324013	0,36	84112	0,30	3,85	C12H24O2	V	Dodecanoic acid
				91109343	100,00	28090491	100,00				

Sample Information												
Analyzed by	: Neal											
Analyzed	: 2018-06-09 10:59:54 AM											
Sample Type	: Unknown											
Level #	: 1											
Sample Name	: 3N1 30 Bar in Ni/HZSM-5 AT 300 DEGREESE											
Sample ID	: 3N1											
IS Amount	: [1]=1											
Sample Amount	: 1											
Dilution Factor	: 1											
Vial #	: 24											
Injection Volume	: 0.10											
Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3N1.qgd											
Org Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3N1.qgd											
Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm											
Org Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm											
Report File	:											
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt											
Modified by	: Neal											
Modified	: 2018-06-09 08:02:49 PM											
Chromatogram 3N1 C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3N1.qgd												
TIC												
6 330 751												
10,0	20,0	30,0										
min												
Peak Report TIC												
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical formula
1	3,284	3,250	3,320	121018	0,14	66970	0,17	1,81	MI	Heptane, 2-met	gasoline	C8H18
2	3,466	3,395	3,500	292130	0,35	101705	0,25	2,87	MI	Heptane, 2-met	gasoline	C8H18
3	3,541	3,505	3,640	10539363	12,61	5712405	14,26	1,84		Toluene	gasoline	C7H8
4	4,064	4,020	4,125	248009	0,30	89369	0,22	2,78	MI	Toluene	gasoline	C7H8
5	4,225	4,195	4,250	203766	0,24	125491	0,31	1,62		1,4-Pentadiene	gasoline	C8H14

6	5,272	5,230	5,345	4587443	5,49	2729359	6,81	1,68		Ethylbenzene	gasoline	C8H10
7	5,463	5,345	5,535	15338060	18,35	5494128	13,71	2,79	V	Benzene, 1,3-d	gasoline	C8H10
8	5,905	5,865	5,965	3140527	3,76	1985620	4,96	1,58		Benzene, 1,3-d	gasoline	C8H10
9	6,014	5,965	6,060	277486	0,33	141810	0,35	1,96	V	Benzene, 1,3-d	gasoline	C8H10
10	6,547	6,515	6,580	197775	0,24	133318	0,33	1,48		Benzene, (1-m	gasoline	C9H12
11	7,270	7,225	7,340	1127327	1,35	561075	1,40	2,01		Benzene, propy	gasoline	C9H12
12	7,483	7,415	7,520	8090470	9,68	3834737	9,57	2,11		Benzene, 1-eth	diesel	C15H17
13	7,565	7,520	7,615	5219177	6,24	2689349	6,71	1,94	V	Benzene, 1-eth	diesel	C15H17
14	7,960	7,925	8,000	369315	0,44	182837	0,46	2,02		Benzene, 1-eth	diesel	C15H17
15	8,463	8,405	8,535	3758512	4,50	1562608	3,90	2,41		Benzene, 1,2,3	gasoline	C9H12
16	8,605	8,570	8,655	109904	0,13	46953	0,12	2,34	MI	Benzene, 1,2,3	gasoline	C9H12
17	9,322	9,280	9,365	280169	0,34	124814	0,31	2,24		1,3,8-p-Mentha	gasoline	C10H14
18	9,494	9,450	9,550	255281	0,31	108756	0,27	2,35		1,3,8-p-Mentha	gasoline	C10H14
19	9,805	9,775	9,860	222926	0,27	94316	0,24	2,36		Indane	gasoline	C9H10
20	10,185	10,140	10,230	1442988	1,73	697809	1,74	2,07		Benzene, 1,2-d	gasoline	C10H14
21	10,287	10,230	10,345	1710352	2,05	845032	2,11	2,02	V	Benzene, 1-me	gasoline	C10H14
22	10,432	10,360	10,500	3115269	3,73	1425318	3,56	2,19		Benzene, 1-me	gasoline	C10H14
23	10,984	10,960	11,020	107118	0,13	75809	0,19	1,41	MI	Benzene, 1-me	gasoline	C10H14
24	11,058	11,015	11,090	317661	0,38	153653	0,38	2,07	V	Benzene, 1-eth	diesel	C15H17
25	11,126	11,090	11,175	199781	0,24	93980	0,23	2,13	V	Benzene, 1-eth	diesel	C15H17
26	11,219	11,175	11,295	2077464	2,49	988256	2,47	2,10	V	Benzene, 4-eth	gasoline	C10H14
27	11,400	11,365	11,435	106923	0,13	56826	0,14	1,88	MI	Benzene, 4-eth	gasoline	C10H14
28	11,595	11,550	11,680	1135605	1,36	505200	1,26	2,25		Undecane	jet fuel	C11H24
29	11,840	11,760	11,890	163280	0,20	50820	0,13	3,21	MI	Undecane	jet fuel	C11H24
30	11,979	11,935	12,005	99102	0,12	61669	0,15	1,61	MI	Undecane	jet fuel	C11H24
31	12,438	12,405	12,485	583770	0,70	340399	0,85	1,71		Benzene, (1,1-	jet fuel	C11H16
32	12,551	12,520	12,615	545281	0,65	290264	0,72	1,88		Benzene, 1-eth	diesel	C15H17
33	12,690	12,655	12,730	570542	0,68	337795	0,84	1,69		Benzene, (1,1-	jet fuel	C11H16
34	12,821	12,730	12,875	607126	0,73	322509	0,80	1,88		Benzenepropan	gasoline	C10H12O
35	12,954	12,890	13,005	667547	0,80	238978	0,60	2,79		Benzene, (1-m	gasoline	C9H12
36	13,126	13,100	13,170	163800	0,20	84935	0,21	1,93	MI	Benzene, (1-m	gasoline	C9H12
37	13,287	13,250	13,330	368328	0,44	214725	0,54	1,72		Benzene, (1,1-	jet fuel	C11H16
38	13,525	13,495	13,550	298313	0,36	172984	0,43	1,72		1H-Indene, 2,3	jet fuel	C11H14

39	13,617	13,550	13,665	665231	0,80	256867	0,64	2,59	V	1H-Indene, 2,3	jet fuel	C11H14
40	13,806	13,755	13,835	307613	0,37	127085	0,32	2,42		1H-Indene, 2,3	jet fuel	C11H14
41	14,449	14,410	14,480	143230	0,17	68406	0,17	2,09	MI	1H-Indene, 2,3	jet fuel	C11H14
42	14,777	14,745	14,805	337112	0,40	144107	0,36	2,34	V	1H-Indene, 2,3	jet fuel	C11H14
43	14,825	14,805	14,865	183530	0,22	90735	0,23	2,02	V	1H-Indene, 2,3	jet fuel	C11H14
44	15,175	15,130	15,200	350025	0,42	153002	0,38	2,29		1H-Indene, 2,3	jet fuel	C11H14
45	15,231	15,200	15,275	398853	0,48	175291	0,44	2,28	V	1H-Indene, 2,3	jet fuel	C11H14
46	15,460	15,415	15,510	386318	0,46	154140	0,38	2,51		1H-Indene, 2,3	jet fuel	C11H14
47	15,708	15,670	15,790	226850	0,27	66563	0,17	3,41	MI	1H-Indene, 2,3	jet fuel	C11H14
48	15,980	15,905	16,025	182345	0,22	54797	0,14	3,33	MI	1H-Indene, 2,3	jet fuel	C11H14
49	16,059	16,020	16,125	123021	0,15	46859	0,12	2,63	MI	1H-Indene, 2,3	jet fuel	C11H14
50	16,624	16,550	16,700	1838228	2,20	644594	1,61	2,85		Naphthalene, 1	jet fuel	C11H10
51	17,096	17,060	17,130	215867	0,26	113663	0,28	1,90		Naphthalene, 1	jet fuel	C11H10
52	17,311	17,270	17,355	79743	0,10	52040	0,13	1,53	MI	Naphthalene, 1	jet fuel	C11H10
53	17,426	17,370	17,460	126759	0,15	62149	0,16	2,04	MI	Naphthalene, 1	jet fuel	C11H10
54	17,651	17,615	17,685	70986	0,08	50256	0,13	1,41	MI	Naphthalene, 1	jet fuel	C11H10
55	17,766	17,730	17,825	103343	0,12	51881	0,13	1,99	MI	Naphthalene, 1	jet fuel	C11H10
56	18,083	17,980	18,105	334895	0,40	89935	0,22	3,72		Naphthalene, 1	jet fuel	C11H10
57	18,344	18,305	18,380	314563	0,38	208521	0,52	1,51		Naphthalene, 1	jet fuel	C11H10
58	18,528	18,480	18,570	1495968	1,79	646121	1,61	2,32		Naphthalene, 1	jet fuel	C11H10
59	18,600	18,580	18,625	88218	0,11	69869	0,17	1,26	MI	Naphthalene, 1	jet fuel	C11H10
60	18,682	18,650	18,705	93194	0,11	71618	0,18	1,30	MI	Naphthalene, 1	jet fuel	C11H10
61	18,742	18,715	18,770	60880	0,07	46863	0,12	1,30	MI	Naphthalene, 1	jet fuel	C11H10
62	18,844	18,800	18,860	106031	0,13	69192	0,17	1,53	MI	Naphthalene, 1	jet fuel	C11H10
63	18,986	18,970	19,015	77497	0,09	53087	0,13	1,46	MI	Naphthalene, 1	jet fuel	C11H10
64	19,426	19,395	19,445	632806	0,76	542279	1,35	1,17		2-Tridecanone	jet fuel	C13H26O
65	19,456	19,445	19,485	256825	0,31	252030	0,63	1,02	V	2-Tridecanone	jet fuel	C13H26O
66	19,620	19,590	19,665	815725	0,98	492883	1,23	1,66		Naphthalene, 2	jet fuel	C11H12
67	20,017	19,975	20,045	96381	0,12	45500	0,11	2,12	MI	Naphthalene, 2	jet fuel	C11H12
68	20,068	20,050	20,100	70592	0,08	51867	0,13	1,36	MI	Naphthalene, 2	jet fuel	C11H12
69	20,253	20,125	20,270	2027050	2,43	546987	1,37	3,71		Dodecanoic ac	jet fuel	C12H24O2
70	20,284	20,270	20,330	588129	0,70	443321	1,11	1,33	V	3-Tetradecanon	diesel	C14H28O
71	20,490	20,455	20,505	233409	0,28	143174	0,36	1,63		3-Tetradecanon	diesel	C14H28O
72	20,944	20,890	20,955	77426	0,09	58264	0,15	1,33	MI	3-Tetradecanon	diesel	C14H28O
73	21,058	21,020	21,075	183184	0,22	115694	0,29	1,58		3-Tetradecanon	diesel	C14H28O
74	21,151	21,130	21,170	95934	0,11	75581	0,19	1,27	MI	3-Tetradecanon	diesel	C14H28O
75	21,259	21,225	21,285	318145	0,38	217521	0,54	1,46		2-Heptadecano	diesel	C17H34O
76	21,996	21,925	22,030	124236	0,15	55868	0,14	2,22	MI	2-Heptadecano	diesel	C17H34O
77	22,279	22,245	22,325	132039	0,16	85773	0,21	1,54	MI	2-Heptadecano	diesel	C17H34O
78	23,033	23,000	23,065	194740	0,23	106785	0,27	1,82		2-Heptadecano	diesel	C17H34O
79	23,143	23,120	23,185	76201	0,09	61589	0,15	1,24	MI	2-Heptadecano	diesel	C17H34O
80	23,199	23,180	23,235	79676	0,10	59945	0,15	1,33	MI	2-Heptadecano	diesel	C17H34O
81	23,293	23,265	23,335	129394	0,15	88700	0,22	1,46	MI	2-Heptadecano	diesel	C17H34O
82	23,708	23,655	23,740	83709	0,10	42799	0,11	1,96	MI	2-Heptadecano	diesel	C17H34O
83	23,899	23,865	23,920	89840	0,11	70763	0,18	1,27	MI	2-Heptadecano	diesel	C17H34O
84	23,997	23,955	24,030	89753	0,11	56823	0,14	1,58	MI	2-Heptadecano	diesel	C17H34O
85	24,064	24,020	24,075	91149	0,11	68323	0,17	1,33	MI	2-Heptadecano	diesel	C17H34O
86	27,762	27,720	27,805	118351	0,14	75007	0,19	1,58	MI	2-Heptadecano	diesel	C17H34O
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Analyzed	: 2018-06-09 01:15:18 AM												
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min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical formula	
1	3,536	3,495	3,615	12782467	18,16	7227033	21,29	1,77		Toluene	gasoline	C7H8	
2	5,266	5,235	5,335	842606	1,20	494185	1,46	1,71		Ethylbenzene	gasoline	C8H10	
3	5,462	5,410	5,545	20760014	29,50	7635240	22,49	2,72		Benzene, 1,3-d	gasoline	C8H10	
4	5,904	5,865	6,020	6960106	9,89	4348680	12,81	1,60	S	Benzene, 1,3-d	gasoline	C8H10	
5	7,266	7,240	7,295	117144	0,17	64235	0,19	1,82		Benzene, 1,3-d	gasoline	C8H10	

6	7,460	7,410	7,505	1141170	1,62	565836	1,67	2,02		Benzene, 1-eth	diesel	C15H17
7	7,546	7,505	7,600	513200	0,73	231065	0,68	2,22	V	Benzene, (1-m	gasoline	C9H12
8	7,699	7,655	7,770	1634279	2,32	796672	2,35	2,05		Benzene, 1,2,3	gasoline	C9H12
9	7,950	7,920	8,000	316445	0,45	144161	0,42	2,20	V	Benzene, 1-eth	diesel	C15H17
10	8,456	8,400	8,515	5221916	7,42	2227021	6,56	2,34		Benzene, 1,2,3	gasoline	C9H12
11	9,368	9,325	9,430	684592	0,97	267273	0,79	2,56	V	Benzene, 1,2,3	gasoline	C9H12
12	9,797	9,750	9,850	226829	0,32	93083	0,27	2,44	S	Benzene, 1,2,3	gasoline	C9H12
13	10,275	10,250	10,325	144366	0,21	60906	0,18	2,37	V	Benzene, 1,2,3	gasoline	C9H12
14	10,425	10,395	10,440	75318	0,11	43677	0,13	1,72		Benzene, 1,2,3	gasoline	C9H12
15	10,465	10,440	10,515	306722	0,44	148851	0,44	2,06	V	Benzene, 1,2,3	gasoline	C9H12
16	10,976	10,940	11,005	143749	0,20	78394	0,23	1,83		Benzene, 1,2,3	gasoline	C9H12
17	11,046	11,005	11,090	153683	0,22	71075	0,21	2,16	V	Benzene, 1,2,3	gasoline	C9H12
18	11,120	11,090	11,165	78598	0,11	34744	0,10	2,26	V	Benzene, 1,2,3	gasoline	C9H12
19	11,211	11,175	11,275	329868	0,47	134501	0,40	2,45		o-Cymene	gasoline	C10H14
20	12,012	11,980	12,040	138038	0,20	73707	0,22	1,87		o-Cymene	gasoline	C10H14
21	12,095	12,060	12,135	203863	0,29	108518	0,32	1,88		o-Cymene	gasoline	C10H14
22	12,547	12,520	12,575	205738	0,29	106099	0,31	1,94	V	o-Cymene	gasoline	C10H14
23	12,748	12,665	12,775	141166	0,20	56809	0,17	2,48	V	o-Cymene	gasoline	C10H14
24	12,809	12,775	12,870	100359	0,14	35738	0,11	2,81	V	o-Cymene	gasoline	C10H14
25	12,945	12,890	12,995	73535	0,10	24945	0,07	2,95		o-Cymene	gasoline	C10H14
26	13,608	13,545	13,690	3097269	4,40	1508052	4,44	2,05	SV	Naphthalene	gasoline	C10H8
27	16,626	16,560	16,710	5052685	7,18	2196600	6,47	2,30		Naphthalene, 1	jet fuel	C11H10
28	16,960	16,905	17,025	2072076	2,94	1059794	3,12	1,96		Naphthalene, 2	jet fuel	C11H12
29	18,339	18,305	18,400	362505	0,52	171925	0,51	2,11		Naphthalene, 1	jet fuel	C11H10
30	18,499	18,400	18,510	899607	1,28	664739	1,96	1,35	V	Naphthalene, 2	jet fuel	C11H12
31	18,524	18,510	18,570	965356	1,37	707204	2,08	1,37	V	Naphthalene, 2	jet fuel	C11H12
32	18,673	18,590	18,705	1410082	2,00	901618	2,66	1,56	V	Naphthalene, 1	jet fuel	C11H10
33	18,730	18,705	18,780	791646	1,12	582208	1,71	1,36	SV	Naphthalene, 1	jet fuel	C11H10
34	18,940	18,900	19,000	428724	0,61	156849	0,46	2,73		Naphthalene, 1	jet fuel	C11H10
35	19,100	19,075	19,130	117290	0,17	80329	0,24	1,46		Naphthalene, 1	jet fuel	C11H10
36	19,621	19,560	19,665	265920	0,38	111299	0,33	2,39	V	Naphthalene, 1	jet fuel	C11H10

37	19,699	19,665	19,725	67611	0,10	29784	0,09	2,27	V	Naphthalene, 1	jet fuel	C11H10
38	19,810	19,725	19,845	237134	0,34	144599	0,43	1,64	V	Naphthalene, 2	jet fuel	C11H12
39	19,879	19,845	19,915	191684	0,27	119456	0,35	1,60	V	Naphthalene, 2	jet fuel	C11H12
40	20,005	19,915	20,045	148134	0,21	78795	0,23	1,88	V	Naphthalene, 2	jet fuel	C11H12
41	20,062	20,045	20,095	117875	0,17	74784	0,22	1,58	V	Naphthalene, 2	jet fuel	C11H12
42	20,166	20,115	20,190	115869	0,16	48139	0,14	2,41	V	Naphthalene, 2	jet fuel	C11H12
43	21,310	21,265	21,380	79561	0,11	17246	0,05	4,61	V	Naphthalene, 2	jet fuel	C11H12
44	25,560	25,470	25,590	72438	0,10	15836	0,05	4,57		Naphthalene, 2	jet fuel	C11H12
45	28,170	28,095	28,200	83295	0,12	21335	0,06	3,90		Naphthalene, 2	jet fuel	C11H12
46	28,876	28,790	28,885	66471	0,09	26921	0,08	2,47	V	Naphthalene, 2	jet fuel	C11H12
47	29,010	28,965	29,060	196705	0,28	59437	0,18	3,31	V	Naphthalene, 2	jet fuel	C11H12
48	29,146	29,060	29,155	71760	0,10	33490	0,10	2,14	V	Naphthalene, 2	jet fuel	C11H12
49	29,888	29,860	29,920	90532	0,13	45978	0,14	1,97		Naphthalene, 2	jet fuel	C11H12
50	30,782	30,735	30,810	78600	0,11	22153	0,07	3,55	V	Naphthalene, 2	jet fuel	C11H12
				70376600	100,00	33951018	100,00					

Sample Information													
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Analyzed	: 2018-06-09 07:57:06 AM												
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min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	product	chemical formula	
1	3,536	3,500	3,620	3704147	15,39	2030328	16,28	1,82		Toluene	gasoline	C7H8	
2	3,906	3,880	3,945	99230	0,41	56738	0,45	1,75		Toluene	gasoline	C7H8	
3	4,063	4,030	4,110	160493	0,67	75537	0,61	2,12		Toluene	gasoline	C7H8	
4	5,269	5,240	5,320	790209	3,28	487759	3,91	1,62		Ethylbenzene	gasoline	C8H10	
5	5,451	5,405	5,530	4250883	17,66	1661565	13,32	2,56		Benzene, 1,3-d	gasoline	C8H10	

6	5,843	5,815	5,870	103914	0,43	69114	0,55	1,50		Benzene, 1,3-d	gasoline	C8H10
7	5,903	5,870	5,950	1202674	5,00	687519	5,51	1,75	V	o-Xylene	gasoline	C8H10
8	6,011	5,950	6,050	385927	1,60	204479	1,64	1,89	V	Nonane	gasoline	C9H20
9	7,270	7,245	7,300	169584	0,70	98884	0,79	1,71		Nonane	gasoline	C9H20
10	7,465	7,425	7,510	910593	3,78	463317	3,71	1,97		Benzene, 1-eth	diesel	C15H17
11	7,551	7,510	7,605	708852	2,94	344422	2,76	2,06	V	Benzene, 1-eth	diesel	C15H17
12	7,714	7,680	7,750	97811	0,41	49679	0,40	1,97		Benzene, 1-eth	diesel	C15H17
13	8,318	8,285	8,360	156711	0,65	78748	0,63	1,99		Benzene, 1-eth	diesel	C15H17
14	8,454	8,360	8,515	1189562	4,94	481359	3,86	2,47	V	Benzene, 1,2,3	gasoline	C9H12
15	8,599	8,515	8,635	110748	0,46	50969	0,41	2,17	V	Benzene, 1,2,3	gasoline	C9H12
16	9,809	9,770	9,840	105223	0,44	48404	0,39	2,17		Benzene, 1,2,3	gasoline	C9H12
17	10,183	10,160	10,215	85250	0,35	42646	0,34	2,00		Benzene, 1,2,3	gasoline	C9H12
18	10,283	10,235	10,325	225041	0,93	100735	0,81	2,23		Benzene, 1,2,3	gasoline	C9H12
19	10,428	10,390	10,465	321179	1,33	155408	1,25	2,07		Benzene, 1-me	gasoline	C10H14
20	11,120	11,095	11,190	97574	0,41	36308	0,29	2,69		Benzene, 1-me	gasoline	C10H14
21	11,217	11,190	11,275	236355	0,98	102702	0,82	2,30	V	Benzene, 1-me	gasoline	C10H14
22	11,384	11,345	11,445	483397	2,01	180592	1,45	2,68		2-Undecene, (Z)	jet fuel	C11H22
23	11,499	11,470	11,530	120683	0,50	64733	0,52	1,86		2-Undecene, (Z)	jet fuel	C11H22
24	11,595	11,550	11,645	1508763	6,27	875947	7,02	1,72		Undecane	jet fuel	C11H24
25	11,711	11,645	11,745	108130	0,45	60159	0,48	1,80	V	Undecane	jet fuel	C11H24
26	12,168	12,140	12,200	113804	0,47	70794	0,57	1,61		Undecane	jet fuel	C11H24
27	12,553	12,525	12,590	137585	0,57	75648	0,61	1,82		Undecane	jet fuel	C11H24
28	13,620	13,575	13,640	341293	1,42	148726	1,19	2,29		Undecane	jet fuel	C11H24
29	13,656	13,640	13,705	396469	1,65	191410	1,53	2,07	V	Undecane	jet fuel	C11H24
30	16,386	16,365	16,430	80174	0,33	45696	0,37	1,75		Undecane	jet fuel	C11H24
31	16,595	16,560	16,670	972949	4,04	308898	2,48	3,15		Hexadecane	diesel	C16H34
32	16,970	16,935	17,080	155019	0,64	49440	0,40	3,14		Hexadecane	diesel	C16H34
33	17,103	17,080	17,135	128702	0,53	69892	0,56	1,84	V	Hexadecane	diesel	C16H34
34	18,214	18,195	18,240	54072	0,22	53647	0,43	1,01		Hexadecane	diesel	C16H34
35	18,350	18,335	18,445	74227	0,31	39148	0,31	1,90	V	Hexadecane	diesel	C16H34
36	18,467	18,445	18,490	306611	1,27	235530	1,89	1,30		Hexadecanal	diesel	C16H34

37	18,506	18,490	18,575	291335	1,21	100440	0,81	2,90	V	Hexadecanal	diesel	C16H34
38	19,425	19,405	19,435	139400	0,58	127464	1,02	1,09		Hexadecanal	diesel	C16H34
39	19,454	19,435	19,480	315040	1,31	292918	2,35	1,08	V	Tetradecane	jet fuel	C13H28
40	19,624	19,595	19,655	105365	0,44	50318	0,40	2,09		Tetradecane	jet fuel	C13H28
41	19,680	19,655	19,730	1054694	4,38	944218	7,57	1,12	V	Methyl tetrade	diesel	C15H30O2
42	20,200	20,130	20,260	780709	3,24	228282	1,83	3,42		Dodecanoic ac	jet fuel	C12H24O2
43	20,284	20,260	20,315	156167	0,65	101585	0,81	1,54	V	Dodecanoic ac	jet fuel	C12H24O2
44	20,486	20,465	20,510	118810	0,49	103237	0,83	1,15		Dodecanoic ac	jet fuel	C12H24O2
45	21,253	21,225	21,290	165747	0,69	105477	0,85	1,57		Hexadecane	diesel	C16H34
46	21,497	21,465	21,540	347938	1,45	225429	1,81	1,54		Methyl tetrade	diesel	C15H30O2
47	23,475	23,445	23,505	161762	0,67	131757	1,06	1,23		Methyl tetrade	diesel	C15H30O2
48	24,616	24,600	24,655	65848	0,27	64246	0,52	1,02		Methyl tetrade	diesel	C15H30O2
49	27,762	27,735	27,800	178187	0,74	135528	1,09	1,31		12-Tricosanone	waxes and related products	C23H46O
50	28,901	28,875	28,935	96918	0,40	64998	0,52	1,49		12-Tricosanone	waxes and related products	C23H46O
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Analyzed	: 2018-06-09 09:26:16 PM												
Sample Type	: Unknown												
Level #	: 1												
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Sample ID	: 2N2												
IS Amount	: [1]=1												
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1	3,543	3,490	3,620	18779596	26,22	10366458	32,20	1,81		Toluene	gasoline	C7H8	
2	5,268	5,225	5,320	2061080	2,88	1265301	3,93	1,63		Ethylbenzene	gasoline	C8H10	
3	5,461	5,405	5,535	14478594	20,22	5627229	17,48	2,57		Benzene, 1,3-d	gasoline	C8H10	
4	5,904	5,870	5,945	3826279	5,34	2596498	8,07	1,47		Benzene, 1,3-d	gasoline	C8H10	
5	6,546	6,525	6,575	60668	0,08	39345	0,12	1,54		Benzene, 1,3-d	gasoline	C8H10	

6	7,267	7,235	7,310	171117	0,24	95195	0,30	1,80		Benzene, 1,3-d	gasoline	C8H10
7	7,467	7,415	7,510	2437796	3,40	1228672	3,82	1,98		Benzene, 1-eth	diesel	C15H17
8	7,551	7,510	7,610	1042318	1,46	526493	1,64	1,98	V	Benzene, 1-eth	diesel	C15H17
9	7,705	7,670	7,755	280044	0,39	146030	0,45	1,92		Mesitylene	gasoline	C8H80
10	7,959	7,915	8,005	224826	0,31	105294	0,33	2,14		Benzene, (1-m	gasoline	C9H12
11	8,456	8,395	8,515	2554169	3,57	1087950	3,38	2,35		Benzene, 1,2,3	gasoline	C9H12
12	9,315	9,290	9,355	83692	0,12	31180	0,10	2,68		Benzene, 1,2,3	gasoline	C9H12
13	9,379	9,355	9,425	114205	0,16	51244	0,16	2,23	V	Benzene, 1,2,3	gasoline	C9H12
14	9,495	9,425	9,535	57114	0,08	23063	0,07	2,48	V	Benzene, 1,2,3	gasoline	C9H12
15	9,802	9,755	9,865	258726	0,36	106874	0,33	2,42		Benzene, 1,2,3	gasoline	C9H12
16	10,181	10,155	10,230	191572	0,27	95766	0,30	2,00	V	Benzene, 1,2,3	gasoline	C9H12
17	10,281	10,250	10,325	236986	0,33	108496	0,34	2,18		Benzene, 1,2,3	gasoline	C9H12
18	10,427	10,325	10,460	245684	0,34	99785	0,31	2,46	V	Benzene, 1,2,3	gasoline	C9H12
19	10,470	10,460	10,515	87919	0,12	49466	0,15	1,78	V	Benzene, 1,2,3	gasoline	C9H12
20	10,982	10,955	11,005	64429	0,09	35930	0,11	1,79		Benzene, 1,2,3	gasoline	C9H12
21	11,059	11,005	11,090	100194	0,14	42579	0,13	2,35	V	Benzene, 1,2,3	gasoline	C9H12
22	11,126	11,090	11,165	119067	0,17	50628	0,16	2,35		Benzene, 1,2,3	gasoline	C9H12
23	11,218	11,165	11,270	427909	0,60	169719	0,53	2,52	V	Benzene, 4-eth	gasoline	C10H14
24	11,592	11,565	11,620	129764	0,18	77982	0,24	1,66		Benzene, 4-eth	gasoline	C10H14
25	12,552	12,520	12,595	257560	0,36	138463	0,43	1,86		Benzene, 4-eth	gasoline	C10H14
26	12,750	12,730	12,795	65961	0,09	20996	0,07	3,14		Benzene, 4-eth	gasoline	C10H14
27	12,827	12,795	12,860	70828	0,10	36550	0,11	1,94	V	Benzene, 4-eth	gasoline	C10H14
28	12,945	12,880	13,015	97692	0,14	23848	0,07	4,10		Benzene, 4-eth	gasoline	C10H14
29	13,522	13,490	13,555	96934	0,14	50311	0,16	1,93		Benzene, 4-eth	gasoline	C10H14
30	13,615	13,555	13,680	1515542	2,12	705350	2,19	2,15		Naphthalene	gasoline	C10H8
31	16,630	16,575	16,710	3156147	4,41	1454124	4,52	2,17		Naphthalene, 2	jet fuel	C11H12
32	16,967	16,930	17,015	753452	1,05	383922	1,19	1,96		Naphthalene, 2	jet fuel	C11H12
33	18,346	18,315	18,405	249341	0,35	140322	0,44	1,78		Naphthalene, 2	jet fuel	C11H12
34	18,507	18,405	18,515	536715	0,75	428810	1,33	1,25	V	Naphthalene, 2	jet fuel	C11H12
35	18,529	18,515	18,580	758202	1,06	494328	1,54	1,53	V	Naphthalene, 1	jet fuel	C11H10
36	18,680	18,580	18,715	571472	0,80	367463	1,14	1,56	V	Naphthalene, 1	jet fuel	C11H10

37	18,740	18,715	18,785	356092	0,50	239370	0,74	1,49	V	Naphthalene, 1	jet fuel	C11H10
38	18,951	18,910	18,995	153638	0,21	63451	0,20	2,42		Naphthalene, 1	jet fuel	C11H10
39	19,628	19,590	19,665	240268	0,34	125408	0,39	1,92		Naphthalene, 2	jet fuel	C11H12
40	19,687	19,665	19,730	117101	0,16	91048	0,28	1,29	V	Naphthalene, 2	jet fuel	C11H12
41	19,891	19,855	19,930	59881	0,08	36216	0,11	1,65		Naphthalene, 2	jet fuel	C11H12
42	20,074	20,035	20,100	52400	0,07	32825	0,10	1,60	V	Naphthalene, 2	jet fuel	C11H12
43	28,729	28,660	28,735	585741	0,82	215890	0,67	2,71		Naphthalene, 2	jet fuel	C11H12
44	28,740	28,735	28,745	116298	0,16	200947	0,62	0,58	V	Naphthalene, 2	jet fuel	C11H12
45	28,845	28,745	28,930	4469868	6,24	668022	2,08	6,69	V	Naphthalene, 2	jet fuel	C11H12
46	28,953	28,930	28,960	515935	0,72	301510	0,94	1,71	V	Naphthalene, 2	jet fuel	C11H12
47	28,985	28,960	29,035	1125323	1,57	303352	0,94	3,71	V	Naphthalene, 2	jet fuel	C11H12
48	29,145	29,035	29,160	2679401	3,74	545724	1,70	4,91	V	Naphthalene, 2	jet fuel	C11H12
49	29,194	29,160	29,250	2967044	4,14	723040	2,25	4,10	V	Naphthalene, 2	jet fuel	C11H12
50	29,276	29,250	29,440	2019687	2,82	372625	1,16	5,42	V	Naphthalene, 2	jet fuel	C11H12
				71622271	100,00	32191092	100,00					

Sample Information													
Analyzed by	: Neal												
Analyzed	: 2018-06-09 05:26:04 PM												
Sample Type	: Unknown												
Level #	: 1												
Sample Name	: 2N1 rpt 1 20 BAR IN NI/HZSM-5 AT 300 DEGREESE												
Sample ID	: 2N1 rpt 1												
IS Amount	: [1]=1												
Sample Amount	: 1												
Dilution Factor	: 1												
Vial #	: 5												
Injection Volume	: 1.00												
Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\2N1 rpt 1.qgd												
Org Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\2N1 rpt 1.qgd												
Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Org Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Report File	:												
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt												
Modified by	: Neal												
Modified	: 2018-06-09 07:33:25 PM												
Chromatogram 2N1 rpt 1 C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\2N1 rpt 1.qgd													
TIC													
8 356 891													
10,0 20,0 30,0													
min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%		A/H	Mark	Name	product	chemical formula
1	3,533	3,490	3,615	4878963	2,83	2689872	7,50	1,81			Toluene	gasoline	C7H8
2	5,270	5,240	5,335	1901062	1,10	1164754	3,25	1,63			Ethylbenzene	gasoline	C8H10
3	5,455	5,410	5,535	5955834	3,46	2323059	6,48	2,56			Benzene, 1,3-d	gasoline	C8H10
4	5,906	5,870	5,955	1097014	0,64	652479	1,82	1,68			Benzene, 1,3-d	gasoline	C8H10
5	6,014	5,955	6,055	337639	0,20	189781	0,53	1,78	V		Decane	gasoline	C10H22

6	7,272	7,230	7,320	512996	0,30	249374	0,70	2,06			Benzene, propy	gasoline	C9H12
7	7,475	7,430	7,520	2850520	1,65	1455073	4,06	1,96			Benzene, 1-eth	diesel	C15H17
8	7,560	7,520	7,605	2224656	1,29	1127634	3,14	1,97	V		Benzene, 1-eth	diesel	C15H17
9	8,464	8,415	8,520	1167911	0,68	471254	1,31	2,48			Benzene, 1,2,3	gasoline	C9H12
10	10,189	10,155	10,235	552153	0,32	267700	0,75	2,06			Benzene, 1,2-d	gasoline	C10H14
11	10,290	10,235	10,340	720529	0,42	352218	0,98	2,05			Benzene, 1-me	gasoline	C10H14
12	10,436	10,385	10,480	1553008	0,90	746906	2,08	2,08			Benzene, 1-me	gasoline	C10H14
13	11,220	11,185	11,285	751217	0,44	351034	0,98	2,14			Benzene, 2-eth	diesel	C10H14
14	11,393	11,285	11,445	309292	0,18	123579	0,34	2,50			Benzene, 2-eth	diesel	C10H14
15	11,605	11,560	11,675	2345750	1,36	1291470	3,60	1,82			Undecane	jet fuel	C11H24
16	12,442	12,410	12,475	233876	0,14	145653	0,41	1,61			Undecane	jet fuel	C11H24
17	12,557	12,520	12,590	194474	0,11	109700	0,31	1,77			Benzene, 1-eth	diesel	C15H17
18	12,695	12,665	12,730	334788	0,19	209207	0,58	1,60			Benzene, (1,1-dimethyl propyl	jet fuel	C11H16
19	12,826	12,795	12,865	286741	0,17	165709	0,46	1,73			Benzene, (1,1-dimethyl propyl	jet fuel	C11H16
20	12,964	12,885	13,010	396858	0,23	145238	0,40	2,73			Benzene, (1,1-dimethyl propyl	jet fuel	C11H16
21	14,344	13,515	14,420	15146772	8,79	676989	1,89	22,37	MI		Octanoic acid	gasoline	C8H16O2
22	14,784	14,760	14,865	290449	0,17	70702	0,20	4,11			Octanoic acid	gasoline	C8H16O2
23	15,181	15,145	15,210	274501	0,16	123607	0,34	2,22			Octanoic acid	gasoline	C8H16O2
24	15,238	15,210	15,285	284667	0,17	126962	0,35	2,24	V		Octanoic acid	gasoline	C8H16O2
25	15,469	15,430	15,515	302090	0,18	132745	0,37	2,28			Octanoic acid	gasoline	C8H16O2
26	16,606	16,555	16,685	1407135	0,82	553181	1,54	2,54			Hexadecane	diesel	C16H34
27	18,186	18,010	18,200	1507179	0,88	211262	0,59	7,13	MI		Hexadecane	diesel	C16H34
28	18,260	18,200	18,285	2331765	1,35	468242	1,31	4,98	MI		Hexadecane	diesel	C16H34
29	18,318	18,285	18,430	1980261	1,15	571432	1,59	3,47	MI		n-Decanoic aci	gasoline	C10H20O2
30	18,473	18,445	18,495	267690	0,16	205010	0,57	1,31			Dodecanal	jet fuel	C12H24O
31	18,510	18,495	18,525	181294	0,11	121641	0,34	1,49	V		Dodecanal	jet fuel	C12H24O
32	18,537	18,525	18,580	249895	0,15	184036	0,51	1,36	V		Dodecanal	jet fuel	C12H24O
33	19,432	19,400	19,445	825211	0,48	700807	1,95	1,18			2-Tridecanone	jet fuel	C13H26O
34	19,460	19,445	19,495	619799	0,36	596700	1,66	1,04	V		Tetradecane	jet fuel	C13H28
35	19,625	19,595	19,665	320519	0,19	185066	0,52	1,73			Napththalene, 2	diesel	C11H12
36	20,290	20,125	20,310	6648637	3,86	1872843	5,22	3,55			3-Tetradecanon	diesel	C14H28O

37	20,536	20,310	21,020	83847984	48,68	7250386	20,21	11,56	V	Dodecanoic ac	jet fuel	C12H24O2
38	21,040	21,020	21,140	2384200	1,38	607254	1,69	3,93	V	Decanoic acid,	jet fuel	C12H24O2
39	21,170	21,140	21,230	1169653	0,68	401326	1,12	2,91	V	Decanoic acid,	jet fuel	C12H24O2
40	21,276	21,230	21,330	855039	0,50	328302	0,92	2,60	V	2-Heptadecano	diesel	C17H34O
41	22,219	22,030	22,490	5927851	3,44	543032	1,51	10,92		Tetradecanoic acid	diesel	C14H28O
42	22,540	22,490	22,640	503376	0,29	125677	0,35	4,01	V	Tetradecanoic acid	diesel	C14H28O
43	23,058	22,990	23,140	485803	0,28	180088	0,50	2,70		Tetradecanoic acid	diesel	C14H28O
44	23,180	23,140	23,280	275507	0,16	89269	0,25	3,09	V	Tetradecanoic acid	diesel	C14H28O
45	24,628	24,560	24,670	733606	0,43	391198	1,09	1,88		8-Pentadecano	diesel	C15H30O
46	26,195	26,150	26,240	560476	0,33	289149	0,81	1,94		12-Tricosanone	waxes and related products	C23H46O
47	27,773	27,710	27,840	2251679	1,31	1528881	4,26	1,47		12-Tricosanone	waxes and related products	C23H46O
48	28,905	28,850	28,960	1889557	1,10	1243294	3,47	1,52		12-Tricosanone	waxes and related products	C23H46O
49	29,030	28,960	29,120	425357	0,25	122605	0,34	3,47	V	12-Tricosanone	waxes and related products	C23H46O
50	29,851	29,590	30,010	7719518	4,48	817887	2,28	9,44		12-Tricosanone	waxes and related products	C23H46O
51	30,092	30,010	30,260	1968865	1,14	919152	2,56	2,14	V	14-Heptacosan	waxes and related products	C27H54O
				#####	100,00	35870419	100,00					

4H4= 450 IN HZSM-5 AT 450 DEGREESE

Pe	R.Tim	I.Time	F.Tim	Area	Area%	Height	Heig	A/	chem	M	Name
1	4,469	4,440	4,590	11400317	4,66	5609325	5,81	2,03	C8H10		Ethylbenzene
2	4,658	4,590	4,820	50935041	20,80	18332063	18,98	2,78	C10H10	V	o-Xylene
3	5,101	5,060	5,215	16387943	6,69	9163052	9,49	1,79	C9H10		Benzene, 1,3-dimethyl-
4	5,726	5,695	5,780	654944	0,27	317539	0,33	2,06	C9H10		Benzene, (1-methylethyl)-
5	6,334	6,300	6,400	1674201	0,68	631170	0,65	2,65	C9H10		Benzene, propyl-
6	6,487	6,400	6,525	18705655	7,64	9680303	10,02	1,93	C9H10	V	Benzene, 1-ethyl-4-
7	6,554	6,525	6,660	9818069	4,01	4146533	4,29	2,37	C9H10	V	Benzene, 1-ethyl-4-
8	6,689	6,660	6,765	1754953	0,72	685132	0,71	2,56	C9H12	V	Mesitylene
9	6,889	6,855	6,975	2650341	1,08	1051635	1,09	2,52	C9H10		Benzene, 1-ethyl-4-
10	7,286	7,240	7,410	19404218	7,93	8247390	8,54	2,35	C9H10		Benzene, 1,2,3-
11	8,465	8,420	8,555	1864961	0,76	545479	0,56	3,42	C10H12		Indane
12	8,901	8,850	8,975	2241305	0,92	628023	0,65	3,57	C9H10		Benzene, 1,2-diethyl-
13	9,026	8,975	9,120	2349559	0,96	638728	0,66	3,68	C9H10	V	Benzene, 1-methyl-4-
14	9,194	9,120	9,225	1786931	0,73	644034	0,67	2,77	C9H10	V	Benzene, 1-methyl-4-
15	9,270	9,225	9,335	1462714	0,60	332381	0,34	4,40	C9H10	V	Benzene, 1-ethyl-2,4-
16	9,851	9,815	9,890	1030283	0,42	383128	0,40	2,69	C9H10		Benzene, 2-ethyl-1,4-
17	9,927	9,890	9,965	1327612	0,54	462363	0,48	2,87	C9H10	V	Benzene, 1-methyl-3-(1-
18	9,994	9,965	10,055	1107210	0,45	378186	0,39	2,93	C10H12	V	Indan, 1-methyl-
19	10,107	10,055	10,215	5827141	2,38	1911774	1,98	3,05	C9H10	V	Benzene, 1-ethyl-3,5-
20	10,580	10,535	10,645	967969	0,40	304944	0,32	3,17	C9H10		Benzene, 1-ethyl-3,5-
21	11,471	11,435	11,510	505184	0,21	224262	0,23	2,25	C9H10		Benzene, (1,1-
22	11,566	11,510	11,675	3678092	1,50	1155060	1,20	3,18	C9H10	V	Benzene, 1-ethenyl-4-
23	11,782	11,750	11,855	701019	0,29	278857	0,29	2,51	C9H10		Benzene, 1-ethenyl-4-
24	11,890	11,865	12,015	231991	0,09	123738	0,13	1,87	C9H10		Benzene, 1-ethenyl-4-
25	12,075	12,015	12,140	1299476	0,53	357019	0,37	3,64	C11H10	V	Naphthalene, 1,2,3,4-
26	12,370	12,335	12,430	552431	0,23	243689	0,25	2,27	C9H10		Benzene, (1,1-
27	12,573	12,535	12,600	1213566	0,50	606355	0,63	2,00	C10H8		1H-Indene, 2,3-dihydro-
28	12,634	12,600	12,795	10363933	4,23	3005691	3,11	3,45	C10H8	V	Naphthalene
29	12,836	12,795	12,885	573729	0,23	199127	0,21	2,88	C11H10	V	Naphthalene, 1,2,3,4-
30	15,248	15,195	15,440	21208697	8,66	5847171	6,05	3,63	C11H10		Naphthalene, 1-methyl-

31	15,701	15,655	15,800	2879887	1,18	767227	0,79	3,75	C11H10		Naphthalene, 1-methyl-
32	17,576	17,545	17,700	3574371	1,46	956421	0,99	3,74	C11H10		Naphthalene, 2-ethyl-
33	17,755	17,700	17,765	4467966	1,82	3052704	3,16	1,46	C11H10	V	Naphthalene, 1,7-
34	17,779	17,765	17,900	8107726	3,31	2918953	3,02	2,78	C11H10	V	Naphthalene, 1,7-
35	17,955	17,900	18,000	4065697	1,66	1787453	1,85	2,27	C11H10	V	Naphthalene, 1,3-
36	18,027	18,000	18,115	2637567	1,08	951621	0,99	2,77	C11H10	V	Naphthalene, 1,6-
37	18,276	18,240	18,320	630000	0,26	297113	0,31	2,12	C11H10		Naphthalene, 1,3-
38	18,867	18,825	18,925	912972	0,37	231474	0,24	3,94	C11H10		Naphthalene, 1,3-
39	19,002	18,925	^{19,095}	4384988	1,79	1458425	1,51	3,01	C11H10	V	Naphthalene, 2-(1-
40	19,124	19,095	19,170	934329	0,38	504082	0,52	1,85	C12H24O2	V	Dodecanoic acid,
41	19,221	19,170	19,260	1061282	0,43	423409	0,44	2,51	C11H10	V	Naphthalene, 2,3,6-
42	19,295	19,260	19,350	713083	0,29	299960	0,31	2,38	C11H10	V	Naphthalene, 2,3,6-
43	19,428	19,350	19,460	272647	0,11	171434	0,18	1,59	C11H10	V	Naphthalene, 2,3,6-
44	19,489	19,460	19,545	652326	0,27	300554	0,31	2,17	C11H10	V	Naphthalene, 2,3,6-
45	19,638	19,565	19,735	11255393	4,60	4173482	4,32	2,70	C12H24O2		Dodecanoic acid
46	21,218	21,190	21,285	1576189	0,64	683617	0,71	2,31	C14H28O		Tetradecanoic acid
47	27,102	27,070	27,155	884000	0,36	493221	0,51	1,79	C23H46O		12-Tricosanone
48	28,340	28,310	28,370	644060	0,26	496567	0,51	1,30	C23H46O		12-Tricosanone
49	28,543	28,440	28,575	975386	0,40	192102	0,20	5,08	C23H46O		12-Tricosanone
50	29,383	29,355	29,430	523631	0,21	307005	0,32	1,71	C27H54O		14-Heptacosanone
				244832985	100,00	96600975	100,00				

Sample Information													
Analyzed by	: Neal												
Analyzed	: 2018-06-09 05:31:01 AM												
Sample Type	: Unknown												
Level #	: 1												
Sample Name	40Bar HZSM-5 AT 400 DEGREESE												
Sample ID	: 4H3												
IS Amount	: [1]=1												
Sample Amount	: 1												
Dilution Factor	: 1												
Vial #	: 17												
Injection Volume	: 0.10												
Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4H3.qgd												
Org Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4H3.qgd												
Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Org Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Report File	:												
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt												
Modified by	: Neal												
Modified	: 2018-06-09 08:32:56 PM												
Chromatogram 4H3 C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4H3.qgd													
TIC													
16 888 302													
10,0	20,0	30,0											
min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	products	chemical formula	
1	3,553	3,495	3,640	32082137	26,09	16292107	27,86	1,97		Toluene	gasoline	C7H8	
2	4,061	4,035	4,120	144107	0,12	58550	0,10	2,46		Toluene	gasoline	C7H8	
3	5,273	5,225	5,340	5080962	4,13	2945242	5,04	1,73		Ethylbenzene	gasoline	C8H10	
4	5,474	5,415	5,530	26923226	21,89	9495733	16,24	2,84		Benzene, 1,3-d	gasoline	C8H10	
5	5,912	5,865	5,950	7705808	6,27	4893712	8,37	1,57	V	Benzene, 1,3-d	gasoline	C8H10	

6	6,015	5,950	6,045	241802	0,20	117715	0,20	2,05	V	Benzene, 1,3-d	gasoline	C8H10
7	6,547	6,510	6,580	208670	0,17	128669	0,22	1,62		Benzene, (1-m	gasoline	C9H12
8	7,268	7,225	7,325	600491	0,49	300237	0,51	2,00		Benzene, propy	gasoline	C9H12
9	7,475	7,420	7,515	5380393	4,37	2661904	4,55	2,02		Benzene, 1-eth	diesel	C15H17
10	7,557	7,515	7,615	2886193	2,35	1500502	2,57	1,92	V	Benzene, 1-eth	diesel	C15H17
11	7,707	7,615	7,760	665094	0,54	300430	0,51	2,21	V	Mesitylene	gasoline	C8H80
12	7,958	7,915	8,010	809243	0,66	373556	0,64	2,17		Benzene, 1-eth	diesel	C15H17
13	8,467	8,400	8,530	5703249	4,64	2363112	4,04	2,41		Benzene, 1,2,3	gasoline	C9H12
14	9,323	9,275	9,345	191627	0,16	77388	0,13	2,48		Benzene, 1,2,3	gasoline	C9H12
15	9,374	9,345	9,420	298842	0,24	122180	0,21	2,45	V	Benzene, 1,2,3	gasoline	C9H12
16	9,488	9,420	9,535	148645	0,12	58799	0,10	2,53	V	Benzene, 1,2,3	gasoline	C9H12
17	9,804	9,760	9,860	670604	0,55	286500	0,49	2,34		Indane	gasoline	C10H12
18	10,118	10,085	10,140	147113	0,12	66762	0,11	2,20		Benzene, 1,2,3	gasoline	C9H12
19	10,180	10,140	10,235	518129	0,42	225154	0,39	2,30	V	Benzene, 1,2-d	gasoline	C10H14
20	10,281	10,235	10,335	672964	0,55	306393	0,52	2,20	V	Benzene, 1-me	gasoline	C10H14
21	10,426	10,335	10,455	991425	0,81	452017	0,77	2,19	V	Benzene, 1-me	gasoline	C10H14
22	10,475	10,455	10,535	293485	0,24	135599	0,23	2,16	V	Benzene, 1-me	gasoline	C10H14
23	10,981	10,945	11,015	248085	0,20	132368	0,23	1,87		Benzene, 2-eth	gasoline	C10H14
24	11,054	11,015	11,095	295704	0,24	159858	0,27	1,85	V	o-Cymene	gasoline	C10H14
25	11,127	11,095	11,170	277793	0,23	137946	0,24	2,01	V	1H-Indene, 2,3	jet fuel	C11H14
26	11,215	11,170	11,290	1269610	1,03	506453	0,87	2,51	V	Benzene, 4-eth	jet fuel	C12H14
27	11,592	11,555	11,620	356465	0,29	197088	0,34	1,81		Undecane	jet fuel	C11H24
28	12,550	12,515	12,600	637568	0,52	349531	0,60	1,82		Benzene, 1-eth	diesel	C15H17
29	12,687	12,655	12,715	144411	0,12	89024	0,15	1,62		Benzene, 1-eth	diesel	C15H17
30	12,748	12,715	12,790	343551	0,28	140884	0,24	2,44	V	Benzene, 1-eth	diesel	C15H17
31	12,819	12,790	12,850	274039	0,22	147960	0,25	1,85	V	Benzene, 1-eth	diesel	C15H17
32	12,951	12,850	13,005	335476	0,27	99347	0,17	3,38	V	Benzene, 1-eth	diesel	C15H17
33	13,533	13,500	13,560	216172	0,18	103144	0,18	2,10		Benzene, 1-eth	diesel	C15H17
34	13,617	13,560	13,680	5116268	4,16	2293074	3,92	2,23	V	Naphthalene	jet fuel	C11H14
35	16,645	16,565	16,700	8913052	7,25	3807285	6,51	2,34		Naphthalene, 2	jet fuel	C11H10
36	16,968	16,920	17,020	2075033	1,69	1060074	1,81	1,96		Naphthalene, 2	jet fuel	C11H10

37	18,341	18,305	18,395	1042543	0,85	578717	0,99	1,80		Naphthalene, 2	jet fuel	C11H10
38	18,504	18,395	18,515	1638823	1,33	1139694	1,95	1,44	V	Naphthalene, 2	jet fuel	C11H10
39	18,529	18,515	18,585	1711184	1,39	1304705	2,23	1,31	V	Naphthalene, 2	jet fuel	C11H10
40	18,676	18,585	18,710	1372050	1,12	885364	1,51	1,55	V	Naphthalene, 1	jet fuel	C11H10
41	18,734	18,710	18,780	856331	0,70	615854	1,05	1,39	V	Naphthalene, 2	jet fuel	C11H10
42	18,936	18,900	18,985	468780	0,38	217915	0,37	2,15		Naphthalene, 1	jet fuel	C11H10
43	19,455	19,440	19,490	142374	0,12	101896	0,17	1,40	V	Naphthalene, 1	jet fuel	C11H10
44	19,617	19,530	19,670	1005266	0,82	494214	0,85	2,03	V	Naphthalene, 2	jet fuel	C11H10
45	19,814	19,800	19,845	159566	0,13	129755	0,22	1,23	V	Naphthalene, 2	jet fuel	C11H10
46	19,880	19,845	19,905	162326	0,13	114409	0,20	1,42	V	Naphthalene, 2	jet fuel	C11H10
47	20,060	20,035	20,085	172886	0,14	140248	0,24	1,23		Naphthalene, 2	jet fuel	C11H10
48	20,171	20,085	20,210	186034	0,15	60378	0,10	3,08	V	Naphthalene, 2	jet fuel	C11H10
49	20,491	20,445	20,540	244875	0,20	87818	0,15	2,79	V	Naphthalene, 2	jet fuel	C11H10
50	29,714	29,650	29,810	952870	0,77	211719	0,36	4,50		Naphthalene, 2	jet fuel	C11H10
				#####	100,00	58468983	100,00					

6	5,906	5,875	5,955	773843	0,78	470333	1,43	1,65		o-Xylene	gasoline	C8H10
7	6,012	5,955	6,045	338425	0,34	179485	0,55	1,89	V	Decane	gasoline	C10H22
8	6,551	6,525	6,590	113841	0,12	58691	0,18	1,94	MI	Decane	gasoline	C10H22
9	7,274	7,240	7,315	329391	0,33	183963	0,56	1,79		Benzene, propy	gasoline	C9H12
10	7,471	7,430	7,515	1789771	1,81	910804	2,78	1,97		Benzene, 1-eth	diesel	C15H17
11	7,556	7,515	7,610	1490101	1,51	739854	2,26	2,01	V	Benzene, 1-eth	diesel	C15H17
12	7,968	7,940	8,035	100661	0,10	48753	0,15	2,06	MI	Benzene, 1-eth	diesel	C15H17
13	8,463	8,415	8,525	1098810	1,11	445606	1,36	2,47		Benzene, 1,2,3	gasoline	C9H12
14	8,610	8,560	8,650	219296	0,22	83991	0,26	2,61	MI	Benzene, 1,2,3	gasoline	C9H12
15	8,751	8,690	8,820	351643	0,36	82660	0,25	4,25	MI	Benzene, 1,2,3	gasoline	C9H12
16	9,812	9,765	9,865	160354	0,16	63648	0,19	2,52	MI	Benzene, 1,2,3	gasoline	C9H12
17	10,189	10,155	10,225	271772	0,28	136768	0,42	1,99		Benzene, 1,2-d	gasoline	C10H14
18	10,288	10,225	10,335	459150	0,47	221295	0,67	2,07	V	Benzene, 1-me	gasoline	C10H14
19	10,432	10,385	10,480	927766	0,94	446054	1,36	2,08		Benzene, 1-me	gasoline	C10H14
20	11,129	11,090	11,165	220225	0,22	115814	0,35	1,90	MI	Benzene, 1-me	gasoline	C10H14
21	11,220	11,165	11,280	542030	0,55	249713	0,76	2,17		o-Cymene	gasoline	C10H14
22	11,391	11,345	11,440	215777	0,22	94610	0,29	2,28	MI	o-Cymene	gasoline	C10H14
23	11,599	11,555	11,640	1090911	1,11	622795	1,90	1,75		Undecane	jet fuel	C11H24
24	12,169	12,135	12,205	222701	0,23	135253	0,41	1,65		Octanoic acid,	gasoline	C8H16O
25	12,441	12,415	12,490	136004	0,14	76060	0,23	1,79	MI	Octanoic acid,	gasoline	C8H16O
26	12,557	12,530	12,600	190867	0,19	119718	0,37	1,59	MI	Octanoic acid,	gasoline	C8H16O
27	12,694	12,660	12,735	175991	0,18	108506	0,33	1,62	MI	Octanoic acid,	gasoline	C8H16O
28	12,827	12,795	12,865	195218	0,20	106739	0,33	1,83	MI	Octanoic acid,	gasoline	C8H16O
29	12,961	12,890	13,020	279227	0,28	88629	0,27	3,15	MI	Octanoic acid,	gasoline	C8H16O
30	13,294	13,250	13,340	102120	0,10	57828	0,18	1,77	MI	Octanoic acid,	gasoline	C8H16O
31	14,202	13,720	14,305	9666597	9,79	512539	1,56	18,86	MI	Octanoic acid	gasoline	C8H16O
32	16,604	16,560	16,625	563289	0,57	264100	0,81	2,13		Hexadecane	diesel	C16H34
33	16,640	16,625	16,685	262941	0,27	144292	0,44	1,82	V	Hexadecane	diesel	C16H34
34	17,106	17,075	17,140	223604	0,23	132868	0,41	1,68		Hexadecane	diesel	C16H34
35	18,145	18,120	18,165	233249	0,24	105046	0,32	2,22		Hexadecane	diesel	C16H34
36	18,185	18,165	18,200	415514	0,42	216762	0,66	1,92	V	Hexadecane	diesel	C16H34

37	18,215	18,200	18,240	748795	0,76	314995	0,96	2,38	V	Hexadecane	diesel	C16H34
38	18,268	18,240	18,315	1015665	1,03	479949	1,46	2,12	V	n-Decanoic aci	gasoline	C10H20O2
39	18,474	18,445	18,495	875543	0,89	711344	2,17	1,23		Dodecanal	jet fuel	C12H24O
40	18,537	18,495	18,565	368445	0,37	145311	0,44	2,54	V	Naphthalene, 1	jet fuel	C11H10
41	19,239	19,210	19,270	206337	0,21	115378	0,35	1,79		Naphthalene, 1	jet fuel	C11H10
42	19,430	19,400	19,445	553175	0,56	498178	1,52	1,11		2-Tridecanone	jet fuel	C13H26O
43	19,458	19,445	19,485	262974	0,27	242350	0,74	1,09	V	Tetradecane	jet fuel	C13H28
44	19,686	19,665	19,720	1512404	1,53	1397429	4,26	1,08	V	Dodecanoic ac	jet fuel	C12H24O2
45	20,291	20,150	20,310	4311896	4,37	1224410	3,73	3,52		3-Tetradecanon	diesel	C14H28O
46	20,482	20,310	20,745	37412995	37,91	4739086	14,45	7,89	V	Dodecanoic ac	jet fuel	C12H24O2
47	21,034	21,010	21,085	568932	0,58	326878	1,00	1,74		Decanoic acid,	jet fuel	C12H24O2
48	21,162	21,085	21,210	527150	0,53	308335	0,94	1,71	V	Dodecanoic ac	jet fuel	C12H24O2
49	21,274	21,235	21,330	386727	0,39	201380	0,61	1,92		2-Heptadecano	jet fuel	C13H26O
50	21,511	21,475	21,550	566337	0,57	414318	1,26	1,37		Methyl tetrade	diesel	C15H30
51	22,538	22,505	22,585	319790	0,32	187957	0,57	1,70		Methyl tetrade	diesel	C15H30
52	22,794	22,760	22,840	519950	0,53	357783	1,09	1,45		Dodecanoyl ch	jet fuel	C12H23ClO
53	23,055	23,005	23,105	395013	0,40	186276	0,57	2,12		Dodecanoyl ch	jet fuel	C12H23ClO
54	23,486	23,445	23,520	339412	0,34	244261	0,74	1,39		Pentadecanoic	diesel	C16H32O2
55	24,420	24,400	24,565	293662	0,30	144072	0,44	2,04		Pentadecanoic	diesel	C16H32O2
56	24,581	24,565	24,600	321115	0,33	255935	0,78	1,25	V	Pentadecanoic	diesel	C16H32O2
57	24,625	24,600	24,665	680676	0,69	479511	1,46	1,42	V	8-Pentadecano	diesel	C15H30O
58	25,324	25,290	25,350	633701	0,64	468890	1,43	1,35		Cetene	diesel	C16H32
59	25,583	25,460	25,660	712676	0,72	187214	0,57	3,81	MI	Cetene	diesel	C16H32
60	26,189	26,150	26,245	595428	0,60	331702	1,01	1,80		10-Nonadecan	waxes and related products	C19H38O
61	26,993	26,945	27,045	672038	0,68	277935	0,85	2,42		Lauryl acetate	waxes and related products	C14H28O2
62	27,770	27,735	27,810	1969587	2,00	1538961	4,69	1,28		12-Tricosanone	waxes and related products	C23H46O
63	28,288	28,245	28,355	2157242	2,19	1699566	5,18	1,27		Lauryl acetate	diesel	C14H28O2
64	28,903	28,855	28,950	1613848	1,64	1208321	3,68	1,34		12-Tricosanone	waxes and related products	C23H46O
65	29,374	29,330	29,445	1860290	1,88	1141324	3,48	1,63		Acetic acid n-o	waxes and related products	C20H40O2
66	29,758	29,675	29,805	1233319	1,25	217971	0,66	5,66	MI	Acetic acid n-o	waxes and related products	C20H40O2
67	29,909	29,840	29,990	1195416	1,21	247892	0,76	4,82	MI	Acetic acid n-o	waxes and related products	C20H40O2
68	30,090	30,055	30,130	1086462	1,10	726948	2,22	1,49		12-Tricosanone	waxes and related products	C23H46O
69	30,648	30,605	30,705	1226121	1,24	645461	1,97	1,90		Acetic acid n-o	waxes and related products	C20H40O2
				98691832	100,00	32793639	100,00					

4H1= 40 BAR IN HZSM-5 AT 300 DEGREESE

Pe	R.Tim	I.Time	F.Ti	Area	Are	Height	Heig	A/H	chem formu	Mark	Name
1	4,687	4,655	4,750	366739	1,37	121816	1,64	3,01	C2H24O2	S	Dodecanoic acid
2	19,638	19,580	19,845	12437544	46,34	4363569	58,60	2,85	C2H24O2	S	Dodecanoic acid
3	21,216	21,185	21,335	2098634	7,82	736816	9,89	2,85	C14H28O2		Tetradecanoic acid
4	23,189	23,155	23,285	437747	1,63	102232	1,37	4,28	C14H28O2		Tetradecanoic
5	27,110	27,065	27,150	208091	0,78	123434	1,66	1,69	C14H28O2		Tetradecanoic
6	28,342	28,320	28,380	204427	0,76	127367	1,71	1,61	C14H28O2		Tetradecanoic
7	31,920	31,915	32,000	225284	0,84	26943	0,36	8,36	C14H28O2		Tetradecanoic
8	32,165	32,000	32,185	4061387	15,13	625127	8,39	6,50	C14H28O2		Tetradecanoic
9	32,196	32,185	32,255	2580767	9,62	645289	8,67	4,00	C14H28O2		Tetradecanoic
10	32,290	32,255	32,510	4218380	15,72	573943	7,71	7,35	C14H28O2		Tetradecanoic
				26839000	100,00	7446536	100,00				

6	6,547	6,510	6,590	365594	0,17	220170	0,25	1,66	benzene,(1-methylethyl	C9H12	gasoline
7	7,270	7,235	7,320	769881	0,36	394729	0,45	1,95	benzene,propyl	C9H12	gasoline
8	7,480	7,425	7,520	6363558	2,94	3235970	3,65	1,97	benzene,1 ethyl-3methyl	C9H12	gasoline
9	7,560	7,520	7,615	3060864	1,41	1650156	1,86	1,85	benzene,1-ethyl-2methyl	C9H12	gasoline
10	7,712	7,615	7,760	2440230	1,13	1253171	1,41	1,95	benzene ,1,2,3-trimethyl	C9H12	gasoline
11	7,960	7,920	8,005	969440	0,45	473492	0,53	2,05	benzene,1 ethyl-4methyl	C9H12	gasoline
12	8,486	8,405	8,540	11451837	5,29	4400550	4,97	2,60	benzene,1,2,3 trimethyl	C9H12	gasoline
13	9,315	9,290	9,340	210334	0,10	88510	0,10	2,38	benzene,1,2,3 trimethyl	C9H12	gasoline
14	9,377	9,340	9,435	976032	0,45	405700	0,46	2,41	benzene,1,2,3 trimethyl	C9H12	gasoline
15	9,803	9,760	9,855	789584	0,36	345586	0,39	2,28	benzene,(1-methylethyl)	C9H12	gasoline
16	10,182	10,155	10,225	311788	0,14	163744	0,18	1,90	indane	C9H10	gasoline
17	10,284	10,245	10,330	739690	0,34	374452	0,42	1,98	benzene 1,2 diethyl	C10H14	gasoline
18	10,428	10,330	10,450	780504	0,36	370519	0,42	2,11	benzene 1-methyl-3propy	C10H14	gasoline
19	10,474	10,450	10,520	697233	0,32	335863	0,38	2,08	benzene 1-methyl-3propy	C10H14	gasoline
20	10,983	10,945	11,015	327459	0,15	182550	0,21	1,79	benzene 2 thyl	C10H14	gasoline
21	11,054	11,015	11,090	355297	0,16	187708	0,21	1,89	o-cymene	C10H14	gasoline
22	11,127	11,090	11,170	383358	0,18	195934	0,22	1,96	benzene,(2-methyl-1-propyl)	C10H12	gasoline
23	11,218	11,170	11,280	1346937	0,62	534732	0,60	2,52	benzene,4-ethyl-1	C10H14	gasoline
24	11,595	11,565	11,620	221989	0,10	149149	0,17	1,49	undane\$\$n-undecane	C11H24	gasoline
25	12,018	11,985	12,060	177143	0,08	103403	0,12	1,71	o-cymene	C10H14	gasoline
26	12,101	12,075	12,140	188601	0,09	108291	0,12	1,74	benzene,1,2,4,5-tetramet	C10H14	gasoline
27	12,551	12,520	12,605	848983	0,39	483807	0,55	1,75	benzene,1-ethyl-4-ethyl	C10H14	gasoline
28	12,755	12,720	12,790	269569	0,12	117258	0,13	2,30	benzene,1-ethyl-4-ethyl	C10H14	gasoline
29	12,819	12,790	12,865	250573	0,12	125903	0,14	1,99	benzene,1-ethyl-4-ethyl	C10H14	gasoline
30	13,540	13,505	13,570	272591	0,13	144533	0,16	1,89	benzene,1-ethyl-4-ethyl	C10H14	gasoline
31	13,629	13,570	13,685	7669311	3,54	3369464	3,80	2,28	naphthalene \$\$albecarbon	C10H8	gasoline
32	16,661	16,570	16,715	14929217	6,90	5670537	6,40	2,63	naphthalene,2-methyl	C11H10	jet fuel
33	16,977	16,920	17,035	5010165	2,32	2547175	2,88	1,97	naphthalene,1-methyl	C11H10	jet fuel
34	18,343	18,305	18,410	1418395	0,66	786555	0,89	1,80	naphthalene,2-ethyl	C12H12	jet fuel
35	18,511	18,410	18,520	2993624	1,38	1902236	2,15	1,57	naphthalene,1,2-dimethyl	C12H12	jet fuel

36	18,536	18,520	18,580	3288592	1,52	2484435	2,80	1,32	1,3 -dimethyl		C12H12	jet fuel
37	18,683	18,580	18,715	3764494	1,74	2330088	2,63	1,62	1,3 -dimethyl		C12H12	jet fuel
38	18,740	18,715	18,785	2432529	1,12	1952029	2,20	1,25	1,3 -dimethyl		C12H12	jet fuel
39	18,938	18,900	19,000	1085482	0,50	409557	0,46	2,65	1,3 -dimethyl		C12H12	jet fuel
40	19,102	19,075	19,130	213956	0,10	151521	0,17	1,41	1,3 -dimethyl		C12H12	jet fuel
41	19,457	19,440	19,485	115574	0,05	114489	0,13	1,01	1,3 -dimethyl		C12H12	jet fuel
42	19,508	19,485	19,530	87709	0,04	74683	0,08	1,17	1,3 -dimethyl		C12H12	jet fuel
43	19,619	19,530	19,665	1205418	0,56	576202	0,65	2,09	naphthalene,2-(1-methylethyl)		C13H14	jet fuel
44	19,682	19,665	19,725	233717	0,11	151911	0,17	1,54	naphthalene,2-(1-methylethyl)		C13H14	jet fuel
45	19,780	19,725	19,795	179289	0,08	137536	0,16	1,30	naphthalene,2-(1-methylethyl)		C13H14	jet fuel
46	19,812	19,795	19,845	448063	0,21	383069	0,43	1,17	naphthalene		C13H14	jet fuel
47	19,878	19,845	19,910	424015	0,20	316390	0,36	1,34	naphthalene		C13H14	jet fuel
48	20,005	19,910	20,035	300440	0,14	211543	0,24	1,42	naphthalene		C13H14	jet fuel
49	20,059	20,035	20,095	321559	0,15	254844	0,29	1,26	naphthalene		C13H14	jet fuel
50	20,171	20,125	20,195	220861	0,10	106024	0,12	2,08	naphthalene		C13H14	jet fuel
				#####	100,00	88587057	100,00					

6	7,270	7,230	7,315	790666	0,45	434048	0,54	1,82		Benzene, propy	gasoline	C9H12
7	7,479	7,420	7,520	6512222	3,69	3178097	3,98	2,05		Benzene, 1-eth	diesel	C15H17
8	7,561	7,520	7,605	3715553	2,11	1935478	2,42	1,92	V	Benzene, 1-eth	diesel	C15H17
9	7,708	7,605	7,760	1055791	0,60	491416	0,61	2,15	V	Mesitylene	gasoline	C8H80
10	7,959	7,915	8,010	1076853	0,61	503399	0,63	2,14		Benzene, 1-eth	diesel	C15H17
11	8,475	8,405	8,535	7727362	4,38	3208246	4,01	2,41		Benzene, 1,2,3	gasoline	C9H12
12	9,315	9,285	9,350	225583	0,13	87615	0,11	2,57		Benzene, 1,2,3	gasoline	C9H12
13	9,372	9,350	9,420	392321	0,22	171101	0,21	2,29	V	Benzene, (1-m	gasoline	C9H12
14	9,804	9,755	9,860	1041436	0,59	455129	0,57	2,29		Indane	gasoline	C10H12
15	10,180	10,145	10,220	367615	0,21	185202	0,23	1,98		Indane	gasoline	C10H12
16	10,284	10,240	10,335	753016	0,43	349305	0,44	2,16		Benzene, 1-me	gasoline	C10H14
17	10,428	10,335	10,455	1148728	0,65	510289	0,64	2,25		Benzene, 1-me	gasoline	C10H14
18	10,474	10,455	10,525	479687	0,27	242598	0,30	1,98	V	o-Cymene	gasoline	C10H14
19	10,981	10,945	11,020	296421	0,17	166733	0,21	1,78		Benzene, 2-eth	gasoline	C6H6
20	11,054	11,020	11,090	352671	0,20	186797	0,23	1,89		o-Cymene	gasoline	C10H14
21	11,128	11,095	11,175	461014	0,26	252929	0,32	1,82		1H-Indene, 2,3	jet fuel	C11H12
22	11,220	11,175	11,285	1582126	0,90	594940	0,74	2,66	V	Benzene, 4-eth	gasoline	C6H6
23	12,551	12,520	12,595	977388	0,55	555883	0,70	1,76		Benzene, 1-eth	diesel	C15H17
24	12,750	12,720	12,785	388929	0,22	166502	0,21	2,34		Benzene, 1-eth	diesel	C15H17
25	12,815	12,785	12,860	359486	0,20	180180	0,23	2,00	V	Benzene, 1-eth	diesel	C15H17
26	12,935	12,880	13,005	436319	0,25	129377	0,16	3,37		Benzene, (1-m	gasoline	C9H12
27	13,536	13,500	13,565	320260	0,18	158171	0,20	2,02		Benzene, (1-m	gasoline	C9H12
28	13,627	13,565	13,690	7599670	4,31	3340913	4,18	2,27	V	Naphthalene	gasoline	C10H8
29	16,664	16,570	16,720	15691376	8,90	5467898	6,84	2,87		Naphthalene, 2	jet fuel	C11H12
30	16,975	16,920	17,030	4007786	2,27	2113703	2,64	1,90		Naphthalene, 2	jet fuel	C11H12
31	18,344	18,305	18,400	2008300	1,14	1158742	1,45	1,73		Naphthalene, 2	jet fuel	C11H12
32	18,471	18,400	18,480	274229	0,16	244939	0,31	1,12	V	Naphthalene, 2	jet fuel	C11H12
33	18,511	18,480	18,520	3168430	1,80	2098575	2,62	1,51	V	Naphthalene, 2	jet fuel	C11H12
34	18,537	18,520	18,580	3789682	2,15	2875192	3,60	1,32	V	Naphthalene, 1	jet fuel	C11H10
35	18,682	18,580	18,715	3278392	1,86	2109709	2,64	1,55	V	Naphthalene, 1	jet fuel	C11H10
36	18,738	18,715	18,785	2152815	1,22	1659520	2,08	1,30	V	Naphthalene, 1	jet fuel	C11H10

37	18,935	18,895	18,990	1005020	0,57	453422	0,57	2,22		Naphthalene, 1	jet fuel	C11H10
38	19,100	19,065	19,145	195081	0,11	117383	0,15	1,66		Naphthalene, 1	jet fuel	C11H10
39	19,426	19,400	19,445	335548	0,19	282681	0,35	1,19		2-Dodecanone	jet fuel	C12H24O
40	19,455	19,445	19,485	173067	0,10	174658	0,22	0,99	V	2-Dodecanone	jet fuel	C12H24O
41	19,619	19,580	19,665	1904974	1,08	931761	1,17	2,04		Naphthalene, 2	jet fuel	C11H12
42	19,781	19,765	19,795	235012	0,13	194734	0,24	1,21	V	Naphthalene, 2	jet fuel	C11H12
43	19,811	19,795	19,845	413477	0,23	341010	0,43	1,21	V	Naphthalene, 2	jet fuel	C11H12
44	19,878	19,845	19,905	378433	0,21	284569	0,36	1,33	V	Naphthalene, 2	jet fuel	C11H12
45	20,008	19,905	20,035	246138	0,14	178769	0,22	1,38	V	4,6,8-Trimethy	jet fuel	C13H14
46	20,058	20,035	20,090	351195	0,20	279082	0,35	1,26		Naphthalene, 2	jet fuel	C11H12
47	20,195	20,095	20,240	994533	0,56	272578	0,34	3,65		Naphthalene, 2	jet fuel	C11H12
48	20,284	20,240	20,305	213961	0,12	126672	0,16	1,69	V	3-Tetradecanon	diesel	C14H28O
49	20,486	20,455	20,535	471380	0,27	256511	0,32	1,84		3-Tetradecanon	diesel	C14H28O
50	27,762	27,740	27,795	195193	0,11	149340	0,19	1,31		12-Tricosanone	waxes and related products	C23H46O
				#####	100,00	79947574	100,00					

3H2= 30 BAR IN HZSM-5 AT 350 DEGREESE

Pe	R.Tim	I.Time	F.Ti	Area	Area%	Height	Heig	A/	chem formula	Mark	Name
1	4,669	4,640	4,755	968600	1,93	299378	1,80	3,24	C8H10		p-Xylene
2	10,564	10,520	10,625	706724	1,41	269249	1,62	2,62	C11H24		Undecane
3	19,673	19,575	19,865	29449346	58,80	7808092	46,93	3,77	C12H24O2		Dodecanoic
4	21,227	21,185	21,360	6061434	12,10	2380089	14,31	2,55	C14H28O		Tetradecanoic
5	23,171	23,140	23,205	695790	1,39	288547	1,73	2,41	C15H30O2		Pentadecanoic
6	24,025	23,995	24,065	614989	1,23	421263	2,53	1,46	C15H30O		8-Pentadeca
7	25,412	25,385	25,465	694648	1,39	385903	2,32	1,80	C23H46O		12-Tricosanon
8	27,095	27,050	27,165	2266795	4,53	1277456	7,68	1,77	C23H46O		12-Tricosanon
9	28,334	28,300	28,385	1698812	3,39	1285683	7,73	1,32	C23H46O		12-Tricosanon
10	28,965	28,870	29,090	2306524	4,61	520515	3,13	4,43	C23H46O		12-Tricosanon
11	29,377	29,340	29,425	1177077	2,35	711454	4,28	1,65	C23H46O		12-Tricosanon
12	30,628	30,590	30,675	556705	1,11	252696	1,52	2,20	C27H54O		14-Heptacosanon
13	32,580	32,520	32,660	969333	1,94	283654	1,70	3,42	C27H54O		14-Heptacosanon
14	34,889	34,825	34,955	1290436	2,58	291792	1,75	4,42	C27H54O		14-Heptacosanon
15	35,002	34,955	35,065	623690	1,25	162382	0,98	3,84	C27H54O		14-Heptacosanon
				50080903	100,00	16638153	100,00				

3H1= 30 BAR IN HZSM-5 AT 300 DEGREESE

P	R.Ti	I.Tim	F.Ti	Area	Area%	Heigh	Height%	A/	chemical formula	M	Name
1	4,489	4,460	4,560	1124523	1,15	387435	1,69	2,90	C8H10		Ethylbenzene
2	4,655	4,620	4,845	3998952	4,10	1174919	5,12	3,40	C8H10	S	p-Xylene
3	5,121	5,090	5,210	665447	0,68	244128	1,06	2,73	C8H10		p-Xylene
4	6,489	6,435	6,535	1860034	1,91	746695	3,25	2,49	C8H10	V	Benzene, 1-ethyl-4-
5	6,564	6,535	6,675	1745198	1,79	432240	1,88	4,04	C8H10	V	Benzene, 1-ethyl-4-
6	7,314	7,275	7,380	556282	0,57	145212	0,63	3,83	C9H12		Mesitylene
7	9,211	9,140	9,270	384687	0,39	93781	0,41	4,10	C9H12	V	Mesitylene
8	10,134	10,090	10,205	433436	0,44	108372	0,47	4,00	C9H12		Mesitylene
9	12,958	12,880	13,040	3603307	3,70	835074	3,64	4,31	C8H16O2		Octanoic
10	13,125	13,110	13,180	297403	0,31	88782	0,39	3,35		V	Octanoic acid
11	17,383	17,340	17,470	2074876	2,13	566407	2,47	3,66	C8H16O2 C12H24O2		n-Decanoic acid
12	17,515	17,500	17,545	332252	0,34	138867	0,60	2,39	C12H24O2	V	n-Decanoic acid
13	17,650	17,595	17,660	264318	0,27	75420	0,33	3,50	C12H24O2	V	n-Decanoic acid
14	17,671	17,660	17,760	315323	0,32	77641	0,34	4,06	C12H24O2	V	n-Decanoic acid
15	17,861	17,775	17,885	244284	0,25	63845	0,28	3,83	C12H24O2	V	n-Decanoic acid

16	19,703	19,575	20,645	51101285	52,44	10310387	44,92	4,96	C12H24O2	S	Dodecanoic acid
17	21,244	21,180	21,670	13634181	13,99	4307873	18,77	3,16	C14H28O	S	Tetradecanoic acid
18	23,168	23,125	23,335	2851940	2,93	783916	3,42	3,64	C16H32O2		n-Hexadecanoic acid
19	23,395	23,335	23,410	222457	0,23	39863	0,17	5,58	C16H32O2	V	n-Hexadecanoic acid
20	27,100	27,070	27,150	449318	0,46	224990	0,98	2,00	C23H46O		12-Tricosanone
21	28,337	28,315	28,395	466350	0,48	285829	1,25	1,63	C23H46O	V	12-Tricosanone
22	29,382	29,350	29,425	352670	0,36	197803	0,86	1,78	C23H46O		12-Tricosanone
23	32,128	31,970	32,135	1359567	1,40	326319	1,42	4,17	C23H46O		12-Tricosanone
24	32,205	32,135	32,255	2025746	2,08	298835	1,30	6,78	C23H46O	V	12-Tricosanone
25	32,298	32,255	32,460	1616478	1,66	245792	1,07	6,58	C23H46O	V	12-Tricosanone
26	32,590	32,515	32,680	478588	0,49	119866	0,52	3,99	C23H46O		12-Tricosanone
27	34,038	33,815	34,100	2669311	2,74	244380	1,06	10,92	C23H46O	V	12-Tricosanone
28	34,130	34,100	34,380	1458494	1,50	199587	0,87	7,31	C23H46O	V	12-Tricosanone
29	34,895	34,790	34,960	574130	0,59	114992	0,50	4,99	C23H46O		12-Tricosanone
30	35,011	34,960	35,080	290391	0,30	74372	0,32	3,90	C23H46O	V	12-Tricosanone
				97451228	100,00	22953622	100,00				

2H4= 20 BAR IN HZSM-5 AT 450 DEGREESE

0	R.Tim	I.Time	F.Ti	Area	Area%	Height	Heigh	A/H	M	Name
1	3,145	3,135	3,270	141214	0,18	30334	0,12	4,66		Hexane, 2,4-
2	3,294	3,270	3,355	337944	0,43	137276	0,54	2,46	V	Hexane, 2,4-
3	3,444	3,415	3,490	133397	0,17	65295	0,26	2,04		Hexane, 2,4-
4	4,481	4,445	4,605	1597396	2,05	532248	2,09	3,00		Ethylbenzene
5	4,648	4,605	4,855	7393304	9,50	2344169	9,19	3,15	SV	o-Xylene
6	5,106	5,075	5,195	1966741	2,53	784635	3,08	2,51	V	o-Xylene
7	5,232	5,195	5,295	582665	0,75	236368	0,93	2,47	V	Nonane
8	6,355	6,325	6,450	267622	0,34	64618	0,25	4,14		Nonane
9	6,489	6,450	6,535	1623864	2,09	659129	2,58	2,46	V	Benzene, 1-ethyl-
10	6,560	6,535	6,660	1291168	1,66	331819	1,30	3,89	V	Benzene, (1-
11	6,730	6,660	6,745	257057	0,33	53023	0,21	4,85	V	Benzene, (1-
12	6,907	6,870	6,945	153394	0,20	53920	0,21	2,84		Benzene, (1-
13	7,290	7,215	7,395	1887316	2,43	558174	2,19	3,38	V	Benzene, 1,2,3-
14	7,422	7,395	7,490	321076	0,41	102013	0,40	3,15	V	Benzene, 1,2,3-
15	10,130	10,085	10,205	352463	0,45	108544	0,43	3,25		Benzene, 1,2,3-
16	10,558	10,515	10,630	1465881	1,88	604160	2,37	2,43		Undecane
17	11,255	11,245	11,340	137380	0,18	33110	0,13	4,15	V	Undecane
18	12,658	12,570	12,675	218132	0,28	61053	0,24	3,57		Undecane
19	12,738	12,685	12,760	198852	0,26	58928	0,23	3,37	V	Undecane
20	12,909	12,875	12,990	1117591	1,44	268041	1,05	4,17		Octanoic acid
21	13,015	12,990	13,045	282951	0,36	97511	0,38	2,90	V	Octanoic acid
22	15,283	15,225	15,290	508625	0,65	220257	0,86	2,31		Octanoic acid
23	15,310	15,290	15,375	719402	0,92	195948	0,77	3,67	V	Octanoic acid
24	17,406	17,360	17,420	187418	0,24	53302	0,21	3,52		Octanoic acid
25	17,831	17,780	17,885	524981	0,67	141052	0,55	3,72		Octanoic acid
26	18,870	18,825	18,960	964902	1,24	418105	1,64	2,31		Hexadecane
27	19,113	19,080	19,205	3435917	4,42	1991460	7,81	1,73		Dodecanoic acid,

28	19,658	19,575	19,975	23161148	29,77	6351289	24,90	3,65	S	Dodecanoic acid
29	20,595	20,570	20,675	332794	0,43	130700	0,51	2,55		Dodecanoic acid
30	20,803	20,765	20,905	1331688	1,71	650016	2,55	2,05	S	Methyl
31	21,219	21,185	21,410	4482852	5,76	1561166	6,12	2,87	S	Tetradecanoic
32	22,798	22,765	22,865	566324	0,73	271070	1,06	2,09		Pentadecanoic
33	23,172	23,135	23,205	488999	0,63	189009	0,74	2,59		n-Hexadecanoic
34	23,230	23,205	23,245	228446	0,29	100305	0,39	2,28	V	n-Hexadecanoic
35	24,024	23,990	24,065	609268	0,78	377008	1,48	1,62	V	8-Pentadecanone
36	24,189	24,105	24,215	198503	0,26	89014	0,35	2,23		8-Pentadecanone
37	24,230	24,215	24,330	154773	0,20	52659	0,21	2,94	V	8-Pentadecanone
38	24,361	24,330	24,390	146724	0,19	99131	0,39	1,48		8-Pentadecanone
39	25,415	25,380	25,480	602481	0,77	331436	1,30	1,82		12-Tricosanone
40	27,095	27,055	27,160	2024947	2,60	1121226	4,40	1,81		12-Tricosanone
41	28,334	28,305	28,400	1610677	2,07	1124449	4,41	1,43		12-Tricosanone
42	28,969	28,820	29,150	5003495	6,43	869931	3,41	5,75	V	12-Tricosanone
43	29,378	29,335	29,430	1105106	1,42	674818	2,65	1,64		12-Tricosanone
44	30,630	30,580	30,670	465993	0,60	227407	0,89	2,05		12-Tricosanone
45	32,304	32,235	32,370	193734	0,25	66493	0,26	2,91		12-Tricosanone
46	32,581	32,505	32,665	575022	0,74	146163	0,57	3,93		12-Tricosanone
47	33,982	33,840	34,070	2168852	2,79	285505	1,12	7,60		12-Tricosanone
48	34,195	34,070	34,395	3056227	3,93	297105	1,16	10,29	V	12-Tricosanone
49	34,884	34,810	34,955	850128	1,09	179730	0,70	4,73		12-Tricosanone
50	35,014	34,955	35,075	385494	0,50	102526	0,40	3,76	V	12-Tricosanone
				77812328	100,00	25502648	100,00			

6	6,549	6,515	6,575	76010	0,15	46033	0,18	1,65		Benzene, 1,3-d	gasoline	C8H10
7	7,270	7,245	7,315	165308	0,33	91430	0,37	1,81	V	Benzene, 1,3-d	gasoline	C8H10
8	7,467	7,415	7,510	2287298	4,59	1118321	4,48	2,05		Benzene, 1-eth	diesel	C15H17
9	7,552	7,510	7,595	927675	1,86	468544	1,87	1,98	V	Benzene, 1-eth	diesel	C15H17
10	7,707	7,680	7,765	200731	0,40	93285	0,37	2,15		Mesitylene	gasoline	C8H80
11	7,958	7,925	8,025	343979	0,69	150610	0,60	2,28		Benzene, (1-m	gasoline	C9H12
12	8,456	8,395	8,520	2786251	5,59	1211196	4,85	2,30		Benzene, 1,2,3	gasoline	C9H12
13	9,381	9,340	9,415	93318	0,19	36999	0,15	2,52	V	Benzene, 1,2,3	gasoline	C9H12
14	9,804	9,755	9,855	333065	0,67	137382	0,55	2,42		Indane	gasoline	C10H12
15	10,184	10,155	10,230	172238	0,35	82851	0,33	2,08	V	Indane	gasoline	C10H12
16	10,283	10,230	10,330	212212	0,43	94373	0,38	2,25	V	Benzene, 1-me	gasoline	C10H14
17	10,430	10,330	10,455	187557	0,38	85590	0,34	2,19	V	Benzene, 1-me	gasoline	C10H14
18	10,472	10,455	10,520	123298	0,25	59960	0,24	2,06	V	Benzene, 1-me	gasoline	C10H14
19	10,984	10,940	11,025	112653	0,23	56589	0,23	1,99		Benzene, 1-me	gasoline	C10H14
20	11,052	11,025	11,090	136062	0,27	66117	0,26	2,06	V	Benzene, 1-me	gasoline	C10H14
21	11,125	11,090	11,175	142749	0,29	66324	0,27	2,15	V	Benzene, 1-me	gasoline	C10H14
22	11,217	11,175	11,290	633891	1,27	224547	0,90	2,82	V	Benzene, 1-eth	diesel	C15H17
23	11,593	11,550	11,735	780134	1,56	445707	1,78	1,75	S	Undecane	jet fuel	C11H24
24	12,020	11,980	12,065	85026	0,17	39996	0,16	2,13		Undecane	jet fuel	C11H24
25	12,552	12,510	12,615	373964	0,75	198482	0,79	1,88		Benzene, 1-eth	diesel	C15H17
26	12,755	12,710	12,805	111952	0,22	46256	0,19	2,42		Benzene, 1-eth	diesel	C15H17
27	12,955	12,920	13,000	67079	0,13	26474	0,11	2,53		Benzene, 1-eth	diesel	C15H17
28	13,525	13,495	13,550	141392	0,28	73359	0,29	1,93		Benzene, 1-eth	diesel	C15H17
29	13,614	13,550	13,670	1050428	2,11	397715	1,59	2,64	V	Naphthalene	gasoline	C10H8
30	14,721	14,695	14,760	65241	0,13	34373	0,14	1,90		Naphthalene	gasoline	C10H8
31	16,622	16,560	16,735	2212421	4,44	828981	3,32	2,67	S	Naphthalene, 1	jet fuel	C11H10
32	16,966	16,925	17,020	370986	0,74	164457	0,66	2,26		Naphthalene, 2	jet fuel	C11H12
33	17,101	17,050	17,135	65683	0,13	24331	0,10	2,70	V	Naphthalene, 2	jet fuel	C11H12
34	18,346	18,305	18,410	303107	0,61	141082	0,56	2,15	V	Naphthalene, 2	jet fuel	C11H12
35	18,502	18,460	18,515	478316	0,96	327866	1,31	1,46		Naphthalene, 2	jet fuel	C11H12
36	18,528	18,515	18,590	535427	1,07	344808	1,38	1,55	SV	Naphthalene, 2	jet fuel	C11H12

37	18,678	18,590	18,715	356852	0,72	212591	0,85	1,68	V	Naphthalene, 1	jet fuel	C11H10
38	18,739	18,715	18,770	226096	0,45	142996	0,57	1,58	V	Naphthalene, 1	jet fuel	C11H10
39	18,955	18,915	19,000	117826	0,24	42237	0,17	2,79		Naphthalene, 1	jet fuel	C11H10
40	19,453	19,420	19,480	283877	0,57	211570	0,85	1,34		Hexadecane	diesel	C16H34
41	19,622	19,595	19,670	285912	0,57	132742	0,53	2,15	V	Naphthalene, 2	jet fuel	C11H12
42	20,168	20,115	20,200	227485	0,46	82428	0,33	2,76	V	Naphthalene, 2	jet fuel	C11H12
43	20,287	20,200	20,315	155053	0,31	56836	0,23	2,73	V	Naphthalene, 2	jet fuel	C11H12
44	21,254	21,185	21,270	107439	0,22	67897	0,27	1,58	V	Naphthalene, 2	jet fuel	C11H12
45	24,615	24,585	24,650	166786	0,33	126638	0,51	1,32		Naphthalene, 2	jet fuel	C11H12
46	26,177	26,140	26,215	170015	0,34	90177	0,36	1,89		Naphthalene, 2	jet fuel	C11H12
47	27,762	27,720	27,840	632378	1,27	449802	1,80	1,41	S	12-Tricosanone	waxes and related products	C23H46
48	28,896	28,870	28,935	431973	0,87	327929	1,31	1,32		14-Heptacosan	waxes and related products	C27H54O
49	29,014	28,985	29,080	61434	0,12	26739	0,11	2,30	V	14-Heptacosan	waxes and related products	C27H54O
50	30,086	30,055	30,135	238175	0,48	113682	0,45	2,10		14-Heptacosan	waxes and related products	C27H54O
				49872471	100,00	24989881	100,00					

2H2= 20 BAR IN HZSM-5 AT 350 DEGREESE

Pe	R.Tim	I.Time	F.Tim	Area	Area%	Height	Heig	A/	chem formula	M	Name
1	4,475	4,440	4,610	2233599	1,50	800055	2,01	2,79	C8H10		Ethylbenzene
2	4,647	4,610	4,870	8374597	5,62	2665564	6,71	3,14	C8H10	SV	p-Xylene
3	5,104	5,075	5,205	2000622	1,34	796434	2,00	2,51	C9H10		Benzene, 1,3-
4	5,234	5,205	5,280	267623	0,18	125716	0,32	2,13	C9H10	V	Benzene, 1,3-
5	6,355	6,310	6,405	230162	0,15	92123	0,23	2,50	C9H10		Benzene, 1,3-
6	6,484	6,405	6,530	2725008	1,83	1237495	3,12	2,20	C9H10	V	Benzene, 1-ethyl-
7	6,554	6,530	6,675	1728140	1,16	553459	1,39	3,12	C9H10	V	Benzene, 1-ethyl-
8	6,909	6,865	6,955	303624	0,20	95862	0,24	3,17	C9H10		Benzene, 1-ethyl-
9	7,291	7,250	7,400	1686021	1,13	485530	1,22	3,47	C9H10		Benzene, 1,2,3-
10	8,015	7,985	8,165	147170	0,10	25779	0,06	5,71	C9H10	V	Benzene, 1,2,3-
11	8,905	8,880	9,005	300018	0,20	54317	0,14	5,52	C9H10		Benzene, 1,2,3-
12	9,050	9,005	9,100	347889	0,23	88457	0,22	3,93	C9H10	V	Benzene, 1,2,3-
13	9,230	9,140	9,255	460478	0,31	106358	0,27	4,33	C9H10	V	Benzene, 1,2,3-
14	9,280	9,255	9,305	222981	0,15	88440	0,22	2,52	C9H10	V	Benzene, 1,2,3-
15	10,005	9,970	10,035	203544	0,14	75657	0,19	2,69	C9H10	V	Benzene, 1,2,3-
16	10,119	10,055	10,200	803785	0,54	235907	0,59	3,41	C9H10	V	Benzene, 1,2,3-
17	10,559	10,515	10,650	1450099	0,97	501949	1,26	2,89	C11H24		Undecane
18	12,658	12,615	12,690	259904	0,17	82008	0,21	3,17	C11H24	V	Undecane
19	13,003	12,880	13,170	6916725	4,64	1213901	3,06	5,70	C8H16O2	S	Octanoic acid
20	15,280	15,230	15,385	2077465	1,39	477011	1,20	4,36	C8H16O2		Octanoic acid
21	17,408	17,350	17,520	4744598	3,18	1181758	2,97	4,01	C10H20O2		n-Decanoic acid
22	17,530	17,520	17,545	248800	0,17	185216	0,47	1,34	C10H20O2	V	n-Decanoic acid
23	17,550	17,545	17,580	280190	0,19	155307	0,39	1,80	C10H20O2	V	n-Decanoic acid
24	17,625	17,580	17,715	1139749	0,76	214820	0,54	5,31	C10H20O2	V	n-Decanoic acid
25	17,817	17,715	17,905	2065251	1,39	375928	0,95	5,49	C10H8	V	Naphthalene, 2,6-
26	17,993	17,945	18,040	223539	0,15	70385	0,18	3,18	C10H8	V	Naphthalene, 2,6-
27	18,870	18,825	18,900	796500	0,53	391471	0,99	2,03	C16H34		Hexadecane

28	18,905	18,900	18,965	181345	0,12	84426	0,21	2,15	C16H34	V	Hexadecane
29	19,029	18,965	^{19,090}	771106	0,52	225805	0,57	3,41	C10H8	V	Naphthalene, 2-(1-
30	19,132	19,090	19,185	287688	0,19	83845	0,21	3,43	C10H8	V	Naphthalene, 2-(1-
31	19,726	19,570	20,120	68421071	45,91	¹²⁶²¹²⁰⁶	31,77	5,42	C12H24O2	S	Dodecanoic acid
32	19,925	19,905	19,970	198733	0,13	112355	0,28	1,77	C12H24O2	T	Dodecanoic acid
33	20,397	20,365	20,485	310264	0,21	118050	0,30	2,63	C12H24O2		Dodecanoic acid
34	20,596	20,575	20,655	301137	0,20	122379	0,31	2,46	C12H24O2		Dodecanoic acid
35	21,260	21,170	^{21,530}	19293245	12,95	5839096	14,70	3,30	C14H28O2	S	Tetradecanoic
36	22,329	22,250	22,365	176984	0,12	52162	0,13	3,39	C14H28O2		Tetradecanoic
37	23,174	23,140	23,345	4880835	3,27	1689598	4,25	2,89	C16H32O2		n-Hexadecanoic
38	23,430	23,345	23,480	378586	0,25	76591	0,19	4,94	C16H32O2	V	n-Hexadecanoic
39	24,025	23,980	24,075	691338	0,46	466383	1,17	1,48	C15H30O		8-Pentadecanone
40	24,671	24,610	24,700	194215	0,13	88270	0,22	2,20	C15H30O		8-Pentadecanone
41	25,415	25,375	25,465	765969	0,51	431926	1,09	1,77	C23H46O		12-Tricosanone
42	27,093	27,055	27,165	2752641	1,85	¹⁵⁷¹³⁹⁰	3,96	1,75	C23H46O		12-Tricosanone
43	27,694	27,660	27,740	195941	0,13	108032	0,27	1,81	C23H46O		12-Tricosanone
44	28,333	28,295	28,385	2248704	1,51	1641848	4,13	1,37	C23H46O		12-Tricosanone
45	29,375	29,320	29,440	1686643	1,13	¹⁰⁴¹⁵⁴⁷	2,62	1,62	C23H46O		12-Tricosanone
46	30,627	30,585	30,680	775510	0,52	370443	0,93	2,09	C23H46O		12-Tricosanone
47	32,295	32,250	32,365	240708	0,16	87858	0,22	2,74	C23H46O		12-Tricosanone
48	32,584	32,515	32,645	669284	0,45	187660	0,47	3,57	C23H46O		12-Tricosanone
49	34,886	34,805	34,955	975996	0,65	209815	0,53	4,65	C23H46O		12-Tricosanone
50	35,003	34,955	35,065	397605	0,27	115794	0,29	3,43	C23H46O	V	12-Tricosanone
				¹⁴⁹⁰³³⁶²⁹	100,00	³⁹⁷²³³⁸⁶	100,00				

6	6,545	6,520	6,565	60727	0,14	44976	0,21	1,35		Benzene, 1,3-d	gasoline	C8H10
7	7,269	7,240	7,300	203689	0,48	121722	0,56	1,67		Benzene, propy	gasoline	C9H12
8	7,465	7,415	7,510	1948467	4,61	995553	4,58	1,96		Benzene, 1-eth	diesel	C15H17
9	7,550	7,510	7,605	1294305	3,06	651074	2,99	1,99	V	Benzene, 1-eth	diesel	C15H17
10	7,705	7,605	7,730	71487	0,17	56678	0,26	1,26	V	Benzene, 1-eth	diesel	C15H17
11	7,956	7,920	8,005	175683	0,42	71676	0,33	2,45		Benzene, 1-eth	diesel	C15H17
12	8,452	8,405	8,520	1714405	4,05	735162	3,38	2,33		Benzene, 1,2,3	gasoline	C9H12
13	9,803	9,755	9,845	246491	0,58	106662	0,49	2,31		Benzene, 1,2,3	gasoline	C9H12
14	10,184	10,155	10,215	125670	0,30	64045	0,29	1,96		Benzene, 1,2,3	gasoline	C9H12
15	10,281	10,245	10,330	221590	0,52	109425	0,50	2,03		Benzene, 1,2,3	gasoline	C9H12
16	10,428	10,385	10,465	391294	0,92	175923	0,81	2,22		Benzene, 1-me	gasoline	C10H14
17	11,050	11,035	11,095	57043	0,13	33340	0,15	1,71		Benzene, 1-me	gasoline	C10H14
18	11,125	11,095	11,150	177481	0,42	99109	0,46	1,79	V	Benzene, 1-me	gasoline	C10H14
19	11,215	11,150	11,280	373011	0,88	152326	0,70	2,45	V	Benzene, 1-eth	diesel	C15H17
20	11,589	11,550	11,620	308072	0,73	181757	0,84	1,69		Undecane	jet fuel	C11H24
21	12,549	12,520	12,580	263364	0,62	156573	0,72	1,68		Benzene, 1-eth	diesel	C15H17
22	12,745	12,715	12,800	73881	0,17	31798	0,15	2,32		Benzene, 1-eth	diesel	C15H17
23	12,815	12,800	12,855	81698	0,19	47532	0,22	1,72	V	Benzene, 1-eth	diesel	C15H17
24	13,521	13,485	13,555	133401	0,32	72800	0,33	1,83		Benzene, 1-eth	diesel	C15H17
25	13,611	13,555	13,690	1150120	2,72	434451	2,00	2,65	V	Naphthalene	gasoline	C10H8
26	16,621	16,555	16,690	1926701	4,55	806771	3,71	2,39		Naphthalene, 2	jet fuel	C11H12
27	16,960	16,925	17,020	471114	1,11	228287	1,05	2,06		Naphthalene, 2	jet fuel	C11H12
28	18,344	18,310	18,385	193591	0,46	107263	0,49	1,80		Naphthalene, 2	jet fuel	C11H12
29	18,470	18,385	18,480	91474	0,22	85741	0,39	1,07	V	Naphthalene, 2	jet fuel	C11H12
30	18,504	18,480	18,515	456605	1,08	314939	1,45	1,45	V	Naphthalene, 2	jet fuel	C11H12

31	18,526	18,515	18,580	462922	1,09	337984	1,55	1,37	V	Naphthalene, 2	jet fuel	C11H12
32	18,676	18,580	18,715	319083	0,75	226272	1,04	1,41	V	Naphthalene, 1	jet fuel	C11H10
33	18,736	18,715	18,775	204756	0,48	140104	0,64	1,46	V	Naphthalene, 1	jet fuel	C11H10
34	19,425	19,405	19,440	73573	0,17	58300	0,27	1,26		Naphthalene, 1	jet fuel	C11H10
35	19,451	19,440	19,470	68971	0,16	73399	0,34	0,94	V	Naphthalene, 1	jet fuel	C11H10
36	19,622	19,595	19,660	215245	0,51	119739	0,55	1,80		Naphthalene, 2	jet fuel	C11H10
37	19,679	19,660	19,710	413116	0,98	403077	1,85	1,02	V	Methyl tetradecane	diesel	C15H30
38	20,205	20,115	20,265	1018811	2,41	291626	1,34	3,49		Undecanoic acid	jet fuel	C11H22
39	20,305	20,265	20,315	156716	0,37	49706	0,23	3,15	V	Undecanoic acid	jet fuel	C11H22
40	20,380	20,315	20,395	106266	0,25	23232	0,11	4,57	V	Undecanoic acid	jet fuel	C11H22
41	20,486	20,470	20,510	55180	0,13	47307	0,22	1,17		Undecanoic acid	jet fuel	C11H22
42	21,495	21,465	21,520	165990	0,39	109649	0,50	1,51		Undecanoic acid	jet fuel	C11H22
43	22,777	22,755	22,810	93467	0,22	60837	0,28	1,54		Undecanoic acid	jet fuel	C11H22
44	23,472	23,445	23,505	87100	0,21	66806	0,31	1,30		Undecanoic acid	jet fuel	C11H22
45	24,614	24,590	24,645	95166	0,22	77373	0,36	1,23		Undecanoic acid	jet fuel	C11H22
46	25,029	25,005	25,050	38668	0,09	33763	0,16	1,15		Undecanoic acid	jet fuel	C11H22
47	26,177	26,155	26,215	65391	0,15	45623	0,21	1,43		Undecanoic acid	jet fuel	C11H22
48	27,761	27,735	27,800	203885	0,48	159534	0,73	1,28		12-Tricosanone	waxes and related products	C23H46
49	28,845	28,815	28,875	121086	0,29	44999	0,21	2,69		12-Tricosanone	waxes and related products	C23H46
50	28,896	28,875	28,930	184410	0,44	96391	0,44	1,91	V	12-Tricosanone	waxes and related products	C23H46
				42307914	100,00	21750853	100,00					

6	7,266	7,230	7,315	384721	0,48	204108	0,51	1,88		Benzene, propy	gasoline	C9H12
7	7,467	7,420	7,515	3482756	4,31	1768548	4,41	1,97		Benzene, 1-eth	diesel	C15H17
8	7,550	7,515	7,600	1831450	2,27	933548	2,33	1,96	V	Benzene, 1-eth	diesel	C15H17
9	7,704	7,600	7,745	208598	0,26	110032	0,27	1,90	V	Mesitylene	gasoline	C8H80
10	7,954	7,910	8,000	469578	0,58	219900	0,55	2,14		Benzene, (1-m	gasoline	C9H12
11	8,458	8,400	8,515	3707365	4,59	1594337	3,98	2,33		Benzene, 1,2,3	gasoline	C9H12
12	9,798	9,755	9,850	602451	0,75	262092	0,65	2,30		Indane	gasoline	C10H12
13	10,121	10,080	10,145	130770	0,16	53316	0,13	2,45		Indane	gasoline	C10H12
14	10,181	10,145	10,230	275823	0,34	117615	0,29	2,35	V	Benzene, 1,2-d	gasoline	C10H14
15	10,278	10,230	10,325	399456	0,49	179868	0,45	2,22		Benzene, 1-me	gasoline	C10H14
16	10,425	10,325	10,455	503017	0,62	208828	0,52	2,41	V	Benzene, 1-me	gasoline	C10H14
17	10,475	10,455	10,515	157457	0,19	75206	0,19	2,09	V	Benzene, 1-me	gasoline	C10H14
18	10,980	10,955	11,020	112093	0,14	63395	0,16	1,77		Benzene, 1-me	gasoline	C10H14
19	11,053	11,020	11,085	153019	0,19	76749	0,19	1,99		Benzene, 1-me	gasoline	C10H14
20	11,123	11,090	11,165	359711	0,45	184077	0,46	1,95		Benzene, 2-but	gasoline	C10H12
21	11,215	11,175	11,280	889371	1,10	320574	0,80	2,77		Benzene, 4-eth	gasoline	C10H14
22	11,590	11,565	11,615	134787	0,17	86962	0,22	1,55		Benzene, 4-eth	gasoline	C10H14
23	12,548	12,520	12,625	649381	0,80	343237	0,86	1,89	V	Benzene, 1-eth	gasoline	C10H12
24	12,756	12,715	12,785	188152	0,23	77901	0,19	2,42	V	Benzene, 1-eth	gasoline	C10H12
25	12,814	12,785	12,850	174702	0,22	88599	0,22	1,97	V	Benzene, 1-eth	gasoline	C10H12
26	12,936	12,850	13,005	188091	0,23	64809	0,16	2,90	V	Benzene, 1-eth	gasoline	C10H12
27	13,029	13,005	13,060	98744	0,12	61710	0,15	1,60		Benzene, 1-eth	gasoline	C10H12
28	13,524	13,480	13,550	230245	0,29	117082	0,29	1,97		1H-Indene, 2,3	gasoline	C11H14
29	13,611	13,550	13,680	2205138	2,73	945883	2,36	2,33	V	Naphthalene	gasoline	C10H8
30	14,716	14,690	14,765	104634	0,13	50147	0,13	2,09		Naphthalene	gasoline	C10H8
31	15,709	15,655	15,730	196828	0,24	67972	0,17	2,90		Naphthalene	gasoline	C10H8
32	16,630	16,560	16,710	4428973	5,48	1961267	4,89	2,26		Naphthalene, 2	jet fuel	C11H12
33	16,962	16,925	17,015	726558	0,90	363610	0,91	2,00		Naphthalene, 2	jet fuel	C11H12
34	18,341	18,315	18,415	578414	0,72	317212	0,79	1,82		Naphthalene, 2	jet fuel	C11H12
35	18,502	18,415	18,510	1041283	1,29	745720	1,86	1,40	V	Naphthalene, 2	jet fuel	C11H12
36	18,527	18,510	18,580	1328602	1,64	905677	2,26	1,47	V	Naphthalene, 2	jet fuel	C11H12

37	18,675	18,580	18,710	762244	0,94	462791	1,15	1,65	V	Naphthalene, 1	jet fuel	C11H10
38	18,734	18,710	18,785	523525	0,65	353831	0,88	1,48	V	Naphthalene, 1	jet fuel	C11H10
39	18,941	18,900	19,000	217652	0,27	91600	0,23	2,38		Naphthalene, 1	jet fuel	C11H10
40	19,426	19,395	19,440	98787	0,12	89418	0,22	1,10		Naphthalene, 1	jet fuel	C11H10
41	19,456	19,440	19,485	116315	0,14	80545	0,20	1,44	V	Naphthalene, 1	jet fuel	C11H10
42	19,617	19,530	19,660	611889	0,76	297520	0,74	2,06	V	Naphthalene, 2	jet fuel	C11H12
43	19,680	19,660	19,725	265379	0,33	214780	0,54	1,24	V	Methyl tetrad	diesel	C15H30
44	20,193	20,120	20,240	779712	0,97	231258	0,58	3,37		Undecanoic ac	jet fuel	C11H22
45	20,285	20,240	20,305	114010	0,14	44987	0,11	2,53	V	Undecanoic ac	jet fuel	C11H22
46	20,487	20,465	20,525	131001	0,16	69315	0,17	1,89		Undecanoic ac	jet fuel	C11H22
47	21,498	21,465	21,530	100862	0,12	63625	0,16	1,59		Undecanoic ac	jet fuel	C11H22
48	24,613	24,585	24,640	92837	0,11	68321	0,17	1,36		Undecanoic ac	jet fuel	C11H22
49	27,759	27,730	27,800	191095	0,24	147189	0,37	1,30		Undecanoic ac	jet fuel	C11H22
50	28,895	28,870	28,945	129012	0,16	88408	0,22	1,46		Undecanoic ac	jet fuel	C11H22
				80783928	100,00	40087201	100,00					

1H2= 10 BAR IN HZSM-5 AT 350 DEGREESE

Pe	R.Time	I.Time	F.Time	Area	Area%	Height	Height	A/H	Ma	chem formula	Name
1	3,269	3,240	3,320	268924	0,13	138653	0,23	1,94		C8H10	Ethylbenzen
2	4,469	4,440	4,520	280139	0,14	140884	0,24	1,99		C8H10	Ethylbenzen
3	4,639	4,615	4,725	1281588	0,64	426184	0,71	3,01		C8H10	o-Xylene
4	5,100	5,070	5,155	331138	0,17	135345	0,23	2,45	V	C8H10	o-Xylene
5	5,210	5,155	5,270	1222809	0,61	657828	1,10	1,86	V	C9H20	Nonane
6	6,315	6,295	6,450	146924	0,07	27861	0,05	5,27		C9H20	Nonane
7	6,475	6,450	6,515	382505	0,19	172188	0,29	2,22	V	C9H20	Nonane
8	6,549	6,515	6,600	362347	0,18	120174	0,20	3,02	V	C9H20	Nonane
9	7,302	7,215	7,330	230363	0,12	55418	0,09	4,16	V	C9H20	Nonane
10	7,398	7,330	7,440	299463	0,15	128389	0,22	2,33	V	C11H24	Undecane
11	9,190	9,140	9,220	178177	0,09	57388	0,10	3,10		C11H24	Undecane
12	10,301	10,255	10,365	540076	0,27	171878	0,29	3,14		C12H24	3-Dodecene,
13	10,542	10,480	10,625	10766162	5,38	4814007	8,07	2,24		C11H24	Undecane
14	10,695	10,625	10,730	143571	0,07	39835	0,07	3,60	V	C11H24	Undecane
15	13,016	12,840	13,210	11312048	5,65	1481533	2,48	7,64	S	C8H16O2	Octanoic
16	15,030	14,980	15,085	201101	0,10	67767	0,11	2,97		C8H16O2	Octanoic
17	15,261	15,190	15,350	5247643	2,62	1927593	3,23	2,72		C13H28	Tridecane
18	17,419	17,315	17,580	8032379	4,01	1672957	2,81	4,80		C10H20O2	n-Decanoic
19	17,601	17,580	17,635	406460	0,20	174414	0,29	2,33	V	C10H20O2	n-Decanoic
20	17,670	17,635	17,720	295832	0,15	78354	0,13	3,78	V	C10H20O2	n-Decanoic
21	17,772	17,720	17,875	637263	0,32	193984	0,33	3,29	V	C12H24O	Dodecanal
22	18,785	18,750	18,810	156079	0,08	93174	0,16	1,68		C12H24O	Dodecanal
23	18,866	18,810	18,960	4395394	2,20	2876063	4,82	1,53	V	C14H30	Tetradecane
24	19,732	19,510	20,715	82149987	41,03	14198555	23,81	5,79	S	C12H24O2	Dodecanoic
25	20,384	20,335	20,475	398522	0,20	106711	0,18	3,73	T	C12H24O2	Dodecanoic
26	20,515	20,475	20,565	233526	0,12	54688	0,09	4,27	TV	C12H24O2	Dodecanoic
27	20,592	20,565	20,675	1630912	0,81	957260	1,61	1,70	TV	C17H36	Heptadecane
28	21,257	21,135	21,435	20909270	10,44	5855012	9,82	3,57		C14H28O	Tetradecano

29	21,465	21,435	21,575	1316721	0,66	319705	0,54	4,12	V	C14H28O	Tetradecano
30	21,715	21,575	21,815	495961	0,25	82430	0,14	6,02	V	C14H28O	Tetradecano
31	22,316	22,245	22,435	694407	0,35	179834	0,30	3,86		C14H28O	Tetradecano
32	22,465	22,435	22,535	219287	0,11	81175	0,14	2,70	V	C14H28O	Tetradecano
33	22,595	22,535	22,675	274263	0,14	81368	0,14	3,37	V	C14H28O	Tetradecano
34	23,174	23,105	23,505	6276474	3,14	2120282	3,56	2,96	S	C16H32O2	n-Hexadecanoi
35	23,435	23,405	23,465	185125	0,09	123758	0,21	1,50	T	C16H32O2	n-Hexadecanoi
36	24,023	23,965	24,095	2921960	1,46	1822105	3,06	1,60		C15H30O	8-Pentadecano
37	24,184	24,095	24,255	372022	0,19	94638	0,16	3,93	V	C15H30O	8-Pentadecano
38	24,355	24,255	24,385	208143	0,10	85217	0,14	2,44	V	C15H30O	8-Pentadecano
39	24,415	24,385	24,465	166336	0,08	90563	0,15	1,84	V	C15H30O	8-Pentadecano
40	24,634	24,465	24,775	1258267	0,63	176265	0,30	7,14	V	C15H30O	8-Pentadecano
41	24,865	24,775	24,935	179113	0,09	41482	0,07	4,32	V	C15H30O	8-Pentadecano
42	25,413	25,305	25,535	3434246	1,72	1757137	2,95	1,95		C23H46O	12-Tricosanone
43	27,096	27,015	27,205	10013699	5,00	5572992	9,35	1,80		C23H46O	12-Tricosanone
44	28,334	28,245	28,435	7519894	3,76	5236252	8,78	1,44		C23H46O	12-Tricosanone
45	29,376	29,285	29,425	5289406	2,64	3184212	5,34	1,66		C23H46O	12-Tricosanone
46	29,572	29,425	29,795	3271579	1,63	230827	0,39	14,17	V	C23H46O	12-Tricosanone
47	29,835	29,795	29,925	164441	0,08	42072	0,07	3,91	V	C23H46O	12-Tricosanone
48	30,626	30,555	30,725	2479559	1,24	1160741	1,95	2,14		C27H54O	14-Heptacosano
49	32,296	32,215	32,365	819835	0,41	268221	0,45	3,06		C27H54O	14-Heptacosano
50	34,684	34,595	34,785	199798	0,10	47964	0,08	4,17		C27H54O	14-Heptacosano
				200201138	100,00	59623337	100,00				

1H1 = 10 BAR IN HZSM-5 AT 300 DEGREESE

Pe	R.Tim	I.Time	F.Ti	Area	Area%	Height	Heig	A/	chemical	Mark	Name
1	11,225	11,195	11,310	1111799	1,60	372377	1,25	2,99	C8H16O2		Octanoic acid, methyl
2	19,118	19,080	19,235	16929835	24,43	12199953	40,80	1,39	C12H24O2		Dodecanoic acid,
3	19,675	19,585	19,825	25782385	37,20	7043828	23,56	3,66	C12H24O2	S	Dodecanoic acid
4	20,805	20,770	20,895	6225475	8,98	4107622	13,74	1,52	C15H30O2		Methyl tetradecanoate
5	21,235	21,195	21,340	5344644	7,71	2323480	7,77	2,30	C14H28O2		Tetradecanoic acid
6	22,804	22,765	22,875	3102960	4,48	1838296	6,15	1,69	C17H34O2		Hexadecanoic acid,
7	28,880	28,790	28,895	1074665	1,55	301900	1,01	3,56	C17H34O2		Hexadecanoic acid,
8	28,950	28,895	29,020	3686994	5,32	561348	1,88	6,57	C12H24O2	V	Dodecanoic acid,
9	29,070	29,020	29,150	4293416	6,19	722273	2,42	5,94	C12H24O2	V	Dodecanoic acid, 1,2,3-propanetriyl ester
10	29,183	29,150	29,285	1752721	2,53	429245	1,44	4,08	C12H24O2	V	Dodecanoic acid, 1,2,3-propanetriyl ester
				69304894	100,00	29900322	100,00				

Analyzed by	: Neal												
Analyzed	: 2018-06-09 01:26:40 PM												
Sample Type	: Unknown												
Level #	: 1	40Bar without catalyst at 450 degrees											
Sample Name	: 4W4												
Sample ID	: 4W4												
IS Amount	: [1]=1												
Sample Amount	: 1												
Dilution Factor	: 1												
Vial #	: 28												
Injection Volume	: 0.10												
Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4W4.qgd												
Org Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4W4.qgd												
Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Org Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm												
Report File	:												
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt												
Modified by	: Neal												
Modified	: 2018-06-09 09:02:59 PM												
Chromatogram 4W4 C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\4W4.qgd													
TIC													
6 286 693													
10,0 20,0 30,0													
min													
Peak Report TIC													
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	Products	Chemical formula	
1	3,044	3,010	3,085	274072	0,53	149939	0,55	1,83		Cyclopentane,	gasoline	C7H14	
2	3,136	3,085	3,185	187943	0,36	72147	0,26	2,61		Cyclopentane,	gasoline	C7H14	
3	3,340	3,315	3,375	94902	0,18	49350	0,18	1,92	MI	Cyclopentane,	gasoline	C7H14	
4	3,474	3,430	3,495	88272	0,17	40109	0,15	2,20	MI	Cyclopentane,	gasoline	C7H14	
5	3,544	3,500	3,640	10235382	19,80	5656033	20,73	1,81		Toluene	gasoline	C7H8	

6	3,758	3,725	3,785	57852	0,11	34799	0,13	1,66	MI	Toluene	gasoline	C7H8
7	3,908	3,870	3,940	890573	1,72	510220	1,87	1,75		1-Octene	gasoline	C8H16
8	3,965	3,940	3,995	175898	0,34	83576	0,31	2,10	V	1-Octene	gasoline	C8H16
9	4,066	3,995	4,100	1408499	2,72	811296	2,97	1,74	V	Hexane, 2,4-di	gasoline	C8H18
10	4,115	4,100	4,155	119873	0,23	80983	0,30	1,48	MI	Hexane, 2,4-di	gasoline	C8H18
11	4,181	4,150	4,210	104855	0,20	68714	0,25	1,53	MI	Hexane, 2,4-di	gasoline	C8H18
12	4,234	4,220	4,265	39642	0,08	31308	0,11	1,27	MI	Hexane, 2,4-di	gasoline	C8H18
13	4,332	4,300	4,365	114556	0,22	54893	0,20	2,09	MI	Hexane, 2,4-di	gasoline	C8H18
14	4,544	4,500	4,575	90009	0,17	35388	0,13	2,54	MI	Hexane, 2,4-di	gasoline	C8H18
15	4,703	4,670	4,735	184771	0,36	90784	0,33	2,04	MI	Hexane, 2,4-di	gasoline	C8H18
16	4,765	4,730	4,805	172461	0,33	87058	0,32	1,98	MI	Cyclohexane, e	gasoline	C8H16
17	5,274	5,235	5,330	2378783	4,60	1468385	5,38	1,62		Ethylbenzene	gasoline	C8H10
18	5,455	5,405	5,530	3525989	6,82	1510665	5,54	2,33		Benzene, 1,3-d	gasoline	C8H10
19	5,754	5,715	5,800	124061	0,24	45956	0,17	2,70	MI	Benzene, 1,3-d	gasoline	C8H10
20	5,847	5,815	5,875	780740	1,51	513198	1,88	1,52		1-Nonene	gasoline	C9H18
21	5,908	5,875	5,950	1921984	3,72	1163398	4,26	1,65	V	Benzene, 1,3-d	gasoline	C8H10
22	6,018	5,950	6,060	1644124	3,18	1045235	3,83	1,57	V	Nonane	gasoline	C9H20
23	6,132	6,065	6,160	174695	0,34	94238	0,35	1,85	MI	Nonane	gasoline	C9H20
24	6,221	6,190	6,240	43656	0,08	38163	0,14	1,14	MI	Nonane	gasoline	C9H20
25	6,298	6,270	6,325	80003	0,15	49461	0,18	1,62	MI	Nonane	gasoline	C9H20
26	6,491	6,455	6,520	70682	0,14	40390	0,15	1,75	MI	Nonane	gasoline	C9H20
27	6,553	6,520	6,580	159389	0,31	91054	0,33	1,75	MI	Nonane	gasoline	C9H20
28	6,724	6,680	6,755	77098	0,15	42697	0,16	1,81	MI	Nonane	gasoline	C9H20
29	6,776	6,750	6,795	35872	0,07	28107	0,10	1,28	MI	Nonane	gasoline	C9H20
30	7,272	7,240	7,320	436804	0,84	225254	0,83	1,94		Benzene, propy	gasoline	C9H12
31	7,472	7,435	7,520	1013933	1,96	506102	1,86	2,00		Benzene, 1-eth	diesel	C15H17
32	7,556	7,520	7,605	496191	0,96	230059	0,84	2,16	V	Benzene, 1-eth	diesel	C15H17
33	7,715	7,685	7,760	141644	0,27	62707	0,23	2,26	MI	Benzene, 1-eth	diesel	C15H17
34	7,964	7,930	8,020	535756	1,04	242448	0,89	2,21		Benzene, (1-m	gasoline	C9H12
35	8,327	8,285	8,380	1222546	2,36	551956	2,02	2,21		1-Decene	gasoline	C10H20
36	8,468	8,380	8,520	743902	1,44	287351	1,05	2,59	V	Mesitylene	gasoline	C10H20

37	8,610	8,520	8,665	947594	1,83	396737	1,45	2,39	V	Decane	gasoline	C10H22
38	8,786	8,740	8,830	228819	0,44	85381	0,31	2,68		Decane	gasoline	C10H22
39	9,385	9,300	9,430	233139	0,45	76230	0,28	3,06	MI	Decane	gasoline	C10H22
40	9,809	9,770	9,860	407564	0,79	170803	0,63	2,39		Indane	gasoline	C10H22
41	10,130	10,095	10,165	121531	0,24	55798	0,20	2,18	MI	Indane	gasoline	C10H22
42	10,187	10,160	10,240	98800	0,19	52726	0,19	1,87	MI	Indane	gasoline	C10H22
43	10,295	10,255	10,330	166130	0,32	81022	0,30	2,05	MI	Indane	gasoline	C10H22
44	10,438	10,405	10,465	214400	0,41	114516	0,42	1,87		Indane	gasoline	C10H22
45	10,993	10,950	11,025	107297	0,21	50372	0,18	2,13	MI	Indane	gasoline	C10H22
46	11,055	11,035	11,190	183671	0,36	36777	0,13	4,99		Indane	gasoline	C10H22
47	11,236	11,190	11,295	394757	0,76	133425	0,49	2,96	V	Indane	gasoline	C10H22
48	11,387	11,305	11,435	923887	1,79	450536	1,65	2,05		1-Undecene	jet fuel	C11H22
49	11,605	11,555	11,665	2071319	4,01	1171037	4,29	1,77		Undecane	jet fuel	C11H22
50	11,720	11,685	11,765	206875	0,40	104679	0,38	1,98	MI	Undecane	jet fuel	C11H22
51	12,556	12,525	12,610	175372	0,34	85304	0,31	2,06		Undecane	jet fuel	C11H22
52	12,759	12,720	12,800	333306	0,64	152950	0,56	2,18		Undecane	jet fuel	C11H22
53	12,949	12,880	13,020	302745	0,59	75931	0,28	3,99	MI	Undecane	jet fuel	C11H22
54	13,619	13,560	13,645	2439029	4,72	1156742	4,24	2,11		Naphthalene	gasoline	C11H22
55	13,665	13,645	13,720	895232	1,73	494260	1,81	1,81	V	1-Dodecene	jet fuel	C12H24
56	13,862	13,825	13,915	555140	1,07	305452	1,12	1,82		Undecane	jet fuel	C11H22
57	16,400	16,365	16,430	272217	0,53	145597	0,53	1,87		1-Tridecene	jet fuel	C13H26
58	16,626	16,560	16,685	2166561	4,19	693241	2,54	3,13		Naphthalene, 1	jet fuel	C13H26
59	16,970	16,935	17,020	980349	1,90	512566	1,88	1,91	V	Naphthalene, 2	jet fuel	C13H26
60	18,020	17,975	18,070	119723	0,23	41490	0,15	2,89	MI	Naphthalene, 2	jet fuel	C13H26
61	18,221	18,200	18,240	279030	0,54	226665	0,83	1,23		1-Tridecene	jet fuel	C13H26
62	18,329	18,300	18,415	570602	1,10	201236	0,74	2,84		Hexadecane	diesel	C13H26
63	18,471	18,440	18,500	663336	1,28	521455	1,91	1,27		Dodecanal	jet fuel	C12H24O
64	18,545	18,500	18,565	172915	0,33	48584	0,18	3,56	V	Dodecanal	jet fuel	C12H24O
65	18,685	18,650	18,715	309479	0,60	204843	0,75	1,51		Naphthalene, 1	jet fuel	C12H24O
66	18,742	18,725	18,775	136022	0,26	100767	0,37	1,35	MI	Naphthalene, 1	jet fuel	C12H24O

67	18,950	18,880	19,000	270324	0,52	72449	0,27	3,73	MI	Naphthalene, 1	jet fuel	C12H24O
68	19,106	19,085	19,125	50658	0,10	51629	0,19	0,98	MI	Naphthalene, 1	jet fuel	C12H24O
69	19,383	19,345	19,405	159759	0,31	122907	0,45	1,30	MI	Naphthalene, 1	jet fuel	C12H24O
70	19,429	19,400	19,445	527682	1,02	402164	1,47	1,31	V	2-Tridecanone	jet fuel	C13H26O
71	19,458	19,445	19,490	350464	0,68	322132	1,18	1,09	V	Tetradecane	diesel	C14H30
72	19,619	19,580	19,660	95987	0,19	34735	0,13	2,76	MI	Tetradecane	diesel	C14H30
73	19,684	19,665	19,715	272911	0,53	265646	0,97	1,03		Methyl tetrade	diesel	C15H30O2
74	20,175	20,125	20,205	383468	0,74	151906	0,56	2,52		Methyl tetrade	diesel	C15H30O2
75	20,286	20,205	20,315	450484	0,87	226508	0,83	1,99	V	Methyl tetrade	diesel	C15H30O2
76	20,344	20,315	20,375	126007	0,24	104840	0,38	1,20	MI	Methyl tetrade	diesel	C15H30O2
77	20,403	20,370	20,450	302332	0,58	177066	0,65	1,71	V	Fluorene	jet fuel	C13H10
78	20,491	20,470	20,530	272131	0,53	221483	0,81	1,23		Tetradecanal	diesel	C14H28O
79	21,261	21,230	21,285	225776	0,44	151282	0,55	1,49		Tetradecanal	diesel	C14H28O
80	21,500	21,470	21,585	223559	0,43	62548	0,23	3,57		Tetradecanal	diesel	C14H28O
81	21,606	21,575	21,630	134801	0,26	70815	0,26	1,90	MI	Tetradecanal	diesel	C14H28O
82	22,509	22,475	22,570	365042	0,71	141128	0,52	2,59		9H-Fluorene, 9	diesel	C14H10
83	24,619	24,570	24,645	184824	0,36	120576	0,44	1,53	MI	9H-Fluorene, 9	diesel	C14H10
84	25,316	25,290	25,345	367189	0,71	224926	0,82	1,63		Pyrene	diesel	C16H10
85	27,764	27,740	27,795	255634	0,49	199473	0,73	1,28		Pyrene	diesel	C16H10
86	28,900	28,875	28,945	154556	0,30	116132	0,43	1.33	MI	Pyrene	diesel	C16H10
				51697841	100,00	27280888	100,00					

4W3= 40 BAR IN WITHOUT CATALYST AT 400 DEGREESE

Pe	R.Time	I.Time	F.Time	Area	Area	Height	Heig	A/	chem	M	Name
1	3,140	3,110	3,220	4359602	2,31	2429192	3,53	1,79	C8H16		1-Octene
2	3,291	3,220	3,370	4453033	2,36	2403688	3,49	1,85	C8H18	V	Hexane, 2,4-
3	4,491	4,460	4,530	528723	0,28	236502	0,34	2,24	C8H10		Ethylbenzene
4	4,620	4,530	4,650	293435	0,16	100604	0,15	2,92	C8H10	V	Ethylbenzene
5	4,669	4,650	4,750	867339	0,46	282239	0,41	3,07	C8H10	V	p-Xylene
6	4,950	4,920	5,035	320994	0,17	87646	0,13	3,66	C8H10		p-Xylene
7	5,062	5,035	5,100	3329136	1,77	1816098	2,64	1,83	C9H18	V	1-Nonene
8	5,116	5,100	5,175	871762	0,46	310523	0,45	2,81	C8H10	V	Benzene, 1,3-
9	5,234	5,175	5,315	6063211	3,22	3404393	4,94	1,78	C9H20	V	Nonane
10	5,356	5,315	5,390	444225	0,24	219166	0,32	2,03	C9H18	V	2-Nonene, (E)-
11	7,195	7,155	7,275	6190532	3,29	2853109	4,14	2,17	C10H20		1-Decene
12	7,424	7,380	7,500	2909100	1,54	1316240	1,91	2,21	C10H22		Decane
13	7,581	7,545	7,625	429446	0,23	184703	0,27	2,33	C10H20		2-Decene, (E)-
14	10,326	10,275	10,410	3577133	1,90	1353526	1,97	2,64	C11H22		1-Undecene
15	10,572	10,515	10,660	10597972	5,63	4728577	6,86	2,24	C11H22		Undecane
16	10,719	10,660	10,775	473570	0,25	170351	0,25	2,78	C8H16	V	Cyclooctane,
17	12,739	12,700	12,800	3421841	1,82	1767933	2,57	1,94	C12H24		1-Dodecene
18	12,915	12,800	12,950	3467913	1,84	1314729	1,91	2,64	C12H26	V	Dodecane
19	13,030	12,950	13,130	6875044	3,65	1459381	2,12	4,71	C8H16O2	V	Octanoic acid
20	15,056	15,010	15,115	1193045	0,63	442176	0,64	2,70	C13H26		1-Tridecene
21	15,287	15,235	15,365	4251450	2,26	1574046	2,29	2,70	C13H28		Tridecane
22	17,433	17,340	17,455	5165913	2,74	1443996	2,10	3,58	C12H24O2		n-Decanoic acid
23	17,483	17,455	17,515	2557332	1,36	1086978	1,58	2,35	C13H26	V	1-Tridecene
24	17,535	17,515	17,550	682357	0,36	349831	0,51	1,95	C13H26	V	1-Tridecene
25	17,612	17,550	17,655	1704462	0,91	608519	0,88	2,80	C13H28	V	Tridecane
26	17,684	17,655	17,730	351979	0,19	152655	0,22	2,31	C13H28	V	Tridecane
27	18,795	18,760	18,820	863131	0,46	569732	0,83	1,51	C15H30		1-Pentadecene

28	18,841	18,820	18,860	3016765	1,60	2089073	3,03	1,44	C13H26O	V	2-Tridecanone
29	18,876	18,860	18,905	2808401	1,49	1996534	2,90	1,41	C14H30	V	Tetradecane
30	18,930	18,905	18,965	352375	0,19	192511	0,28	1,83	C14H30	V	Tetradecane
31	19,121	19,065	19,200	1575311	0,84	913734	1,33	1,72	C12H24O2	V	Dodecanoic acid,
32	19,728	19,555	19,975	64582847	34,29	12977997	18,84	4,98	C12H24O2	S	Dodecanoic acid
33	19,925	19,905	19,970	332368	0,18	238466	0,35	1,39	C14H28O	T	Tetradecanal
34	20,427	20,355	20,510	1462182	0,78	304744	0,44	4,80	C14H28O		Tetradecanal
35	20,545	20,510	20,570	301966	0,16	156820	0,23	1,93	C14H28O	V	Tetradecanal
36	20,600	20,570	20,680	2170553	1,15	1288929	1,87	1,68	C17H34O	V	2-Heptadecanone
37	20,808	20,765	20,865	555622	0,30	312895	0,45	1,78	C15H30O2		Methyl tetradecanoate
38	21,260	21,175	21,420	15298261	8,12	4966225	7,21	3,08	C14H28O2		Tetradecanoic acid
39	22,332	22,285	22,365	617477	0,33	249900	0,36	2,47	C14H28O2		Tetradecanoic acid
40	22,596	22,570	22,660	538691	0,29	335345	0,49	1,61	C17H34O		2-Heptadecanone
41	23,178	23,140	23,215	2790589	1,48	1296335	1,88	2,15	C16H32O2		n-Hexadecanoic
42	23,290	23,215	23,345	1860443	0,99	313222	0,45	5,94	C16H32O2	V	n-Hexadecanoic
43	24,028	24,000	24,070	1717424	0,91	1144381	1,66	1,50	C15H30O		8-Pentadecanone
44	24,665	24,635	24,690	362264	0,19	182575	0,27	1,98	C15H30O		8-Pentadecanone
45	24,711	24,690	24,780	621521	0,33	293053	0,43	2,12	C27H56O	V	1-Heptacosanol
46	25,419	25,390	25,490	1682464	0,89	943556	1,37	1,78	C23H46O		12-Tricosanone
47	27,101	27,055	27,170	4168844	2,21	2518548	3,66	1,66	C23H46O		12-Tricosanone
48	28,338	28,300	28,390	2802457	1,49	2030989	2,95	1,38	C23H46O		12-Tricosanone
49	29,382	29,345	29,440	1725371	0,92	1122872	1,63	1,54	C23H46O		12-Tricosanone
50	30,635	30,595	30,695	747376	0,40	345945	0,50	2,16	C23H46O		12-Tricosanone
				188335252	100,00	68881182	100,00				

4W2= 40 BAR IN WITHOUT CATALYST AT 350 DEGREESE

Pe	R.Time	L.Time	F.Time	Area	Area	Height	Heig	A/	CHEM	M	Name
1	3,141	3,110	3,210	741508	0,28	350669	0,49	2,11	C8H16		1-Octene
2	3,287	3,210	3,365	2033455	0,77	1056288	1,48	1,93	C8H18	V	Hexane, 2,4-dimethyl-
3	5,062	5,035	5,115	621231	0,24	321812	0,45	1,93	C9H18		1-Nonene
4	5,229	5,200	5,320	3547232	1,34	2017434	2,82	1,76	C9H20		Nonane
5	7,191	7,150	7,285	1694359	0,64	610192	0,85	2,78	C10H20		1-Decene
6	7,335	7,285	7,380	275439	0,10	74545	0,10	3,69	C10H20	V	1-Decene
7	7,413	7,380	7,515	2710607	1,03	1112447	1,55	2,44	C10H22	V	Decane
8	10,324	10,275	10,395	982752	0,37	336917	0,47	2,92	C10H20		1-Decene
9	10,562	10,510	10,670	11711472	4,44	4923095	6,88	2,38	C11H24		Undecane
10	12,736	12,695	12,790	921641	0,35	438773	0,61	2,10	C12H26		1-Dodecene
11	12,907	12,865	12,935	3044577	1,15	1250851	1,75	2,43	C13H28		Tridecane
12	13,068	12,935	13,160	11562124	4,38	1683483	2,35	6,87	C8H16O2	V	Octanoic acid
13	15,045	15,000	15,105	482133	0,18	172653	0,24	2,79	C13H28		1-Tridecene
14	15,272	15,210	15,360	5393123	2,04	1911896	2,67	2,82	C14H30		Tetradecane
15	17,454	17,335	17,505	10802140	4,09	2268379	3,17	4,76	C10H20O2		n-Decanoic acid
16	17,521	17,505	17,580	1845913	0,70	537199	0,75	3,44	C10H20O2	V	n-Decanoic acid
17	17,603	17,580	17,650	1744293	0,66	726857	1,02	2,40	C14H30	V	Tetradecane
18	17,679	17,650	17,725	691673	0,26	242580	0,34	2,85	C14H30	V	Tetradecane
19	17,821	17,725	17,880	1028879	0,39	208490	0,29	4,93	C11H22O	V	Undecanal
20	18,788	18,755	18,815	553883	0,21	310244	0,43	1,79	C24H50O		n-Tetracosanol-1
21	18,870	18,815	18,910	4781695	1,81	2630164	3,68	1,82	C14H30	V	Tetradecane
22	19,115	19,080	19,205	1866768	0,71	1011568	1,41	1,85	C10H20O2	V	Dodecanoic acid, methyl
23	19,764	19,550	19,975	106010126	40,15	16558583	23,15	6,40	C10H20O2	S	Dodecanoic acid
24	19,919	19,900	19,960	396290	0,15	278893	0,39	1,42	C12H24O	T	Dodecanal
25	20,453	20,355	20,485	1060916	0,40	218660	0,31	4,85	C13H26		1-Tridecene
26	20,590	20,565	20,665	1785071	0,68	1105355	1,55	1,61	C18H38		Octadecane
27	20,803	20,760	20,870	745828	0,28	402271	0,56	1,85	C15H30O2		Methyl tetradecanoate

28	21,288	21,160	21,420	33290563	12,61	8757059	12,24	3,80	C14H28O		Tetradecanoic acid
29	21,495	21,420	21,600	1888754	0,72	281921	0,39	6,70	C14H30	V	Tetradecane
30	22,321	22,265	22,360	698207	0,26	251225	0,35	2,78	C14H30		Tetradecane
31	22,591	22,570	22,650	373922	0,14	183103	0,26	2,04	C14H28O	V	2-Tetradecanone
32	22,797	22,755	22,845	329458	0,12	184104	0,26	1,79	C16H32O2		Hexadecanoic acid,
33	23,188	23,120	23,265	10293041	3,90	4211253	5,89	2,44	C16H32O2		n-Hexadecanoic acid
34	23,280	23,265	23,360	1704763	0,65	674898	0,94	2,53	C19H38	V	1-Nonadecene
35	23,431	23,360	23,485	809421	0,31	294230	0,41	2,75	C19H38	V	1-Nonadecene
36	24,022	23,960	24,090	2361899	0,89	1243350	1,74	1,90	C15H30O		8-Pentadecanone
37	24,664	24,605	24,680	1078389	0,41	360706	0,50	2,99	C17H34		1-Heptadecene
38	24,703	24,680	24,780	972682	0,37	446767	0,62	2,18	C23H46	V	9-Tricosene, (Z)-
39	25,411	25,375	25,480	2133138	0,81	1194032	1,67	1,79	C23H46O		12-Tricosanone
40	26,145	26,100	26,195	353681	0,13	105054	0,15	3,37	C23H46O		12-Tricosanone
41	26,225	26,195	26,290	524675	0,20	193627	0,27	2,71	C23H46O	V	12-Tricosanone
42	27,092	27,050	27,165	5145170	1,95	2887249	4,04	1,78	C23H46O		12-Tricosanone
43	27,691	27,665	27,720	317658	0,12	203876	0,28	1,56	C23H46O		12-Tricosanone
44	27,770	27,720	27,815	383956	0,15	137658	0,19	2,79	C23H46O	V	12-Tricosanone
45	28,332	28,285	28,385	3586361	1,36	2588393	3,62	1,39	C23H46O		12-Tricosanone
46	28,840	28,785	28,860	529897	0,20	193787	0,27	2,73	C23H46O	V	12-Tricosanone
47	28,966	28,860	29,145	11595834	4,39	1964061	2,75	5,90	C23H46O	V	12-Tricosanone
48	29,372	29,340	29,415	2231733	0,85	1464008	2,05	1,52	C23H46O		12-Tricosanone
49	30,623	30,580	30,690	1041411	0,39	468471	0,65	2,22	C23H46O		12-Tricosanone
50	33,985	33,845	34,085	3361077	1,27	492494	0,69	6,82	C10H20O2		Dodecanoic acid, 1,2,3-
				264040818	100,00	71541624	100,00				

4W1= 40 BAR IN WITHOUT CATALYST AT 300 DEGRESE

Pe	R.Time	I.Time	F.Time	Area	Area%	Height	Heig	A/	chem formula	M	Name
1	5,242	5,205	5,290	275156	0,20	129707	0,28	2,12	C6H14		Hexane, 2,4-
2	10,561	10,515	10,645	1522155	1,08	590764	1,30	2,58	C11H24		Undecane
3	12,988	12,885	13,075	5153575	3,65	1046403	2,30	4,93	C8H16O2		Octanoic acid
4	15,275	15,220	15,360	766460	0,54	232698	0,51	3,29	C12H26		Dodecane
5	17,407	17,350	17,460	3440715	2,44	1132741	2,49	3,04	C10H20O2		n-Decanoic acid
6	17,829	17,760	17,890	669285	0,47	183260	0,40	3,65	C12H24O		Dodecanal
7	18,870	18,830	18,915	818882	0,58	442645	0,97	1,85	C16H34		Hexadecane
8	19,116	19,085	19,220	1688069	1,20	797975	1,75	2,12	C10H20O2		Dodecanoic acid,
9	19,719	19,570	^{19,980}	63272236	44,84	¹²⁷⁹²⁸⁹⁴	28,08	4,95	C10H20O2	S	Dodecanoic acid
10	19,923	19,895	19,970	391117	0,28	255467	0,56	1,53	C14H28O	T	Tetradecanal
11	20,395	20,360	20,435	1326436	0,94	716863	1,57	1,85	C10H20O2		Decanoic acid, 2-
12	20,502	20,470	20,555	676834	0,48	302871	0,66	2,23	C10H20O2	V	Dodecanoic acid,
13	20,595	20,555	20,660	424948	0,30	179413	0,39	2,37	C10H20O2	V	Dodecanoic acid,
14	20,804	20,775	20,880	658342	0,47	347130	0,76	1,90	C15H30O2		Methyl tetradecanoate
15	21,254	21,180	21,410	17440315	12,36	5752634	12,63	3,03	C14H28O		Tetradecanoic acid
16	22,003	21,975	22,085	747082	0,53	293162	0,64	2,55	C14H28O	V	Tetradecanoic acid
17	22,310	22,270	22,365	806111	0,57	346996	0,76	2,32	C10H20O2		Decanoic acid, 2-
18	22,445	22,365	22,480	286167	0,20	96960	0,21	2,95	C10H20O2	V	Decanoic acid, 2-
19	22,800	22,765	22,830	298764	0,21	179780	0,39	1,66	C16H32O2		Hexadecanoic acid,
20	23,171	23,135	23,205	3604410	2,55	1869275	4,10	1,93	C16H32O2		n-Hexadecanoic
21	23,224	23,205	23,255	1907994	1,35	1039286	2,28	1,84	C19H38	V	1-Nonadecene
22	23,277	23,255	23,335	994242	0,70	479375	1,05	2,07	C19H38	V	1-Nonadecene
23	23,816	23,795	23,870	296452	0,21	173716	0,38	1,71	C19H38		1-Nonadecene
24	24,019	23,975	24,070	1967710	1,39	1208511	2,65	1,63	C15H30O		8-Pentadecanone
25	24,485	24,435	24,610	543811	0,39	98612	0,22	5,51	C15H30O		8-Pentadecanone
26	24,665	24,610	24,685	1162781	0,82	602460	1,32	1,93	C19H38	V	1-Nonadecene
27	24,705	24,685	24,760	541421	0,38	306529	0,67	1,77	C19H38	V	1-Nonadecene

28	25,408	25,370	25,470	1844744	1,31	985966	2,16	1,87	C23H46O		12-Tricosanone
29	26,179	26,120	26,210	604466	0,43	173002	0,38	3,49	C19H38		1-Nonadecene
30	26,240	26,210	26,295	263333	0,19	96985	0,21	2,72	C19H38	V	1-Nonadecene
31	27,090	27,045	27,150	5218754	3,70	3015135	6,62	1,73	C23H46O		12-Tricosanone
32	27,690	27,655	^{27,715}	667810	0,47	426970	0,94	1,56	C2H4O2		Acetic acid n-
33	28,330	28,295	28,395	3623546	2,57	2955365	6,49	1,23	C23H46O		12-Tricosanone
34	28,755	28,730	^{28,785}	475651	0,34	357515	0,78	1,33	C2H4O2		Acetic acid n-
35	28,896	28,860	28,925	501822	0,36	282627	0,62	1,78	C2H4O2		Acetic acid n-
36	28,988	28,925	29,020	597024	0,42	157420	0,35	3,79	C23H46O	V	12-Tricosanone
37	29,371	29,340	29,420	2200179	1,56	1461195	3,21	1,51	C23H46O		12-Tricosanone
38	29,845	29,815	29,890	357055	0,25	205594	0,45	1,74	C23H46O		12-Tricosanone
39	29,951	29,915	29,975	321867	0,23	179321	0,39	1,79	C23H46O		12-Tricosanone
40	30,081	30,020	30,165	335199	0,24	81647	0,18	4,11	C23H46O	V	12-Tricosanone
41	30,472	30,435	30,545	402531	0,29	132455	0,29	3,04	C23H46O		12-Tricosanone
42	30,620	30,585	30,695	977009	0,69	504448	1,11	1,94	C27H54O		14-Heptacosanone
43	30,892	30,850	30,925	478618	0,34	204839	0,45	2,34	C27H54O		14-Heptacosanone
44	30,951	30,925	31,020	594567	0,42	205486	0,45	2,89	C27H54O	V	14-Heptacosanone
45	31,309	31,265	31,365	665987	0,47	269378	0,59	2,47	C27H54O		14-Heptacosanone
46	31,496	31,455	31,555	373970	0,27	144717	0,32	2,58	C27H54O		14-Heptacosanone
47	32,575	32,495	32,640	3218964	2,28	910864	2,00	3,53	C27H54O		14-Heptacosanone
48	33,962	33,890	34,090	794050	0,56	107067	0,24	7,42	C27H54O		14-Heptacosanone
49	34,889	34,800	34,950	3443164	2,44	735805	1,62	4,68	C27H54O		14-Heptacosanone
50	35,002	34,950	35,065	1456770	1,03	360139	0,79	4,05	C27H54O	V	14-Heptacosanone
				¹⁴¹⁰⁹⁸⁵⁵⁰	100,00	⁴⁵⁵⁵²⁰⁶⁷	100,00				

Analyzed by	: Neal											
Analyzed	: 2018-06-09 12:49:45 PM											
Sample Type	: Unknown											
Level #	: 1 30 Bar without catalyst at 450 degreee											
Sample Name	: 3W4											
Sample ID	: 3W4											
IS Amount	: [1]=1											
Sample Amount	: 1											
Dilution Factor	: 1											
Vial #	: 27											
Injection Volume	: 0.10											
Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3W4.qgd											
Org Data File	: C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3W4.qgd											
Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm											
Org Method File	: C:\GCMSsolution\Methods\Hydrocarbon 050618 31 min Used.qgm											
Report File	:											
Tuning File	: C:\GCMSsolution\System\Tune1\2017 Tune Files\2018 Tuning Files\04052018.qgt											
Modified by	: Neal											
Modified	: 2018-06-09 08:20:42 PM											
Chromatogram 3W4 C:\GCMSsolution\Data\2018 DUT\070618 Hydrocarbon\3W4.qgd												
TIC												
6 978 242												
10,0 20,0 30,0												
min												
Peak Report TIC												
Peak#	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H	Mark	Name	product	chemical formula
1	3,045	3,015	3,090	326615	0,60	165762	0,58	1,97		Cyclopentane,	gasoline	C7H14
2	3,140	3,090	3,185	408060	0,74	154391	0,54	2,64		Cyclohexene, 1	gasoline	C6H10
3	3,341	3,325	3,410	124631	0,23	78983	0,27	1,58	MI	Cyclohexene, 1	gasoline	C6H10
4	3,545	3,500	3,640	11978355	21,82	6352012	22,07	1,89		Toluene	gasoline	C7H8
5	3,909	3,870	3,945	1244210	2,27	687203	2,39	1,81		1-Octene	gasoline	C8H16

6	4,065	4,005	4,100	1125812	2,05	650857	2,26	1,73	V	Hexane, 2,4-di	gasoline	C8H18
7	4,705	4,660	4,740	135252	0,25	80889	0,28	1,67	MI	Hexane, 2,4-di	gasoline	C8H18
8	4,768	4,740	4,810	131742	0,24	78780	0,27	1,67	MI	Hexane, 2,4-di	gasoline	C8H18
9	5,274	5,240	5,320	2496181	4,55	1579084	5,49	1,58		Ethylbenzene	gasoline	C8H10
10	5,456	5,405	5,530	3659958	6,67	1531363	5,32	2,39		Benzene, 1,3-d	gasoline	C8H10
11	5,848	5,815	5,875	1035097	1,89	645956	2,24	1,60		1-Nonene	gasoline	C9H18
12	5,908	5,875	5,950	1954623	3,56	1158518	4,02	1,69	V	Benzene, 1,3-d	gasoline	C8H10
13	6,019	5,950	6,060	1520615	2,77	985064	3,42	1,54	V	Nonane	gasoline	C9H20
14	6,134	6,095	6,175	132408	0,24	83331	0,29	1,59	MI	cis-2-Nonene	gasoline	C9H18
15	6,549	6,520	6,610	165907	0,30	86585	0,30	1,92	MI	cis-2-Nonene	gasoline	C9H18
16	7,273	7,245	7,315	366264	0,67	193203	0,67	1,90		Benzene, propy	gasoline	C9H12
17	7,472	7,430	7,520	959122	1,75	483513	1,68	1,98		Benzene, 1-eth	diesel	C15H17
18	7,559	7,520	7,600	434166	0,79	221245	0,77	1,96	V	Benzene, 1-eth	diesel	C15H17
19	7,716	7,660	7,755	139652	0,25	59903	0,21	2,33	MI	Benzene, 1-eth	diesel	C15H17
20	7,964	7,920	8,005	483341	0,88	225600	0,78	2,14		Benzene, 1-eth	diesel	C15H17
21	8,329	8,275	8,370	1573283	2,87	703553	2,44	2,24		1-Decene	gasoline	C10H20
22	8,468	8,370	8,525	919561	1,68	293863	1,02	3,13	V	Mesitylene	gasoline	C8H30
23	8,609	8,525	8,655	859858	1,57	344409	1,20	2,50	V	Decane	gasoline	C10H22
24	8,792	8,745	8,845	206208	0,38	74306	0,26	2,78	MI	Decane	gasoline	C10H22
25	9,385	9,300	9,445	248340	0,45	76652	0,27	3,24	MI	Decane	gasoline	C10H22
26	9,807	9,770	9,865	429729	0,78	181280	0,63	2,37		Indane	gasoline	C9H10
27	10,117	10,090	10,160	216269	0,39	102533	0,36	2,11		Indane	gasoline	C9H10
28	10,291	10,245	10,325	120072	0,22	58067	0,20	2,07	MI	Indane	gasoline	C9H10
29	10,439	10,405	10,465	212907	0,39	112064	0,39	1,90		Indane	gasoline	C9H10
30	11,238	11,185	11,285	329032	0,60	115332	0,40	2,85		Indane	gasoline	C9H10
31	11,386	11,340	11,455	1179043	2,15	586875	2,04	2,01		1-Undecene	jet fuel	C11H22
32	11,605	11,560	11,655	2497003	4,55	1441989	5,01	1,73		Undecane	jet fuel	C11H22
33	11,721	11,675	11,760	172746	0,31	86992	0,30	1,99	MI	Undecane	jet fuel	C11H22
34	12,556	12,505	12,620	227984	0,42	97783	0,34	2,33	MI	Undecane	jet fuel	C11H22
35	12,762	12,725	12,800	452870	0,83	185123	0,64	2,45		Undecane	jet fuel	C11H22
36	12,942	12,925	12,990	204023	0,37	99618	0,35	2,05	V	Undecane	jet fuel	C11H22

37	13,617	13,565	13,645	1982965	3,61	907152	3,15	2,19		Naphthalene	gasoline	C10H8
38	13,663	13,645	13,735	1179796	2,15	552280	1,92	2,14	V	1-Dodecene	jet fuel	C11H22
39	13,859	13,830	13,895	357416	0,65	199956	0,69	1,79		Undecane	jet fuel	C11H22
40	16,398	16,355	16,430	326749	0,60	168111	0,58	1,94		1-Dodecene	jet fuel	C11H22
41	16,611	16,560	16,680	2057521	3,75	646141	2,24	3,18		Tridecane	jet fuel	C13H28
42	16,969	16,930	17,020	820927	1,50	433925	1,51	1,89	V	Naphthalene, 2	jet fuel	C11H12
43	18,039	17,965	18,080	216544	0,39	81750	0,28	2,65	MI	Naphthalene, 2	jet fuel	C11H12
44	18,220	18,185	18,240	333813	0,61	270776	0,94	1,23		1-Tridecene	jet fuel	C13H26
45	18,329	18,240	18,420	601889	1,10	150642	0,52	4,00	V	Hexadecane	diesel	C16H34
46	18,471	18,440	18,500	435590	0,79	347322	1,21	1,25		Dodecanal	jet fuel	C12H24O
47	18,685	18,650	18,725	290512	0,53	183574	0,64	1,58		Naphthalene, 1	jet fuel	C11H10
48	18,946	18,890	19,050	313333	0,57	76350	0,27	4,10	MI	Naphthalene, 1	jet fuel	C11H10
49	19,429	19,400	19,445	875540	1,60	724286	2,52	1,21	V	2-Tridecanone	jet fuel	C13H26O
50	19,457	19,445	19,480	488220	0,89	472987	1,64	1,03	V	Tetradecane	diesel	C14H30
51	19,683	19,665	19,730	262615	0,48	232809	0,81	1,13		Dodecanoic ac	jet fuel	C13H26O2
52	20,205	20,120	20,265	1166479	2,13	297931	1,04	3,92		Dodecanoic ac	jet fuel	C13H26O2
53	20,285	20,265	20,315	473931	0,86	334326	1,16	1,42	V	1-Decanol, 2-h	gasoline	C10H22O
54	20,344	20,315	20,370	249114	0,45	133790	0,46	1,86	V	1-Decanol, 2-h	gasoline	C10H22O
55	20,402	20,370	20,445	337616	0,62	164603	0,57	2,05	V	1-Decanol, 2-h	gasoline	C10H22O
56	20,490	20,445	20,525	304448	0,55	171555	0,60	1,77	V	Hexadecanal	diesel	C16H32O
57	21,260	21,230	21,290	404793	0,74	275660	0,96	1,47		2-Heptadecano	diesel	C17H34O
58	21,505	21,440	21,570	212524	0,39	76597	0,27	2,77	MI	2-Heptadecano	diesel	C17H34O
59	22,518	22,490	22,565	249107	0,45	105651	0,37	2,36		2-Heptadecano	diesel	C17H34O
60	23,068	23,030	23,100	96017	0,17	56954	0,20	1,69	MI	2-Heptadecano	diesel	C17H34O
61	23,296	23,250	23,330	167222	0,30	116551	0,40	1,43	MI	2-Heptadecano	diesel	C17H34O
62	24,619	24,585	24,645	281351	0,51	232741	0,81	1,21		8-Pentadecano	diesel	C15H30
63	25,315	25,290	25,345	248947	0,45	160359	0,56	1,55		8-Pentadecano	diesel	C15H30
64	26,188	26,150	26,230	251667	0,46	133490	0,46	1,89		10-Nonadecan	waxes and related products	C19H38O
65	27,764	27,735	27,805	685096	1,25	569382	1,98	1,20		12-Tricosanone	waxes and related products	C23H46O
66	28,898	28,870	28,925	393536	0,72	334940	1,16	1,17		14-Heptacosan	waxes and related products	C27H54O
67	30,086	30,045	30,135	155843	0,28	110298	0,38	1,41	MI	14-Heptacosan	waxes and related products	C27H54O
				54892060	100,00	28785570	100,00					

6	5,836	5,800	5,880	617876	2,80	431202	3,41	1,43		1-Nonene	gasoline	C9H18
7	6,007	5,975	6,050	1055119	4,77	709360	5,61	1,49		Nonane	gasoline	C9H20
8	6,121	6,095	6,145	57381	0,26	38189	0,30	1,50		Nonane	gasoline	C9H20
9	8,311	8,260	8,355	1252144	5,67	585636	4,63	2,14		1-Decene	gasoline	C10H20
10	8,591	8,550	8,640	591582	2,68	268327	2,12	2,20		Decane	gasoline	C10H22
11	8,780	8,740	8,805	87507	0,40	42510	0,34	2,06		Decane	gasoline	C10H22
12	11,373	11,330	11,425	754697	3,42	381013	3,01	1,98		1-Undecene	jet fuel	C11H22
13	11,592	11,540	11,635	2361897	10,69	1378327	10,89	1,71		Undecane	jet fuel	C11H24
14	11,707	11,675	11,740	90050	0,41	52558	0,42	1,71		Undecane	jet fuel	C11H24
15	13,565	13,540	13,615	140430	0,64	34035	0,27	4,13		Undecane	jet fuel	C11H24
16	13,650	13,615	13,685	1028858	4,66	476973	3,77	2,16	V	1-Dodecene	jet fuel	C12H24
17	13,755	13,685	13,790	611744	2,77	153983	1,22	3,97	V	Octanoic acid	gasoline	C8H16O2
18	13,847	13,810	13,895	328453	1,49	178172	1,41	1,84		Undecane	jet fuel	C11H24
19	16,381	16,335	16,420	257109	1,16	127301	1,01	2,02		Undecane	jet fuel	C11H24
20	16,589	16,545	16,645	989284	4,48	516766	4,08	1,91		Dodecane	jet fuel	C12H26
21	16,691	16,645	16,725	87376	0,40	49780	0,39	1,76		Dodecane	jet fuel	C12H26
22	16,901	16,870	16,935	69625	0,32	40733	0,32	1,71		Dodecane	jet fuel	C12H26
23	18,066	18,020	18,105	220935	1,00	93318	0,74	2,37		Dodecane	jet fuel	C12H26
24	18,213	18,190	18,230	298112	1,35	238052	1,88	1,25		3-Tetradecene	diesel	C14H28
25	18,318	18,300	18,345	158643	0,72	134504	1,06	1,18		Hexadecane	diesel	C16H34
26	19,375	19,350	19,395	162957	0,74	135800	1,07	1,20		8-Heptadecene	diesel	C17H34
27	19,421	19,395	19,435	492287	2,23	462446	3,65	1,06	V	2-Tridecanone	jet fuel	C13H26O
28	19,450	19,435	19,470	525461	2,38	524195	4,14	1,00	V	Tetradecane	diesel	C14H30
29	19,676	19,655	19,710	383405	1,73	354075	2,80	1,08		Dodecanoic ac	jet fuel	C12H24O2
30	20,238	20,095	20,260	2389359	10,81	619217	4,89	3,86		Dodecanoic ac	jet fuel	C12H24O2
31	20,277	20,260	20,315	669816	3,03	389050	3,07	1,72	V	Dodecanoic ac	jet fuel	C12H24O2
32	20,334	20,315	20,365	190617	0,86	124727	0,99	1,53	V	Hexadecane	diesel	C16H34
33	21,054	20,990	21,070	138862	0,63	47300	0,37	2,94		Hexadecane	diesel	C16H34
34	21,251	21,220	21,280	351572	1,59	235821	1,86	1,49		Hexadecane	diesel	C16H34
35	21,492	21,460	21,525	145155	0,66	100290	0,79	1,45		Hexadecane	diesel	C16H34
36	22,084	22,060	22,115	72617	0,33	53690	0,42	1,35		Hexadecane	diesel	C16H34

37	23,059	23,015	23,085	191306	0,87	94720	0,75	2,02		Hexadecane	diesel	C16H34
38	23,288	23,265	23,315	106825	0,48	92818	0,73	1,15		Hexadecane	diesel	C16H34
39	23,474	23,450	23,490	69857	0,32	60786	0,48	1,15		Hexadecane	diesel	C16H34
40	23,868	23,850	23,900	176642	0,80	101795	0,80	1,74		Hexadecane	diesel	C16H34
41	23,917	23,900	23,945	111220	0,50	79843	0,63	1,39	V	Hexadecane	diesel	C16H34
42	24,055	24,030	24,080	61399	0,28	52504	0,41	1,17		Hexadecane	diesel	C16H34
43	24,611	24,585	24,655	471611	2,13	375286	2,97	1,26		8-Pentadecane	diesel	C15H30O
44	25,307	25,275	25,335	99650	0,45	52368	0,41	1,90		8-Pentadecane	diesel	C15H30O
45	25,350	25,335	25,380	98509	0,45	67664	0,53	1,46	V	8-Pentadecane	diesel	C15H30O
46	26,176	26,140	26,215	445291	2,01	250019	1,98	1,78		12-Tricosane	waxes and related products	C23H46O
47	27,758	27,720	27,800	1046565	4,74	794085	6,28	1,32		12-Tricosane	waxes and related products	C23H46O
48	28,585	28,545	28,635	117222	0,53	43688	0,35	2,68		12-Tricosane	waxes and related products	C23H46O
49	28,891	28,865	28,920	585259	2,65	479007	3,79	1,22		12-Tricosane	waxes and related products	C23H46O
50	30,078	30,045	30,120	281496	1,27	163014	1,29	1,73		12-Tricosane	waxes and related products	C23H46O
				22099196	100,00	12653673	100,00					

3W2= 30 BAR IN WITHOUT CATALYST AT 350 DEGREESE

Pe	R.Time	I.Time	F.Time	Area	Area	Height	Heig	A/	chemical	M	Name
1	3,140	3,105	3,200	761656	0,30	388961	0,48	1,96	C8H16		1-Octene
2	3,287	3,200	3,360	1545524	0,60	833537	1,03	1,85	C8H18	V	Hexane, 2,4-
3	4,487	4,450	4,545	510450	0,20	227825	0,28	2,24	C8H10		Ethylbenzene
4	4,655	4,630	4,780	2869085	1,12	934527	1,15	3,07	C8H10		p-Xylene
5	5,061	5,030	5,090	897492	0,35	493370	0,61	1,82	C9H18		1-Nonene
6	5,110	5,090	5,175	873611	0,34	339086	0,42	2,58	C8H10	V	p-Xylene
7	5,226	5,175	5,300	3582416	1,40	2004221	2,47	1,79	C9H20	V	Nonane
8	7,185	7,145	7,280	2346064	0,92	984879	1,21	2,38	C10H20		1-Decene
9	7,412	7,370	7,500	2896206	1,13	1251539	1,54	2,31	C10H22		Decane
10	10,312	10,270	10,400	1561086	0,61	545191	0,67	2,86	C11H22		1-Undecene
11	10,558	10,505	10,655	13208569	5,16	5825506	7,19	2,27	C11H24		Undecane
12	12,729	12,695	12,795	1449609	0,57	683611	0,84	2,12	C12H24		1-Dodecene
13	12,901	12,865	12,935	3608190	1,41	1432044	1,77	2,52	C11H24		Undecane
14	13,060	12,935	13,155	10896697	4,26	1636289	2,02	6,66	C8H16O2	V	Octanoic acid
15	15,039	14,985	15,100	737715	0,29	258319	0,32	2,86	C13H28		1-Tridecene
16	15,267	15,200	15,360	6392552	2,50	2229765	2,75	2,87	C13H28		Tridecane
17	17,447	17,325	17,500	10708341	4,19	2132285	2,63	5,02	C10H20O2		n-Decanoic acid
18	17,515	17,500	17,540	1058732	0,41	499044	0,62	2,12	C10H20O2	V	n-Decanoic acid
19	17,550	17,540	17,570	569576	0,22	355674	0,44	1,60	C10H20O2	V	n-Decanoic acid
20	17,598	17,570	17,645	1925323	0,75	836140	1,03	2,30	C14H30	V	Tetradecane
21	17,670	17,645	17,730	673608	0,26	218683	0,27	3,08	C14H30	V	Tetradecane
22	17,814	17,730	17,865	678197	0,27	166172	0,20	4,08	C14H30	V	Tetradecane
23	18,782	18,745	18,805	892083	0,35	483255	0,60	1,85	C18H36	V	1-Octadecene
24	18,830	18,805	18,845	1929355	0,75	1313756	1,62	1,47	C13H26O	V	2-Tridecanone
25	18,863	18,845	18,895	4404033	1,72	3143945	3,88	1,40	C14H30	V	Tetradecane
26	18,915	18,895	18,945	440131	0,17	229132	0,28	1,92	C14H30	V	Tetradecane
27	19,107	19,070	19,180	2009646	0,79	1109756	1,37	1,81	C12H24O2		Dodecanoic acid,

28	19,746	19,535	20,005	95593944	37,37	16280285	20,08	5,87	C12H24O2	S	Dodecanoic acid
29	20,386	20,335	20,480	1802324	0,70	380531	0,47	4,74	C12H24O2		Decanoic acid, 2-
30	20,582	20,480	20,660	2952264	1,15	1463529	1,81	2,02	C18H38	V	Octadecane
31	20,791	20,755	20,865	760612	0,30	447301	0,55	1,70	C15H30O2		Pentadecanoic acid,
32	21,264	21,160	21,405	26242428	10,26	7882930	9,72	3,33	C14H28O2		Tetradecanoic acid
33	22,302	22,245	22,345	1022332	0,40	357720	0,44	2,86	C19H38O		10-Nonadecanone
34	22,579	22,560	22,675	665628	0,26	299648	0,37	2,22	C17H34O	V	2-Heptadecanone
35	23,170	23,110	23,250	8141208	3,18	3264659	4,03	2,49	C16H32O2		n-Hexadecanoic
36	23,270	23,250	23,340	1713488	0,67	684070	0,84	2,50	C19H38	V	1-Nonadecene
37	23,420	23,340	23,475	854097	0,33	343541	0,42	2,49	C21H44	V	Heneicosane
38	24,010	23,935	24,100	3732240	1,46	2106112	2,60	1,77	C15H30O		8-Pentadecanone
39	24,649	24,595	24,670	822888	0,32	324635	0,40	2,53	C19H38		1-Nonadecene
40	24,692	24,670	24,755	1149804	0,45	579034	0,71	1,99	CC27H56O	V	1-Heptacosanol
41	25,397	25,360	25,470	3126657	1,22	1748746	2,16	1,79	C23H46O		12-Tricosanone
42	26,214	26,180	26,280	522087	0,20	225107	0,28	2,32	C23H46O		12-Tricosanone
43	27,080	27,030	27,155	7952984	3,11	4733666	5,84	1,68	C23H46O		12-Tricosanone
44	27,757	27,710	27,805	457825	0,18	179958	0,22	2,54	C23H46O	V	12-Tricosanone
45	28,319	28,270	28,375	5588042	2,18	4316532	5,32	1,29	C23H46O		12-Tricosanone
46	28,954	28,850	29,130	5700119	2,23	1032077	1,27	5,52	C23H46O		12-Tricosanone
47	29,356	29,295	29,420	3617793	1,41	2546794	3,14	1,42	C23H46O		12-Tricosanone
48	30,599	30,550	30,665	1617462	0,63	806350	0,99	2,01	C23H46O		12-Tricosanone
49	32,261	32,210	32,325	495783	0,19	184143	0,23	2,69	C23H46O		12-Tricosanone
50	33,955	33,815	34,040	1859459	0,73	322000	0,40	5,77	C23H46O		12-Tricosanone
				255817415	100,00	81065880	100,00				

3W1= 30 BAR IN WITHOUT CATALYST AT 300 DEGREESE

Pe	R.Time	I.Time	F.Ti	Area	Area%	Height	Heig	A/	chem	M	Name
1	10,573	10,530	10,630	493083	0,79	182381	1,02	2,70	C11H24		Undecane
2	12,924	12,890	13,005	1222872	1,95	386791	2,16	3,16	C8H16O2		Octanoic acid
3	19,126	19,100	19,210	847194	1,35	358768	2,00	2,36	C12H24O2		Dodecanoic acid,
4	19,685	19,575	19,975	37814609	60,42	8959644	50,02	4,22	C12H24O2	S	Dodecanoic acid
5	20,402	20,375	20,445	703775	1,12	373897	2,09	1,88	C12H22O2		Allyl nonanoate
6	20,811	20,780	20,875	341151	0,55	158089	0,88	2,16	C12H22O2		Allyl nonanoate
7	21,238	21,180	21,405	9316249	14,89	3419542	19,09	2,72	C14H28O2		Tetradecanoic acid
8	23,169	23,140	23,210	1540820	2,46	698320	3,90	2,21	C16H32O2		n-Hexadecanoic
9	23,229	23,210	23,265	865643	1,38	413172	2,31	2,10	C19H38	V	1-Nonadecene
10	23,285	23,265	23,335	431795	0,69	216813	1,21	1,99	C23H46	V	9-Tricosene, (Z)-
11	24,026	24,000	24,075	393441	0,63	211307	1,18	1,86	C23H46		9-Tricosene, (Z)-
12	27,098	27,065	27,150	686594	1,10	373079	2,08	1,84	C23H46O		12-Tricosanone
13	28,336	28,310	28,370	479532	0,77	343140	1,92	1,40	C23H46O		12-Tricosanone
14	29,376	29,350	29,410	295820	0,47	196514	1,10	1,51	C23H46O		12-Tricosanone
15	31,313	31,280	31,355	296210	0,47	143029	0,80	2,07	C23H46O		12-Tricosanone
16	32,582	32,515	32,650	1556052	2,49	448856	2,51	3,47	C23H46O		12-Tricosanone
17	33,900	33,845	33,935	712621	1,14	187938	1,05	3,79	C23H46O		12-Tricosanone
18	33,997	33,935	34,110	2173935	3,47	302207	1,69	7,19	C23H46O	V	12-Tricosanone
19	34,895	34,825	34,955	1647690	2,63	342444	1,91	4,81	C23H46O		12-Tricosanone
20	35,011	34,955	35,070	763901	1,22	194628	1,09	3,92	C23H46O	V	12-Tricosanone
				62582987	100,00	17910559	100,00				

6	3,896	3,780	3,935	2164667	5,34	1226057	5,51	1,77	V	1-Octene	gasoline	C8H16
7	4,053	3,980	4,085	1409269	3,48	787585	3,54	1,79	V	Hexane, 2,4-di	gasoline	C8H18
8	4,169	4,125	4,200	215597	0,53	114656	0,52	1,88	V	2-Octene, (Z)-	gasoline	C8H16
9	4,319	4,290	4,355	127503	0,31	78422	0,35	1,63	MI	2-Octene, (Z)-	gasoline	C8H16
10	4,538	4,495	4,600	199283	0,49	54997	0,25	3,62		2-Octene, (Z)-	gasoline	C8H16
11	4,693	4,600	4,725	224201	0,55	84102	0,38	2,67		2-Octene, (Z)-	gasoline	C8H16
12	4,752	4,730	4,795	119211	0,29	73870	0,33	1,61	MI	Cyclohexane, e	gasoline	C8H16
13	4,943	4,875	4,980	118042	0,29	43386	0,19	2,72	MI	Cyclohexane, e	gasoline	C8H16
14	5,067	5,045	5,120	109023	0,27	64927	0,29	1,68	MI	Cyclohexane, e	gasoline	C8H16
15	5,263	5,230	5,310	862709	2,13	505760	2,27	1,71		Ethylbenzene	gasoline	C8H10
16	5,443	5,390	5,510	1189170	2,93	460429	2,07	2,58		Benzene, 1,3-d	gasoline	C8H10
17	5,594	5,550	5,625	71273	0,18	44993	0,20	1,58	MI	Benzene, 1,3-d	gasoline	C8H10
18	5,749	5,690	5,785	121253	0,30	47352	0,21	2,56	MI	Benzene, 1,3-d	gasoline	C8H10
19	5,835	5,805	5,870	1716884	4,24	1169896	5,26	1,47	V	1-Nonene	gasoline	C9H18
20	5,898	5,870	5,935	697282	1,72	391425	1,76	1,78	V	o-Xylene	gasoline	C8H16
21	6,007	5,975	6,040	1732732	4,27	1172225	5,27	1,48	V	Nonane	gasoline	C9H20
22	6,121	6,040	6,165	264578	0,65	140621	0,63	1,88	V	cis-2-Nonene	gasoline	C9H18
23	6,282	6,220	6,315	187433	0,46	90757	0,41	2,07	V	cis-2-Nonene	gasoline	C9H18
24	6,708	6,680	6,735	76344	0,19	44593	0,20	1,71	MI	cis-2-Nonene	gasoline	C9H18
25	7,259	7,220	7,305	248314	0,61	118569	0,53	2,09		Benzene, propy	gasoline	C9H12
26	7,457	7,420	7,490	302865	0,75	157016	0,71	1,93		Benzene, 1-eth	diesel	C15H17
27	7,544	7,515	7,600	121040	0,30	69174	0,31	1,75	MI	Benzene, 1-eth	diesel	C15H17
28	7,947	7,905	8,020	199075	0,49	83957	0,38	2,37	MI	Benzene, 1-eth	diesel	C15H17
29	8,312	8,255	8,355	2426407	5,99	1081904	4,86	2,24		1-Decene	gasoline	C10H20
30	8,454	8,355	8,490	388718	0,96	103628	0,47	3,75	V	1-Decene	gasoline	C10H20
31	8,590	8,490	8,640	1019259	2,51	424453	1,91	2,40	V	Decane	gasoline	C10H22
32	8,769	8,720	8,815	273890	0,68	103932	0,47	2,64		Decane	gasoline	C10H22
33	9,054	9,005	9,100	121858	0,30	49070	0,22	2,48	MI	Decane	gasoline	C10H22
34	9,792	9,745	9,840	277645	0,68	120680	0,54	2,30		Decane	gasoline	C10H22
35	10,114	10,050	10,145	144178	0,36	66493	0,30	2,17	MI	Decane	gasoline	C10H22
36	10,421	10,375	10,490	228623	0,56	94620	0,43	2,42	MI	Decane	gasoline	C10H22

37	11,229	11,170	11,280	196146	0,48	72413	0,33	2,71	MI	Decane	gasoline	C10H22
38	11,375	11,330	11,440	1919753	4,74	1030864	4,63	1,86		1-Undecene	jet fuel	C11H22
39	11,593	11,540	11,635	2922274	7,21	1701419	7,64	1,72		Undecane	jet fuel	C11H22
40	11,705	11,635	11,730	200331	0,49	121479	0,55	1,65	V	4-Undecene, (Z)	jet fuel	C11H22
41	11,905	11,865	11,950	119363	0,29	73424	0,33	1,63	MI	4-Undecene, (Z)	jet fuel	C11H22
42	12,544	12,500	12,600	115019	0,28	60972	0,27	1,89	MI	4-Undecene, (Z)	jet fuel	C11H22
43	12,753	12,710	12,790	233668	0,58	94126	0,42	2,48		4-Undecene, (Z)	jet fuel	C11H22
44	12,935	12,865	12,990	225216	0,56	62782	0,28	3,59	MI	4-Undecene, (Z)	jet fuel	C11H22
45	13,605	13,580	13,620	434893	1,07	235016	1,06	1,85	V	4-Undecene, (Z)	jet fuel	C11H22
46	13,649	13,620	13,700	1388206	3,42	731947	3,29	1,90	V	1-Dodecene	jet fuel	C12H24
47	13,845	13,805	13,880	420390	1,04	246226	1,11	1,71		Undecane	jet fuel	C11H22
48	13,963	13,920	13,995	98520	0,24	57133	0,26	1,72	MI	Undecane	jet fuel	C11H22
49	16,381	16,340	16,410	518267	1,28	229963	1,03	2,25		1-Tridecene	jet fuel	C13H26
50	16,435	16,410	16,475	203038	0,50	83419	0,37	2,43	V	1-Tridecene	jet fuel	C13H26
51	16,589	16,475	16,665	1283915	3,17	529794	2,38	2,42	V	Hexadecane	diesel	C16H34
52	16,691	16,660	16,720	180265	0,44	100834	0,45	1,79	MI	Hexadecane	diesel	C16H34
53	16,900	16,865	16,935	164330	0,41	103085	0,46	1,59	MI	Hexadecane	diesel	C16H34
54	16,961	16,935	17,005	178068	0,44	91958	0,41	1,94	MI	Hexadecane	diesel	C16H34
55	18,212	18,190	18,230	347881	0,86	287215	1,29	1,21		8-Heptadecene	diesel	C17H34
56	18,317	18,295	18,345	189931	0,47	141399	0,64	1,34		Hexadecane	diesel	C16H34
57	18,463	18,435	18,490	428472	1,06	337422	1,52	1,27		Dodecanal	jet fuel	C12H24O
58	19,375	19,345	19,395	187263	0,46	158966	0,71	1,18		1-Tridecene	jet fuel	C13H26
59	19,420	19,395	19,435	1196169	2,95	1113787	5,00	1,07	V	2-Tridecanone	jet fuel	C13H26O
60	19,450	19,435	19,475	452246	1,12	429197	1,93	1,05	V	Tetradecane	jet fuel	C13H28
61	19,676	19,610	19,715	285771	0,70	223616	1,00	1,28	V	Methyl tetradecane	diesel	C15H30O2
62	20,166	20,110	20,195	402276	0,99	153547	0,69	2,62		Methyl tetradecane	diesel	C15H30O2
63	20,276	20,250	20,310	406761	1,00	308086	1,38	1,32	V	1-Decanol, 2-h	gasoline	C10H21OH
64	20,336	20,310	20,365	117667	0,29	98567	0,44	1,19	MI	1-Decanol, 2-h	gasoline	C10H21OH
65	20,481	20,445	20,535	170418	0,42	112632	0,51	1,51	MI	1-Decanol, 2-h	gasoline	C10H21OH
66	21,054	21,025	21,070	69964	0,17	52819	0,24	1,32	MI	1-Decanol, 2-h	gasoline	C10H21OH
67	21,086	21,065	21,130	61598	0,15	43072	0,19	1,43	MI	1-Decanol, 2-h	gasoline	C10H21OH
68	21,253	21,225	21,300	495028	1,22	325998	1,46	1,52		2-Heptadecano	diesel	C17H34O
69	21,494	21,445	21,525	91165	0,22	57281	0,26	1,59	MI	2-Heptadecano	diesel	C17H34O
70	23,058	23,010	23,090	121600	0,30	64375	0,29	1,89	MI	2-Heptadecano	diesel	C17H34O
71	23,287	23,260	23,320	182240	0,45	136878	0,61	1,33	MI	2-Heptadecano	diesel	C17H34O
72	23,865	23,810	23,895	103231	0,25	47566	0,21	2,17	MI	2-Heptadecano	diesel	C17H34O
73	23,916	23,900	23,970	49481	0,12	43378	0,19	1,14	MI	2-Heptadecano	diesel	C17H34O
74	24,611	24,585	24,655	289090	0,71	226554	1,02	1,28		8-Pentadecano	diesel	C15H30O
75	25,348	25,260	25,390	155986	0,38	41393	0,19	3,77	MI	8-Pentadecano	diesel	C15H30O
76	26,171	26,140	26,215	206214	0,51	110878	0,50	1,86		8-Pentadecano	diesel	C15H30O
77	27,757	27,730	27,795	397192	0,98	304660	1,37	1,30		12-Tricosanone	waxes and related products	C23H46O
78	28,590	28,550	28,655	198809	0,49	58991	0,27	3,37		12-Tricosanone	waxes and related products	C23H46O
79	28,890	28,865	28,940	321824	0,79	162738	0,73	1,98	V	12-Tricosanone	waxes and related products	C23H46O
80	29,692	29,680	29,760	228629	0,56	82732	0,37	2,76	V	12-Tricosanone	waxes and related products	C23H46O
				40539007	100,00	22257369	100,00					

2W2= 20 BAR IN WITHOUT CATALYST AT 350 DEGREESE

Pe	R.Tim	I.Time	F.Tim	Area	Area%	Height	Heigh	A/H	CHEM	M	Name
1	3,139	3,110	3,215	917334	0,50	455141	0,77	2,02	C8H16		1-Octene
2	3,287	3,255	3,360	1922423	1,05	1062958	1,80	1,81	C8H18		Hexane, 2,4-dimethyl-
3	5,062	5,030	5,110	810211	0,44	432332	0,73	1,87	C9H18		1-Nonene
4	5,230	5,200	5,315	3378813	1,84	1932994	3,27	1,75	C9H20		Nonane
5	7,191	7,150	7,280	1932635	1,05	721085	1,22	2,68	C10H20		1-Decene
6	7,355	7,280	7,370	191696	0,10	55558	0,09	3,45	C10H20	V	1-Decene
7	7,416	7,370	7,490	2549506	1,39	1076562	1,82	2,37	C10H22	V	Decane
8	10,321	10,275	10,395	1320043	0,72	462816	0,78	2,85	C11H22		1-Undecene
9	10,563	10,500	10,670	12143852	6,60	5106020	8,64	2,38	C11H22		Undecane
10	10,710	10,670	10,765	337352	0,18	110486	0,19	3,05	C11H22	V	Undecane
11	12,736	12,690	12,795	1105065	0,60	512197	0,87	2,16	C12H24		1-Dodecene
12	12,908	12,865	12,935	2992746	1,63	1229620	2,08	2,43	C12H26		Dodecane
13	13,002	12,935	13,125	5779658	3,14	1248235	2,11	4,63	C8H16O2	V	Octanoic acid
14	15,053	15,000	15,110	563208	0,31	188486	0,32	2,99	C13H26		1-Tridecene
15	15,275	15,220	15,375	5838056	3,18	2026001	3,43	2,88	C13H28		Tridecane
16	15,425	15,375	15,450	267330	0,15	85490	0,14	3,13	C13H28	V	Tridecane
17	17,408	17,330	17,450	4296318	2,34	1303701	2,21	3,30	C12H24O2		n-Decanoic acid
18	17,477	17,450	17,505	1494748	0,81	583414	0,99	2,56	C13H26	V	1-Tridecene
19	17,524	17,505	17,580	1353471	0,74	387839	0,66	3,49	C13H26	V	1-Tridecene
20	17,607	17,580	17,655	1587904	0,86	661581	1,12	2,40	C13H28	V	Tridecane
21	17,685	17,655	17,735	559974	0,30	176691	0,30	3,17	C13H28	V	Tridecane
22	17,823	17,735	17,885	675511	0,37	164518	0,28	4,11	C13H28	V	Tridecane
23	18,791	18,750	18,815	553506	0,30	324356	0,55	1,71	C15H30		1-Pentadecene
24	18,870	18,815	18,905	5279590	2,87	2862066	4,84	1,84	C14H30	V	Tetradecane
25	18,920	18,905	18,960	395521	0,22	207797	0,35	1,90	C14H30	V	Tetradecane
26	19,119	19,095	19,200	1149553	0,63	560361	0,95	2,05	C12H24O2		Dodecanoic acid,
27	19,708	19,545	19,990	54501638	29,64	11246695	19,03	4,85	C12H24O2	S	Dodecanoic acid

28	19,790	19,775	19,815	354517	0,19	369383	0,62	0,96	C14H30	T	Tetradecane
29	19,920	19,905	19,970	255686	0,14	173583	0,29	1,47	C10H20O	T	Decanal
30	20,400	20,365	20,430	671184	0,37	236276	0,40	2,84	C10H20O		Decanal
31	20,455	20,430	20,505	841977	0,46	334593	0,57	2,52	C10H20O	V	Decanal
32	20,592	20,505	20,680	2532314	1,38	1235029	2,09	2,05	C17H36	V	Heptadecane
33	20,807	20,765	20,870	381850	0,21	207521	0,35	1,84	C15H30O2		Methyl tetradecanoate
34	21,246	21,165	21,420	12907386	7,02	4311443	7,29	2,99	C14H28O2		Tetradecanoic acid
35	22,324	22,265	22,360	575978	0,31	203031	0,34	2,84	C14H28O2		Tetradecanoic acid
36	22,385	22,360	22,435	228533	0,12	99269	0,17	2,30	C14H28O2	V	Tetradecanoic acid
37	22,594	22,570	22,660	382394	0,21	182447	0,31	2,10	C14H28O2	V	Tetradecanoic acid
38	22,800	22,760	22,855	179223	0,10	93768	0,16	1,91	C14H28O2		Tetradecanoic acid
39	23,170	23,140	23,210	2274698	1,24	1090952	1,85	2,09	C16H32O2		n-Hexadecanoic acid
40	23,226	23,210	23,265	1255079	0,68	453493	0,77	2,77	C16H32O2	V	n-Hexadecanoic acid
41	23,284	23,265	23,345	1047458	0,57	467255	0,79	2,24	C19H38	V	1-Nonadecene
42	23,432	23,345	23,485	600595	0,33	223700	0,38	2,68	C19H38	V	1-Nonadecene
43	24,022	23,960	24,110	2304020	1,25	1182017	2,00	1,95	C15H30O		Pentadecanone
44	24,175	24,110	24,210	258187	0,14	118796	0,20	2,17	C15H30O	V	Pentadecanone
45	24,665	24,610	24,685	390535	0,21	185884	0,31	2,10	C15H30O		Pentadecanone
46	24,707	24,685	24,780	756950	0,41	352067	0,60	2,15	C23H46	V	9-Tricosene, (Z)-
47	24,844	24,815	24,895	211528	0,12	117053	0,20	1,81	C23H46		9-Tricosene, (Z)-
48	25,413	25,375	25,485	2031632	1,10	1096952	1,86	1,85	C23H46O		12-Tricosanone
49	26,236	26,195	26,285	325028	0,18	145319	0,25	2,24	C23H46O		12-Tricosanone
50	27,095	27,050	27,170	4928027	2,68	2849575	4,82	1,73	C23H46O		12-Tricosanone
51	27,778	27,715	27,815	351009	0,19	125544	0,21	2,80	C23H46O	V	12-Tricosanone
52	28,333	28,290	28,385	3350434	1,82	2376692	4,02	1,41	C23H46O		12-Tricosanone
53	28,755	28,710	28,785	232575	0,13	99569	0,17	2,34	C23H46O		12-Tricosanone
54	28,905	28,785	28,935	5243878	2,85	1023926	1,73	5,12	C23H46O	V	12-Tricosanone
55	28,954	28,935	29,075	3234720	1,76	934865	1,58	3,46	C23H46O	V	12-Tricosanone
56	29,375	29,340	29,440	2123915	1,16	1397999	2,37	1,52	C23H46O		12-Tricosanone
57	30,628	30,580	30,675	952996	0,52	445335	0,75	2,14	C23H46O		12-Tricosanone
58	32,302	32,255	32,355	294814	0,16	104262	0,18	2,83	C23H46O		12-Tricosanone
59	33,943	33,745	34,030	8743359	4,76	866691	1,47	10,09	C23H46O		12-Tricosanone
60	34,078	34,030	34,490	9748115	5,30	821753	1,39	11,86	C23H46O	V	12-Tricosanone
				183868256	100,00	59111042	100,00				

2W1= 20 BAR IN WITHOUT CATALYST AT 300 DEGREESE

Pe	R.Tim	I.Time	F.Ti	Area	Area	Height	Heigh	A/H	chem formula	Mark	Name
1	19,668	19,570	19,825	29339031	48,44	8060174	49,74	3,64	C12H24O2		Dodecanoic acid
2	20,395	20,365	20,435	374223	0,62	216865	1,34	1,73	C12H24O2		Decanoic acid, 2-
3	21,220	21,170	21,380	7624291	12,59	3063084	18,90	2,49	C14H28O2		Tetradecanoic acid
4	23,156	23,125	23,200	1447124	2,39	629538	3,88	2,30	C16H32O2		n-Hexadecanoic acid
5	23,217	23,200	23,250	614911	1,02	282247	1,74	2,18	C16H32O2		n-Hexadecanoic acid
6	23,280	23,250	23,325	359501	0,59	135256	0,83	2,66	C16H32O2		n-Hexadecanoic acid
7	24,014	23,985	24,050	224644	0,37	134995	0,83	1,66	C16H32O2		n-Hexadecanoic acid
8	24,655	24,635	24,715	148493	0,25	65150	0,40	2,28	C16H32O2		n-Hexadecanoic acid
9	25,404	25,375	25,445	177597	0,29	104617	0,65	1,70	C16H32O2		n-Hexadecanoic acid
10	27,082	27,055	27,125	618725	1,02	375096	2,31	1,65	C23H46O		12-Tricosanone
11	28,324	28,290	28,360	552459	0,91	397434	2,45	1,39	C23H46O		12-Tricosanone
12	29,360	29,335	29,395	438435	0,72	304705	1,88	1,44	C23H46O		12-Tricosanone
13	29,646	29,620	29,660	91700	0,15	71424	0,44	1,28	C23H46O		12-Tricosanone
14	30,601	30,570	30,650	198329	0,33	119149	0,74	1,66	C23H46O		12-Tricosanone
15	30,865	30,835	30,910	147852	0,24	81042	0,50	1,82	C23H46O		12-Tricosanone
16	31,286	31,250	31,340	240965	0,40	111814	0,69	2,16	C23H46O		12-Tricosanone
17	32,149	31,960	32,465	12633687	20,86	794551	4,90	15,90	C12H24O2		Dodecanoic acid, 1,2,3-
18	32,548	32,465	32,620	2073963	3,42	550802	3,40	3,77	C12H24O2		Dodecanoic acid, 1,2,3-
19	34,854	34,755	34,915	2255117	3,72	444827	2,74	5,07	C12H24O2		Dodecanoic acid, 1,2,3-
20	34,960	34,915	35,040	1007657	1,66	262580	1,62	3,84	C12H24O2		Dodecanoic acid, 1,2,3-
				60568704	100,00	16205350	100,00				

6	3,904	3,865	3,940	2089559	3,23	1279886	3,50	1,63		1-Octene	gasoline	C8H16
7	4,061	4,020	4,095	2443823	3,78	1396440	3,82	1,75		Hexane, 2,4-di	gasoline	C8H18
8	4,110	4,095	4,150	236331	0,37	126627	0,35	1,87	V	Hexane, 2,4-di	gasoline	C8H18
9	4,176	4,150	4,210	363866	0,56	233927	0,64	1,56	V	2-Octene	gasoline	C8H16
10	4,226	4,210	4,265	67155	0,10	39980	0,11	1,68	MI	2-Octene	gasoline	C8H16
11	4,324	4,295	4,360	216508	0,34	132267	0,36	1,64		2-Octene, (Z)-	gasoline	C8H16
12	4,536	4,495	4,605	133350	0,21	35604	0,10	3,75	MI	2-Octene, (Z)-	gasoline	C8H16
13	4,690	4,670	4,740	147311	0,23	61111	0,17	2,41		2-Octene, (Z)-	gasoline	C8H16
14	4,759	4,740	4,795	131577	0,20	76055	0,21	1,73	V	2-Octene, (Z)-	gasoline	C8H16
15	4,954	4,915	4,990	67074	0,10	37244	0,10	1,80	MI	2-Octene, (Z)-	gasoline	C8H16
16	5,076	5,040	5,120	86276	0,13	40408	0,11	2,14	MI	2-Octene, (Z)-	gasoline	C8H16
17	5,269	5,230	5,325	1486960	2,30	907370	2,48	1,64		Ethylbenzene	gasoline	C8H10
18	5,450	5,400	5,525	1498114	2,32	594448	1,62	2,52		Benzene, 1,3-d	gasoline	C8H10
19	5,605	5,575	5,635	63772	0,10	38969	0,11	1,64	MI	Benzene, 1,3-d	gasoline	C8H10
20	5,749	5,710	5,795	120273	0,19	47934	0,13	2,51	MI	Benzene, 1,3-d	gasoline	C8H10
21	5,843	5,810	5,875	1886904	2,92	1234109	3,37	1,53		1-Nonene	gasoline	C9H18
22	5,905	5,875	5,945	1158458	1,79	635218	1,74	1,82	V	Benzene, 1,3-d	gasoline	C8H10
23	5,964	5,945	5,980	215546	0,33	140267	0,38	1,54	V	Benzene, 1,3-d	gasoline	C8H10
24	6,017	5,980	6,060	3187077	4,93	2116565	5,78	1,51	V	Nonane	gasoline	C9H20
25	6,128	6,060	6,165	388506	0,60	231750	0,63	1,68	V	cis-2-Nonene	gasoline	C9H18
26	6,216	6,185	6,240	55704	0,09	39214	0,11	1,42	MI	cis-2-Nonene	gasoline	C9H18
27	6,289	6,260	6,325	199997	0,31	127473	0,35	1,57		cis-2-Nonene	gasoline	C9H18
28	6,489	6,450	6,520	80308	0,12	33711	0,09	2,38	MI	cis-2-Nonene	gasoline	C9H18
29	6,548	6,530	6,580	30277	0,05	24473	0,07	1,24	MI	cis-2-Nonene	gasoline	C9H18
30	6,712	6,680	6,745	98463	0,15	49218	0,13	2,00	MI	cis-2-Nonene	gasoline	C9H18
31	6,771	6,740	6,805	31548	0,05	29768	0,08	1,06	MI	cis-2-Nonene	gasoline	C9H18
32	7,075	7,045	7,100	38552	0,06	21178	0,06	1,82	MI	cis-2-Nonene	gasoline	C9H18
33	7,267	7,230	7,315	442390	0,68	225349	0,62	1,96		Benzene, propy	gasoline	C9H12
34	7,466	7,430	7,515	432221	0,67	222001	0,61	1,95		Benzene, (1-m	gasoline	C9H12
35	7,552	7,515	7,600	195444	0,30	95227	0,26	2,05	V	Benzene, (1-m	gasoline	C9H12
36	7,701	7,655	7,740	57652	0,09	23081	0,06	2,50	MI	Benzene, (1-m	gasoline	C9H12

37	7,959	7,925	8,010	372786	0,58	180084	0,49	2,07		Benzene, 1-eth	diesel	C15H17
38	8,120	8,065	8,160	37839	0,06	23177	0,06	1,63	MI	Benzene, 1-eth	diesel	C15H17
39	8,324	8,265	8,365	2768838	4,29	1233323	3,37	2,25		1-Decene	gasoline	C10H20
40	8,466	8,365	8,525	644246	1,00	139533	0,38	4,62	V	Mesitylene	gasoline	C8H30
41	8,608	8,525	8,650	2020013	3,13	883284	2,41	2,29	V	Decane	gasoline	C10H22
42	8,781	8,735	8,830	420853	0,65	162592	0,44	2,59		2-Decene, (E)-	gasoline	C10H20
43	9,065	9,030	9,105	175974	0,27	75173	0,21	2,34		2-Decene, (E)-	gasoline	C10H20
44	9,803	9,765	9,850	322941	0,50	143084	0,39	2,26		Indane	gasoline	C9H10
45	10,125	10,060	10,230	230093	0,36	56077	0,15	4,10	MI	Indane	gasoline	C9H10
46	10,285	10,230	10,325	129139	0,20	56774	0,16	2,27	MI	Indane	gasoline	C9H10
47	10,431	10,395	10,470	300222	0,46	159110	0,43	1,89		Indane	gasoline	C9H10
48	11,235	11,165	11,310	235378	0,36	79490	0,22	2,96	MI	Benzene, butyl	gasoline	C10H14
49	11,384	11,330	11,450	2250847	3,48	1077870	2,94	2,09		1-Undecene	jet fuel	C11H22
50	11,495	11,450	11,560	214647	0,33	85122	0,23	2,52	V	1-Undecene	jet fuel	C11H22
51	11,613	11,560	11,655	6880774	10,65	3756460	10,26	1,83	V	Undecane	jet fuel	C11H22
52	11,716	11,675	11,760	383003	0,59	225640	0,62	1,70		2-Undecene, (Z)	jet fuel	C11H22
53	11,916	11,880	11,950	191735	0,30	121436	0,33	1,58		2-Undecene, (Z)	jet fuel	C11H22
54	12,556	12,490	12,645	227959	0,35	58964	0,16	3,87	MI	2-Undecene, (Z)	jet fuel	C11H22
55	12,754	12,720	12,800	213225	0,33	94958	0,26	2,25		2-Undecene, (Z)	jet fuel	C11H22
56	12,921	12,875	13,015	334274	0,52	103434	0,28	3,23	MI	2-Undecene, (Z)	jet fuel	C11H22
57	13,613	13,580	13,635	841111	1,30	418755	1,14	2,01		Naphthalene	gasoline	C10H8
58	13,660	13,635	13,730	1678818	2,60	829707	2,27	2,02	V	1-Dodecene	jet fuel	C11H22
59	13,855	13,815	13,895	930584	1,44	532020	1,45	1,75		Undecane	jet fuel	C11H22
60	13,967	13,940	14,005	150542	0,23	82359	0,23	1,83		2-Dodecene, (E)	jet fuel	C11H22
61	15,466	15,390	15,505	134400	0,21	70357	0,19	1,91	MI	2-Dodecene, (E)	jet fuel	C11H22
62	16,393	16,350	16,425	501681	0,78	248679	0,68	2,02		3-Tetradecene,	diesel	C14H28
63	16,602	16,550	16,675	2832964	4,39	1312926	3,59	2,16		Tridecane	jet fuel	C13H28
64	16,702	16,675	16,740	186279	0,29	98884	0,27	1,88	V	4-Dodecene, (E)	jet fuel	C12H24
65	16,909	16,875	16,935	111024	0,17	72689	0,20	1,53		4-Dodecene, (E)	jet fuel	C12H24
66	16,967	16,935	17,010	304863	0,47	155408	0,42	1,96		4-Dodecene, (E)	jet fuel	C12H24
67	18,216	18,195	18,240	429916	0,67	354610	0,97	1,21		1-Tridecene	jet fuel	C13H26
68	18,324	18,240	18,345	467891	0,72	327895	0,90	1,43		Hexadecane	diesel	C16H34
69	18,385	18,345	18,410	174179	0,27	67345	0,18	2,59	V	Hexadecane	diesel	C16H34
70	18,467	18,440	18,495	657754	1,02	517168	1,41	1,27		Hexadecanal	diesel	C16H32O
71	19,379	19,345	19,400	247848	0,38	194456	0,53	1,27		1-Tridecene	jet fuel	C13H26
72	19,425	19,400	19,440	1154014	1,79	1048162	2,86	1,10	V	2-Tridecanone	jet fuel	C13H26O

73	19,455	19,440	19,480	1050895	1,63	1007362	2,75	1,04	V	Tetradecane	diesel	C14H30
74	19,679	19,660	19,715	379726	0,59	333881	0,91	1,14		Dodecanoic ac	jet fuel	C13H26O2
75	20,140	20,120	20,155	147917	0,23	91368	0,25	1,62		Dodecanoic ac	jet fuel	C13H26O2
76	20,195	20,155	20,230	690058	1,07	236919	0,65	2,91	V	Dodecanoic ac	jet fuel	C13H26O2
77	20,281	20,230	20,310	688897	1,07	451145	1,23	1,53	V	3-Tetradecanon	diesel	H14H28O
78	20,339	20,310	20,365	210559	0,33	157693	0,43	1,34	V	Hexadecane	diesel	C16H34
79	20,484	20,460	20,510	231806	0,36	189820	0,52	1,22		Tetradecanal	diesel	C14H28O
80	21,016	20,985	21,040	199245	0,31	107474	0,29	1,85		Tetradecanal	diesel	C14H28O
81	21,060	21,040	21,070	102264	0,16	64631	0,18	1,58	V	Tetradecanal	diesel	C14H28O
82	21,090	21,070	21,230	219010	0,34	84739	0,23	2,58	V	Tetradecanal	diesel	C14H28O
83	21,255	21,230	21,290	642868	1,00	453668	1,24	1,42		2-Heptadecano	diesel	C17H34O
84	21,496	21,470	21,515	95985	0,15	69165	0,19	1,39		2-Heptadecano	diesel	C17H34O
85	22,521	22,455	22,595	120730	0,19	71253	0,19	1,69	MI	2-Heptadecano	diesel	C17H34O
86	23,063	23,020	23,085	284591	0,44	123341	0,34	2,31		2-Heptadecano	diesel	C17H34O
87	23,292	23,270	23,325	192476	0,30	157315	0,43	1,22		2-Heptadecano	diesel	C17H34O
88	23,871	23,855	23,950	249210	0,39	82136	0,22	3,03		2-Heptadecano	diesel	C17H34O
89	24,616	24,585	24,665	905725	1,40	714908	1,95	1,27		8-Pentadecano	diesel	C15H30
90	25,351	25,255	25,435	295160	0,46	97601	0,27	3,02	MI	8-Pentadecano	diesel	C15H30
91	26,179	26,150	26,235	809023	1,25	470924	1,29	1,72		10-Nonadecano	waxes and related products	C19H38O
92	27,764	27,725	27,805	2163947	3,35	1696637	4,64	1,28		12-Tricosanone	waxes and related products	C23H46O
93	28,896	28,865	28,930	1156368	1,79	1006368	2,75	1,15		12-Tricosanone	waxes and related products	C23H46O
94	30,083	30,055	30,125	499928	0,77	311293	0,85	1,61		12-Tricosanone	waxes and related products	C23H46O
				64601827	100,00	36600537	100,00					

1W3=10 BAR IN WITHOUT CATALYST AT 400 DEGREESE

Pe	R.Tim	I.Time	F.Tim	Area	Area%	Height	Heig	A/H	chem	M	Name
1	3,138	3,100	3,210	2481917	1,19	1347427	1,88	1,84	C8H16		1-Octene
2	3,289	3,210	3,360	1316195	0,63	684032	0,95	1,92	C6H14	V	Hexane, 2,4-
3	4,674	4,645	4,765	857959	0,41	247984	0,35	3,46	C8H10		p-Xylene
4	5,060	5,025	5,105	1982348	0,95	1192577	1,66	1,66	C9H18		1-Nonene
5	5,231	5,200	5,320	2319707	1,11	1238485	1,73	1,87	C9H20		Nonane
6	7,190	7,145	7,290	5010960	2,40	2154954	3,01	2,33	C10H20		1-Decene
7	7,418	7,380	7,505	1298189	0,62	543577	0,76	2,39	C10H22		Decane
8	10,319	10,265	10,420	2812762	1,35	1043245	1,46	2,70	C11H22		1-Undecene
9	10,562	10,515	10,665	6766821	3,25	2861161	3,99	2,37	C11H24		Undecane
10	12,733	12,690	12,815	3587660	1,72	1698783	2,37	2,11	C12H24		1-Dodecene
11	12,910	12,865	12,940	2310173	1,11	796083	1,11	2,90	C10H22		Decane, 3-methyl-
12	13,028	12,940	13,120	7153658	3,43	1457759	2,03	4,91	C8H16O2	V	Octanoic acid
13	15,046	15,000	15,115	1161730	0,56	409788	0,57	2,83	C13H26		1-Tridecene
14	15,276	15,220	15,355	2876107	1,38	1015318	1,42	2,83	C13H28		Tridecane
15	17,428	17,340	17,455	5571763	2,67	1591911	2,22	3,50	C10H20O2		n-Decanoic acid
16	17,479	17,455	17,550	3337642	1,60	1223956	1,71	2,73	C13H26	V	1-Tridecene
17	17,565	17,550	17,580	366782	0,18	219330	0,31	1,67	C13H26	V	1-Tridecene
18	17,607	17,580	17,650	887048	0,43	362190	0,51	2,45	C14H30	V	Tetradecane
19	17,788	17,730	17,805	441151	0,21	222103	0,31	1,99	C14H30	V	Tetradecane
20	17,820	17,805	17,855	286935	0,14	150056	0,21	1,91	C14H30	V	Tetradecane
21	18,791	18,750	18,815	794706	0,38	507940	0,71	1,56	C13H26		1-Tridecene
22	18,838	18,815	18,855	2143381	1,03	1353929	1,89	1,58	C13H26O	V	2-Tridecanone
23	18,870	18,855	18,910	2516302	1,21	1663076	2,32	1,51	C14H30	V	Tetradecane
24	18,920	18,910	18,990	341377	0,16	178124	0,25	1,92	C14H30	V	Tetradecane
25	19,116	19,085	19,190	2072789	0,99	1144420	1,60	1,81	C12H24O2	S	Dodecanoic acid,
26	19,734	19,545	20,040	76775570	36,82	14720452	20,54	5,22	C12H24O2	S	Dodecanoic acid
27	19,922	19,900	19,965	433378	0,21	286551	0,40	1,51	C14H28O	T	Tetradecanal
28	20,397	20,335	20,435	1457783	0,70	599399	0,84	2,43	C10H20O2		Decanoic acid, 2-

29	20,450	20,435	20,495	603651	0,29	246376	0,34	2,45	C10H20O2	V	Decanoic acid, 2-
30	20,540	20,495	20,570	439344	0,21	146439	0,20	3,00	C10H20O2	V	Decanoic acid, 2-
31	20,595	20,570	20,670	1756998	0,84	992527	1,39	1,77	C14H28O	V	2-Tetradecanone
32	20,802	20,765	20,875	801562	0,38	428229	0,60	1,87	CH3		Methyl
33	21,262	21,170	21,410	20564968	9,86	6139391	8,57	3,35	C14H28O2		Tetradecanoic
34	21,438	21,410	21,550	1092689	0,52	249545	0,35	4,38	C14H28O2	V	Tetradecanoic
35	21,710	21,665	21,760	282973	0,14	144167	0,20	1,96	C14H28O2		Tetradecanoic acid
36	22,009	21,970	22,065	308862	0,15	131819	0,18	2,34	C14H28O2		Tetradecanoic
37	22,319	22,275	22,365	1125962	0,54	417108	0,58	2,70	C10H20O2		Decanoic acid, 2-
38	22,590	22,560	22,660	563073	0,27	312354	0,44	1,80	C15H30O2		2-Pentadecanone
39	22,799	22,770	22,845	365295	0,18	202947	0,28	1,80	C15H30O2		2-Pentadecanone
40	23,176	23,130	23,205	3770045	1,81	2023973	2,82	1,86	C16H32O2		n-Hexadecanoic
41	23,225	23,205	23,265	2107439	1,01	855124	1,19	2,46	C19H38	V	1-Nonadecene
42	23,280	23,265	23,340	1085249	0,52	500458	0,70	2,17	C19H38	V	1-Nonadecene
43	23,433	23,340	23,475	550398	0,26	168412	0,24	3,27	C19H38	V	1-Nonadecene
44	24,021	23,935	24,145	3538284	1,70	2017338	2,82	1,75	C19H30O		8-Pentadecanone
45	24,664	24,610	24,685	816532	0,39	411388	0,57	1,98	C19H38		1-Nonadecene
46	24,706	24,685	24,775	775771	0,37	422062	0,59	1,84	C18H36	V	1-Octadecene
47	25,411	25,365	25,490	2668314	1,28	1581836	2,21	1,69	C23H46O		12-Tricosanone
48	26,230	26,110	26,285	792179	0,38	171521	0,24	4,62	C23H46O		12-Tricosanone
49	27,095	27,045	27,160	7356052	3,53	4336566	6,05	1,70	C23H46O		12-Tricosanone
50	27,775	27,715	27,805	303641	0,15	109994	0,15	2,76	C23H46O	V	12-Tricosanone
51	28,333	28,285	28,400	5220696	2,50	3924121	5,48	1,33	C23H46O		12-Tricosanone
52	28,900	28,860	28,920	296940	0,14	177783	0,25	1,67	C23H46O		12-Tricosanone
53	28,968	28,920	29,070	1341231	0,64	306093	0,43	4,38	C23H46O	V	12-Tricosanone
54	29,375	29,325	29,435	3326677	1,60	2140465	2,99	1,55	C23H46O		12-Tricosanone
55	30,475	30,425	30,590	485143	0,23	161939	0,23	3,00	C23H46O		12-Tricosanone
56	30,628	30,590	30,695	1483703	0,71	711543	0,99	2,09	C23H46O	V	12-Tricosanone
57	32,291	32,255	32,350	438941	0,21	154841	0,22	2,83	C23H46O		12-Tricosanone
58	32,576	32,505	32,655	1595453	0,77	444236	0,62	3,59	C23H46O		12-Tricosanone
59	34,894	34,795	34,955	2239645	1,07	464735	0,65	4,82	C23H46O		12-Tricosanone
60	35,010	34,955	35,090	1032298	0,50	246321	0,34	4,19	C23H46O	V	12-Tricosanone
				208492801	100,00	71656261	100,00				

1W2= 10 BAR IN WITHOUT CATALYST AT 350 DEGREESE

Pe	R.Tim	I.Time	F.Tim	Area	Are	Height	Heigh	A/H	M	chem formu	Name
1	3,142	3,110	3,215	704189	0,36	345487	0,48	2,04		C8H16	1-Octene
2	3,290	3,215	3,360	1033295	0,52	576692	0,80	1,79	V	C8H18	Hexane, 2,4-dimethyl-
3	4,680	4,650	4,750	482094	0,24	150305	0,21	3,21		C8H18	Hexane, 2,4-dimethyl-
4	5,064	5,035	5,110	710975	0,36	390752	0,54	1,82		C9H18	1-Nonene
5	5,230	5,195	5,315	2174181	1,10	1168730	1,61	1,86		C9H20	Nonane
6	7,191	7,150	7,295	1978901	1,00	716706	0,99	2,76		C10H20	1-Decene
7	7,416	7,295	7,505	1821604	0,92	664034	0,92	2,74	V	C10H22	Decane
8	10,320	10,275	10,410	1463470	0,74	504651	0,70	2,90		C11H22	1-Undecene
9	10,561	10,505	10,675	9734667	4,91	4281517	5,91	2,27		C11H22	Undecane
10	12,738	12,695	12,795	1223175	0,62	549775	0,76	2,22		C12H24	1-Dodecene
11	12,911	12,870	12,935	2169712	1,09	902488	1,25	2,40		C16H34	Hexadecane
12	13,011	12,935	13,110	5866772	2,96	1218780	1,68	4,81	V	C8H16O2	Octanoic acid
13	15,054	15,000	15,110	710180	0,36	228935	0,32	3,10		C12H26O	1-Dodecanol
14	15,276	15,225	15,375	4650013	2,35	1681564	2,32	2,77		C13H28	Tridecane
15	17,414	17,330	17,455	4426836	2,23	1326037	1,83	3,34		C12H24O2	n-Decanoic acid
16	17,481	17,455	17,510	1567403	0,79	612381	0,85	2,56	V	C13H26	1-Tridecene
17	17,525	17,510	17,550	734342	0,37	353956	0,49	2,07	V	C13H26	1-Tridecene
18	17,555	17,550	17,585	473314	0,24	258782	0,36	1,83	V	C13H26	1-Tridecene
19	17,609	17,585	17,660	1210333	0,61	500076	0,69	2,42	V	C13H28	Tridecane
20	17,690	17,660	17,725	388573	0,20	135804	0,19	2,86	V	C13H28	Tridecane
21	17,825	17,725	17,875	665131	0,34	163606	0,23	4,07	V	C13H28	Tridecane
22	18,791	18,765	18,815	619917	0,31	399628	0,55	1,55	V	C16H34O	1-Hexadecanol
23	18,837	18,815	18,855	2292828	1,16	1505641	2,08	1,52	V	C13H26O	2-Tridecanone
24	18,871	18,855	18,965	3840150	1,94	2557417	3,53	1,50	SV	C14H30	Tetradecane
25	19,122	19,090	19,215	1458457	0,74	747755	1,03	1,95		C12H24O2	Dodecanoic acid,
26	19,718	19,550	19,975	59874948	30,21	11564473	15,97	5,18	S	C12H24O2	Dodecanoic acid
27	19,925	19,905	19,960	269116	0,14	205252	0,28	1,31	T	C12H24O	Dodecanal
28	20,397	20,345	20,435	1632944	0,82	721962	1,00	2,26		C12H24O2	Decanoic acid, 2-

29	20,452	20,435	20,495	683551	0,34	294009	0,41	2,32	V	C12H24O2	Decanoic acid, 2-
30	20,595	20,495	20,685	2800140	1,41	1391459	1,92	2,01	V	C12H26	Dodecane, 2-methyl-
31	20,807	20,780	20,870	534369	0,27	293836	0,41	1,82		C15H30O2	Methyl tetradecanoate
32	21,250	21,165	21,425	14906608	7,52	4716784	6,51	3,16		C14H28O2	Tetradecanoic acid
33	21,475	21,425	21,525	655705	0,33	162991	0,23	4,02	V	C14H28O2	Tetradecanoic acid
34	22,314	22,270	22,365	1238775	0,63	474764	0,66	2,61		C12H24O2	Decanoic acid, 2-
35	22,380	22,365	22,405	174809	0,09	109293	0,15	1,60	V	C12H24O2	Decanoic acid, 2-
36	22,593	22,565	22,675	640544	0,32	316259	0,44	2,03		C17H34O	2-Hentadecanone
37	22,801	22,770	22,860	256952	0,13	132717	0,18	1,94		C17H34O	2-Heptadecanone
38	23,170	23,130	23,205	1918342	0,97	954199	1,32	2,01		C16H32O2	n-Hexadecanoic acid
39	23,229	23,205	23,265	1604329	0,81	679584	0,94	2,36	V	C19H38	1-Nonadecene
40	23,285	23,265	23,335	932568	0,47	522571	0,72	1,78	V	C19H38	1-Nonadecene
41	23,435	23,415	23,490	274025	0,14	185988	0,26	1,47		C19H38	1-Nonadecene
42	24,024	23,960	24,105	4397367	2,22	2568736	3,55	1,71		C15H30O	8-Pentadecanone
43	24,232	24,205	24,255	220322	0,11	141886	0,20	1,55	V	C15H30O	8-Pentadecanone
44	24,670	24,620	24,685	505255	0,25	293192	0,40	1,72		C14H30O	1-Tetradecanol
45	24,706	24,685	24,775	921124	0,46	473822	0,65	1,94	V	C27H56O	1-Heptacosanol
46	25,413	25,345	25,520	4486408	2,26	2385519	3,29	1,88		C23H46O	12-Tricosanone
47	26,238	26,205	26,300	418520	0,21	181004	0,25	2,31		C23H46O	12-Tricosanone
48	27,099	27,050	27,175	12047332	6,08	7221961	9,97	1,67		C23H46O	12-Tricosanone
49	27,775	27,725	27,825	383364	0,19	193399	0,27	1,98		C23H46O	12-Tricosanone
50	28,335	28,290	28,400	8898689	4,49	6977000	9,63	1,28		C23H46O	12-Tricosanone
51	28,845	28,805	28,880	196953	0,10	133169	0,18	1,48		C23H46O	12-Tricosanone
52	28,982	28,880	29,015	199330	0,10	77622	0,11	2,57	V	C23H46O	12-Tricosanone
53	29,378	29,345	29,450	5756887	2,90	3782118	5,22	1,52		C23H46O	12-Tricosanone
54	30,491	30,425	30,555	604364	0,30	139588	0,19	4,33		C23H46O	12-Tricosanone
55	30,630	30,555	30,730	2834469	1,43	1294045	1,79	2,19	V	C23H46O	12-Tricosanone
56	32,145	31,975	32,180	4455914	2,25	662965	0,92	6,72		C23H46O	12-Tricosanone
57	32,301	32,180	32,530	10214148	5,15	1021019	1,41	10,00	V	C12H24O2	Dodecanoic acid, 1,2,3-
58	32,587	32,530	32,680	356256	0,18	110955	0,15	3,21		C12H24O2	Dodecanoic acid, 1,2,3-
59	34,660	34,630	34,840	217565	0,11	36189	0,05	6,01		C12H24O2	Dodecanoic acid, 1,2,3-
60	34,895	34,840	34,970	271825	0,14	65849	0,09	4,13		C12H24O2	Dodecanoic acid, 1,2,3-
				198184329		72427678	100,00				

1W1= 10 BAR IN WITHOUT CATALYST AT 300 DEGREESE

Peak	R.Time	I.Time	F.Time	Area	Area%	Height	Height%	A/H		Mark	Name
1	5,244	5,215	5,315	216362	0,18	90995	0,23	2,38	C11H24		Undecane
2	10,564	10,520	10,645	1243690	1,05	466250	1,19	2,67	C11H24		Undecane
3	12,973	12,890	13,100	4120962	3,49	860474	2,20	4,79	C8H16O2		Octanoic acid
4	15,284	15,230	15,335	513450	0,43	178674	0,46	2,87	C16H34		Hexadecane
5	17,398	17,355	17,475	2326290	1,97	816232	2,09	2,85	C12H24O2		n-Decanoic acid
6	17,793	17,760	17,800	373718	0,32	244201	0,62	1,53	C12H24O2		n-Decanoic acid
7	17,830	17,800	17,875	660077	0,56	225768	0,58	2,92	C12H24O2	V	n-Decanoic acid
8	18,798	18,775	18,830	120563	0,10	69478	0,18	1,74	C12H24O2		n-Decanoic acid
9	18,872	18,830	18,965	933257	0,79	406431	1,04	2,30	C16H34		Hexadecane
10	19,122	19,095	19,215	1326936	1,12	588396	1,50	2,26	C12H24O2		Dodecanoic acid,
11	19,708	19,565	19,970	52079141	44,05	11024267	28,17	4,72	C12H24O2	S	Dodecanoic acid
12	19,925	19,880	19,970	585734	0,50	404019	1,03	1,45	C14H28O	T	Tetradecanal
13	20,397	20,360	20,435	1590916	1,35	925746	2,37	1,72	C12H24O2		Decanoic acid, 2-
14	20,455	20,435	20,475	250825	0,21	122654	0,31	2,04	C12H24O2	V	Decanoic acid, 2-
15	20,505	20,475	20,560	361772	0,31	134020	0,34	2,70	C12H24O2	V	Decanoic acid, 2-
16	20,599	20,560	20,665	374426	0,32	144069	0,37	2,60	C16H34	V	Hexadecane
17	20,808	20,780	20,865	492080	0,42	249200	0,64	1,97	C15H30O2		Methyl tetradecanoate
18	21,249	21,180	21,420	14587771	12,34	4688239	11,98	3,11	C14H28O		Tetradecanoic acid
19	21,490	21,420	21,540	516992	0,44	76797	0,20	6,73	C14H28O	V	Tetradecanoic acid
20	21,716	21,690	21,770	289437	0,24	151709	0,39	1,91	C18H38O		Octadecanal
21	21,950	21,920	21,980	164425	0,14	81447	0,21	2,02	C18H38O		Octadecanal
22	22,009	21,980	22,095	551980	0,47	200133	0,51	2,76	C18H38O	V	Octadecanal
23	22,315	22,275	22,365	772501	0,65	376460	0,96	2,05	C12H24O2		Decanoic acid, 2-
24	22,804	22,770	22,840	222145	0,19	132724	0,34	1,67	C16H32O2		Hexadecanoic acid,
25	23,171	23,135	23,205	2250450	1,90	1167157	2,98	1,93	C16H32O2		n-Hexadecanoic
26	23,228	23,205	23,260	1640870	1,39	861033	2,20	1,91	C19H38	V	1-Nonadecene
27	23,283	23,260	23,330	752716	0,64	420692	1,07	1,79	C19H38	V	1-Nonadecene

28	23,438	23,415	23,470	102253	0,09	66491	0,17	1,54	C19H38		1-Nonadecene
29	23,630	23,605	23,760	151408	0,13	57500	0,15	2,63	C19H38		1-Nonadecene
30	23,823	23,795	23,860	162664	0,14	100524	0,26	1,62	C19H38	V	1-Nonadecene
31	24,022	23,985	24,085	1779697	1,51	1000692	2,56	1,78	C15H30O		8-Pentadecanone
32	24,668	24,625	24,690	720828	0,61	418712	1,07	1,72	C19H38		1-Nonadecene
33	24,710	24,690	24,765	415481	0,35	238024	0,61	1,75	C23H46	V	9-Tricosene, (Z)-
34	25,214	25,190	25,240	108038	0,09	69962	0,18	1,54	C23H46		9-Tricosene, (Z)-
35	25,413	25,380	25,480	1539637	1,30	859033	2,19	1,79	C23H46O		12-Tricosanone
36	26,150	26,125	26,165	138262	0,12	80544	0,21	1,72	C23H46O		12-Tricosanone
37	26,183	26,165	26,215	265571	0,22	121735	0,31	2,18	C23H46O	V	12-Tricosanone
38	26,250	26,215	26,280	183559	0,16	65653	0,17	2,80	C23H46O	V	12-Tricosanone
39	27,095	27,055	27,155	4407506	3,73	2537464	6,48	1,74	C23H46O		12-Tricosanone
40	27,698	27,670	27,730	371364	0,31	225732	0,58	1,65	C23H46O		12-Tricosanone
41	27,775	27,730	27,805	152319	0,13	51673	0,13	2,95	C23H46O	V	12-Tricosanone
42	28,334	28,300	28,385	3261456	2,76	2545822	6,50	1,28	C23H46O		12-Tricosanone
43	28,763	28,735	28,800	253534	0,21	177368	0,45	1,43	C23H46O		12-Tricosanone
44	28,902	28,840	28,925	406976	0,34	210553	0,54	1,93	C23H46O		12-Tricosanone
45	28,994	28,925	29,105	1567171	1,33	287617	0,73	5,45	C23H46O	V	12-Tricosanone
46	29,377	29,345	29,425	2288224	1,94	1539464	3,93	1,49	C23H46O		12-Tricosanone
47	29,440	29,425	29,470	96059	0,08	58653	0,15	1,64	C23H46O	V	12-Tricosanone
48	29,664	29,640	29,715	204752	0,17	108971	0,28	1,88	C23H46O		12-Tricosanone
49	29,852	29,820	29,885	191755	0,16	112943	0,29	1,70	C23H46O		12-Tricosanone
50	29,959	29,930	29,985	158354	0,13	95157	0,24	1,66	C23H46O		12-Tricosanone
51	30,479	30,435	30,535	532727	0,45	177357	0,45	3,00	C23H46O		12-Tricosanone
52	30,627	30,535	30,690	977408	0,83	506359	1,29	1,93	C23H46O	V	12-Tricosanone
53	30,896	30,865	30,935	390416	0,33	141947	0,36	2,75	C23H46O		12-Tricosanone
54	30,959	30,935	31,035	454575	0,38	155192	0,40	2,93	C23H46O	V	12-Tricosanone
55	31,314	31,280	31,360	424988	0,36	204175	0,52	2,08	C23H46O		12-Tricosanone
56	32,302	32,255	32,350	305175	0,26	114575	0,29	2,66	C23H46O		12-Tricosanone
57	32,586	32,500	32,655	2457799	2,08	705525	1,80	3,48	C23H46O		12-Tricosanone
58	33,215	33,175	33,250	165000	0,14	73900	0,19	2,23	C23H46O		12-Tricosanone
59	34,884	34,810	34,965	3038556	2,57	609624	1,56	4,98	C23H46O		12-Tricosanone
60	35,012	34,965	35,080	1244610	1,05	311431	0,80	4,00	C23H46O	V	12-Tricosanone
				118237608	100,00	39137637	100,00				

A: Relative crystallinity

The relative crystallinity of zeolite was calculated as follows:

$$\% \text{ XRD Relative crystallinity of ZSM-5} = \frac{H_s}{H_r} \times 100 \dots\dots\dots A1$$

$$\% \text{ XRD Relative crystallinity of Ni/HZSM-5} = \frac{30101}{42500} \times 100 = 70.8\%$$

H_s indicates the Peak height for the Sample/catalyst.

H_r indicates the Peak height for the reference catalyst.

B: Average crystallite size (Debye scherrer equation)

The following equation was used for calculation of particle size of the crystalline structure:

$$d = \frac{K\lambda}{B \cos\theta} \dots\dots\dots A2$$

Where as:

d indicates the Particle size of the crystalline structure

K indicates the constant dependent on crystallite shape=0.89

λ indicates the X-Ray wavelength=0.154056

B indicates the FWHM (Full width at halfmax)

θ represents a Brass Angle.

Particle size of the crystalline structure

Catalyst type	2Theta (degreese)	FWHM(Rad)	Particle size of the crystalline structure(Um)
NH ₄ ⁺ ZSM-5	23.75	0.005063	35.15
HZSM-5	23.96	0.005587	29.46
Ni/HZSM-5	23.94	0.010127	16.36

Miller indices

Crystal systems

Catalyst samples	2Theta	h	k	l	m	Crystal system
HZSM-5	7.99	0	K	1	4	monoclinic
	8.83	0	K	0	2	
	23.04	0	K	1	4	
	23.94	0	K	1	2	
NH₄⁺ZSM-5	7.74	h	0	1	2	monoclinic
	8.64	0	K	0	2	
	22.93	0	K	L	4	
	23.94	h	l	1	4	
Ni/HZSM-5	7.63	h	0	1	2	Monoclinic and orthorhombic
	8.57	0	K	0	2	
	22.8	0	K	1	4	
	23.85	h	k	1	4	

CRYSTAL DATA: $P12_1/n1$ (No. 14) unique axis **b**, cell choice 2

$a = 19.879 \text{ \AA}$ $b = 20.107 \text{ \AA}$ $c = 13.369 \text{ \AA}$

$\alpha = 90^\circ$ $\beta = 90.67^\circ$ $\gamma = 90^\circ$

X-ray single crystal refinement, $R_w = 0.045$

REFERENCE: H. van Koningsveld, J. C. Jansen and H. van Bekkum,
Zeolites **10** 235–242 (1990).

<i>h</i>	<i>k</i>	<i>l</i>	2θ	<i>d</i>	<i>M</i>	I_{rel}	<i>h</i>	<i>k</i>	<i>l</i>	2θ	<i>d</i>	<i>M</i>	I_{rel}	<i>h</i>	<i>k</i>	<i>l</i>	2θ	<i>d</i>	<i>M</i>	I_{rel}
-1	0	1	7.93	11.153	2	37.1	-5	0	1	23.27	3.823	2	16.1	5	4	2	31.78	2.816	4	0.4
0	1	1	7.94	11.132	4	100.0	5	0	1	23.42	3.798	2	18.2	-7	0	1	32.15	2.784	2	0.7
1	0	1	8.01	11.033	2	31.9	-5	1	1	23.69	3.756	4	8.1	-3	6	2	32.74	2.735	4	1.6
0	2	0	8.80	10.054	2	47.8	5	1	1	23.84	3.732	4	10.4	3	6	2	32.87	2.724	4	1.2
2	0	0	8.90	9.939	2	51.6	-3	0	3	23.93	3.718	2	1.4	3	3	4	32.99	2.715	4	0.4
-1	1	1	9.07	9.753	4	13.9	0	3	3	23.98	3.711	4	23.0	0	6	3	33.46	2.678	4	1.3
1	1	1	9.14	9.673	4	14.1	5	2	0	24.07	3.697	4	0.9	-1	0	5	33.77	2.654	2	0.9
1	2	0	9.86	8.971	4	1.4	3	0	3	24.20	3.678	2	2.1	0	7	2	33.97	2.639	4	0.4
0	2	1	11.01	8.035	4	1.2	-3	1	3	24.35	3.656	4	7.6	-5	5	2	34.34	2.612	4	1.6
-2	1	1	11.88	7.450	4	1.1	3	1	3	24.61	3.618	4	8.2	5	5	2	34.55	2.596	4	1.1
2	1	1	11.99	7.378	4	0.6	-2	5	1	24.77	3.595	4	1.0	-3	7	1	34.66	2.588	4	0.9
2	2	0	12.52	7.068	4	0.5	2	5	1	24.82	3.587	4	0.5	-5	1	4	35.16	2.552	4	0.6
0	0	2	13.25	6.684	2	7.3	-2	3	3	25.54	3.488	4	1.5	-1	5	4	35.17	2.552	4	0.9
0	1	2	13.96	6.343	4	11.0	-3	2	3	25.54	3.487	4	0.4	0	8	0	35.72	2.513	2	1.6
-1	1	2	14.61	6.062	4	0.7	2	3	3	25.71	3.465	4	0.9	8	0	0	36.15	2.485	2	1.1
0	3	1	14.79	5.991	4	13.7	3	2	3	25.79	3.454	4	1.0	0	3	5	36.17	2.483	4	1.4
-3	0	1	14.85	5.964	2	2.7	-3	4	2	25.85	3.446	4	3.1	7	4	0	36.34	2.472	4	0.7
3	0	1	14.99	5.909	2	4.9	3	4	2	26.02	3.425	4	4.1	-3	1	5	36.36	2.471	4	0.6
-3	1	1	15.50	5.718	4	5.0	-1	5	2	26.22	3.399	4	1.2	3	0	5	36.38	2.469	2	0.4
3	1	1	15.63	5.669	4	5.0	-5	1	2	26.32	3.385	4	0.4	2	8	0	36.89	2.437	4	0.4
-2	0	2	15.89	5.577	2	2.0	5	1	2	26.59	3.352	4	0.7	0	7	3	37.24	2.414	4	1.3
0	2	2	15.92	5.566	4	6.1	0	6	0	26.60	3.351	2	2.8	-5	3	4	37.44	2.402	4	0.5
3	2	0	16.02	5.532	4	1.3	6	0	0	26.91	3.313	2	2.7	-5	6	2	37.50	2.399	4	0.8
2	0	2	16.07	5.517	2	1.4	0	1	4	27.05	3.297	4	5.1	-7	1	3	37.63	2.390	4	0.9
-2	1	2	16.50	5.374	4	1.5	-1	1	4	27.37	3.258	4	0.6	3	5	4	37.65	2.389	4	0.7
2	1	2	16.66	5.320	4	2.0	0	6	1	27.44	3.251	4	1.1	5	3	4	37.83	2.378	4	0.9
-2	3	1	17.24	5.143	4	0.6	-5	2	2	27.44	3.250	4	0.8	-7	4	2	38.70	2.327	4	0.4
2	3	1	17.32	5.119	4	1.1	5	2	2	27.70	3.220	4	0.7	8	4	1	41.15	2.193	4	0.4
0	4	0	17.64	5.027	2	3.6	0	2	4	28.14	3.171	4	0.6	0	7	4	41.45	2.178	4	0.7
4	0	0	17.85	4.969	2	5.4	-2	1	4	28.42	3.140	4	1.1	0	10	0	45.09	2.011	2	3.2
1	4	0	18.20	4.873	4	0.7	2	1	4	28.62	3.118	4	0.4	0	8	4	45.14	2.009	4	3.4
0	4	1	18.86	4.705	4	0.6	-5	3	2	29.22	3.057	4	3.0	-8	0	4	45.22	2.005	2	0.9
-1	3	2	19.24	4.613	4	2.2	5	3	2	29.46	3.032	4	3.3	-8	4	3	45.32	2.001	4	1.1
1	3	2	19.31	4.596	4	1.5	3	6	0	29.88	2.990	4	0.7	10	0	0	45.64	1.988	2	4.6
-1	0	3	20.37	4.359	2	2.2	0	5	3	29.93	2.985	4	6.6	8	4	3	45.73	1.984	4	0.8
0	1	3	20.41	4.350	4	1.9	-5	0	3	29.94	2.984	2	4.0	8	0	4	45.76	1.983	2	1.4
1	0	3	20.48	4.337	2	1.3	-1	3	4	30.17	2.962	4	0.8	-3	4	6	46.50	1.953	4	1.4
-3	2	2	20.74	4.282	4	0.8	1	6	2	30.19	2.960	4	0.4	8	2	4	46.69	1.945	4	0.5
-2	4	1	20.85	4.259	4	2.6	-5	1	3	30.28	2.952	4	2.6	3	4	6	46.80	1.941	4	0.8
2	4	1	20.92	4.246	4	3.4	5	0	3	30.30	2.949	2	1.9	-5	8	3	47.28	1.922	4	0.8
3	2	2	20.94	4.242	4	0.7	5	1	3	30.64	2.918	4	0.9	-3	9	3	47.48	1.915	4	0.6
0	2	3	21.82	4.074	4	2.1	-2	5	3	31.21	2.865	4	1.0	5	8	3	47.53	1.913	4	0.6
3	4	0	22.20	4.005	4	2.8	-5	2	3	31.27	2.861	4	0.4	3	9	3	47.62	1.909	4	0.8
0	5	1	23.10	3.851	4	44.7	2	5	3	31.35	2.853	4	0.6	-5	3	6	48.54	1.875	4	1.4
3	3	2	23.19	3.836	4	1.0	-5	4	2	31.55	2.836	4	0.6	5	3	6	49.02	1.858	4	1.0