

# Catalytic Cracking



# Cracking Processes

- Cracking processes break down heavier hydrocarbon molecules (high-boiling point oils) into lighter products such as gasoline and light gas oils. These processes include catalytic cracking (e.g., FCC), thermal cracking, and hydrocracking.
- Cracking Reactions, e.g.,



# Catalytic cracking

- Most important and most widely used refinery process
- Catalytic cracking converts heavy oils into a mixture of more useful products (high octane gasoline, light gases, and less heavy fuels)
- Feed in catalytic cracking undergoes a chemical breakdown, under controlled temperature (480-540°C) and pressure in the presence of a catalyst.

## Feed to cracking processes

- Feed mostly comes from the crude residue and vacuum unit gas oils (VLGO and VHGO) with a boiling temperature range of 500-800°F.

# Cracking Products:

**Light Gases**  
(H<sub>2</sub>, C<sub>1</sub>, C<sub>2</sub>'s)

**C5+ gasoline**  
high octane

**HCO**  
Heavy cycle  
oil for fuel oil

**LPG**  
(contain light olefins)

**LCO**  
Light cycle oil  
for diesel fuel

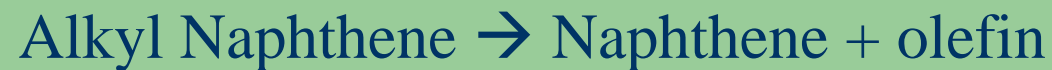
**Coke**  
Byproduct burned  
in the regenerator

# Thermal Cracking vs. Catalytic Cracking

- Higher temperature process
- Gasoline (32%)
- Residual oil (50%)
- No coke product
- Feed: Vacuum Residue
- Lower catalytic temperature
- More gasoline (47 vol%)
- Light cycle oil (32 vol%)
- About 5 wt% coke
- Feed: Vacuum Gas Oil

# Cracking Reactions

## Primary Reactions:



The products formed are the result of both primary & secondary reactions

# Catalytic Cracking Processes

Three basic steps in catalytic cracking processes:

- **Reaction:** Feedstock reacts with catalyst and cracks into different hydrocarbons.
- **Regeneration:** Catalyst is reactivated by burning off coke.
- **Fractionation:** Cracked hydrocarbon stream is separated into various products.



# Catalytic Cracking Processes

- \* Types of catalytic cracking processes:
  - **Moving-bed catalytic cracking** (e.g., Thermofor catalytic cracking, TCC): almost obsolete now
  - **Fluidized-bed catalytic cracking** (e.g., Fluid catalytic cracking, FCC): most used & modernized.
- \* Catalytic cracking processes are very flexible, and operating parameters can be adjusted to meet changing product demand.

# Cracking Catalysts

- Catalytic cracking is similar to thermal cracking except that catalysts facilitate the conversion of the heavier molecules into lighter products.
- Catalysts used in the cracking reaction increase the yield of improved-quality products under much less severe operating conditions than in thermal cracking.
- Catalysts used in refinery cracking units are typically solid materials: zeolite, aluminum hydrosilicate, treated bentonite clay, fuller's earth, bauxite, and silica-alumina.
- Catalysts come in the form of powders, beads, pellets or shaped materials.

## Cracking Catalysts: cont ...

- Classes of commercial cracking catalysts:
  - 1- Acid-treatment aluminosilicates
  - 2- Amorphous silica-alumina combinations
  - 3- Crystalline synthetic silica-alumina catalyst called zeolites or molecular sieves.
- Most catalysts used in commercial units are either class 3 or mixtures of classes 2 & 3 catalysts.

## Advantages of Zeolite Catalysts over other Amorphous Catalysts

- High activity
- Higher gasoline yields at a given conversion
- Production of gasolines containing a larger % of paraffinic & aromatic HC's
- Lower coke yield
- Increased i-butane production
- Ability to go to higher conversions per pass w/o overcracking.

# 1- The FCC Process

- FCC Feed mostly comes from vacuum distillation unit (VLGO and VHGO) at temperature of 500-800°F.
- Feed is mixed with recycle gas oil.
- Net feed is mixed with the regenerated catalyst at 1200-1500°F.
- The (Gas Oil + catalyst) mixture enters the reactor where the reaction riser temperature is 900-1000°F (reaction is endothermic).

## 2- The FCC Process: cont..

- Stripping steam is used to strip out the HC products from the reactor to the fractionator in gaseous form.
- Spent catalyst is air blown to the regenerator. Some HC's are adsorbed on the catalyst. Coke also deposits on the catalyst.
- Coke is burned in the regenerator, with air to CO or CO<sub>2</sub> (nowadays to CO<sub>2</sub>). This requires more air resulting in higher blower capacity and operating cost but lower coke deposits ( and better catalyst activity).

## 3- The FCC Process: cont..

- Regeneration process is exothermic and the heat generated is used to preheat the feed, recover energy in WHB, or produce power.
- Catalyst will have 0.01-0.04 wt% coke
- Main products:
  - Olefinic gases (useful for polymerization or alkylation)
  - Cracked gasoline (FCC gasoline)
  - Catalytic cycle gas oil (CGO)

## Process Variables

- Major variables affecting conversion and product distribution are nature of feed charge, cracking temperature, catalyst to oil ratio, space velocity, catalyst type & activity, and recycle ratio.
- Conversion =  $100 \frac{\text{volume of feed} - \text{volume of cycle stock}}{\text{volume of feed}}$
- Cycle Stock = portion of product not converted to naphtha and lighter products (BP > 430°F)
- C/O = Catalyst to Oil ratio = lb catalyst / lb feed
- Recycle Ratio = volume of recycle/volume of fresh feed



## Process Variables: cont..

- **Selectivity** = yield of desirable products (e.g., gasoline and naphtha) / yield of undesirable products (e.g., gas and coke)
- **Efficiency** = % gasoline produced x conversion
- **Space Velocity:**

$$\begin{aligned}\text{WHSV} &= \text{Weight Hour Space Velocity} \\ &= (\text{lb liquid feed/h})/(\text{lb catalyst}) \\ &= [1/(\text{C/O})]/t\end{aligned}$$

where  $t$  is catalyst residence time, h

## Effects of Process Variables:

- Increasing (reaction time, catalyst/oil ratio, catalyst activity, and contact time) results in an increase in the conversion.
- Decreasing space velocity increases conversion.
- Increase in conversion does not necessarily mean an increase in gasoline yield.