Question 80: Where in the isomerization reactor catalyst bed does the hydrogenation of benzene (exothermic) occur? How does this affect the other isomerization reactions? What concentration of benzene in the isomerization feed is acceptable?

ZMICH (UOP LLC)

This question refers to or asks about benzene hydrogenation and how it affects to isomerization reactions, maximum levels in the feed, and where does it happen in the reactors. So what I thought we would do is start out with what am I talking about: benzene saturation.

If you look at the slide, you see that benzene in the presence of hydrogen over a platinum-containing catalyst will generate heat and saturate to cyclohexene. Now, this benzene saturation reaction is fast and it happens near the inlet of the isomerization reactor; or if you have a saturation reactor, near the inlet of this benzene saturation reactor.

If you look at point number 2 and 3, in order to assure a maximum octane and yield from an isomerization unit, it is necessary to saturate the benzene. There are two things that happen: One, benzene is an acid function poison that will basically increase the effective space velocity through the remainder of the reactors. Benzene reaction is also highly exothermic, so it tends to increase, the temperature of the reactant as it progresses through the reactor. So the reactor outlet temperature is higher.

There are problems with higher reactor temperatures. If we look at the graph here, we see the equilibrium of isopentane relative to total pentanes. The “y” axis is the iso-to-normal ratio and the “x” axis is the reactor outlet temperature. Increasing temperature in the case of benzene saturation, or having to operate at a higher reactor inlet temperature to effectively get the same level of conversion, forces you to the right on this graph. So that forces you to a lower iso-to-normal, a lower octane at the reactor outlet or lower PIN number: paraffin iso-to-normal ratio.

Gasoline ProcessesGasoline ProcessesIsomerization-Feed Benzene•Saturation happens near reactor inlet•Benzene saturation necessary for max octane & yield•Acid function poison-activity loss for isom reaction•High dHrxnincreases reactant temperature•>3% benzene-multiple reactors with intercooling •>5% benzene possible with UOP PenexPlusTMBenzene+ 3H2HeatCatalystHydrogenCyclohexane

The fourth comment is about greater than 3% benzene and multiple reactors. In general, multiple reactors with inner-cooling may be required to process a feed with more than 3 vol% benzene because of the high heat of reaction. And then for most purposes, what we see as a general rule is anywhere from 0 vol% to 5 vol% is pretty typical for chlorided alumina isomerization unit. For units that are processing benzene or desire to process benzene with greater than 5 vol% in the feed, then we need to look at perhaps revamping the unit to include or add a separate benzene saturation reactor upstream of the isomerization unit.

KAISER (Delek Refining Ltd.)
In the Isom units that I've run, we have periodically run with as much as 5 vol% benzene in the feed and as much as 8 vol% total benzene plus material, not always on purpose. We'd rather those heavies be down in the reformer feed where they belong, but we did have experience with that. Again, it was a multi-bed reactor with quench between a few of the reactors to handle any exotherms that might have developed.
Gasoline ProcessesGasoline ProcessesEquilibriumiC5/C5P Equilibrium CurvesiC5/C5P = iC5/(iC5 + nC5) x 100%68707274767880828420022525027530032535037540 0Reactor Outlet Temperature, FiC5/C5P, wt%Vapor Phase Liquid Phase

QUINTANA (Valero Energy Corporation)
Our experience is similar to what Joe and Allen have indicated. We've processed Isom feed as high as 5 vol% benzene without a dedicated saturation reactor and, of course, see the exotherm that results. The inter-reactor cooling capacity and the resulting temperature to the lag reactor inlet will determine the isomerate product quality that results, in line with the equilibrium charts that Joe showed earlier.

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2008

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