New Technologies for cost-efficient Paraxylene Production

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Overview

– Clariant and its Petrochemical Catalysts at a Glance
– PX Market Fundamentals
– Zeolites - Indispensable Tool for Aromatics Production
– Clariant - Full- Scope Partner for Aromatics Production
  ▪ Adsorptive PX Separation
  ▪ Xylene Isomerization
  ▪ TDP & Transalkylation
  ▪ Aromatics Purification
– The Clariant advantage
Clariant focuses on creating value through innovation and sustainability

**Portfolio with leading Market Positions**
Four Business Areas

- Care Chemicals
- Catalyst former Süd-Chemie
- Plastics & Coatings
- Natural Resources

**Clariant in Numbers**

- **5,807** Sales 2015 (CHF m) from continuing operations
- **227** Net result 2015 (CHF m) from continuing operations
- **853** EBITDA 2015 (CHF m) before exceptionals
- **14.7%** EBITDA margin 2015 before exceptionals
- **4** Business Areas
- **17,213** Employees 2015
Clariant Focus Areas in Petrochemicals
PX Market Fundamentals

Public
Dr. Olivier Larlus
Clariant BU Catalysts
Petrochemicals
15.11.2016

what is precious to you?
PX Market
Strong Growth in Polyester-based Products

Scheme and numbers (w/o formulas and pictures) from ICIS
Aromatics in Time of Volatility - Have Fundamentals Changed?
May 8, 2015
PX Market: The Future of Aromatics is bright

Long-term
ICIS: As a result of mobility, urbanization, environmental and innovation trends:
- Benzene consumption: +55%

![Diagram showing Global Paraxylene Market from 2014 to 2030 with a 4.4% CAGR.]

Short/mid-term
“PX oversupply remains on paper and there may not be enough capacity in 2018 and beyond“ (HIS - Ashish Pujari – 37th APIC, May 18-20, 2016, Singapore)
Zeolites – Unique Properties

Acidity & Shape Selectivity

Reactant Shape Selectivity
Example: Catalytic Dewaxing

Product Shape Selectivity
Example: Xylene Isomerization

Transition State Shape Selectivity
Example: Transalkylation
Indispensable Tool for Aromatics Production

Clariant has 30 years Experience in Zeolite R&D and Manufacture
Clariant Catalysts
Global Zeolite Catalyst & Adsorbent Operations

Includes JV operations
Clariant - A Full-Scope Partner for Aromatics Production
Clariant Products for Aromatics Production
## Clariant Products for Aromatics Production

<table>
<thead>
<tr>
<th>Process</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paraxylene Adsorptive Separation</td>
<td>ZeoSorb® PX-200</td>
</tr>
<tr>
<td>Xylene Isomerization (EB Dealkylation)</td>
<td>ISOXYL® MPH</td>
</tr>
<tr>
<td>Xylene Isomerization (EB Isomerization)</td>
<td>ISOXYL® EBI-610</td>
</tr>
<tr>
<td>Toluene Disproportionation</td>
<td>TransMax® 302</td>
</tr>
<tr>
<td>Heavy Aromatics Transalkylation</td>
<td>TransMax® 501</td>
</tr>
<tr>
<td>Toluene Methylation</td>
<td>TM® 101</td>
</tr>
<tr>
<td>Aromatics Purification (Clay Treatment)</td>
<td>Tonsil® CO &amp; APT</td>
</tr>
</tbody>
</table>

- **ZeoSorb® PX-200**
- **ISOXYL® MPH**
- **ISOXYL® EBI-610**
- **TransMax® 302**
- **TransMax® 501**
- **TM® 101**
- **Tonsil® CO & APT**
Clariant Products for Aromatics Production
Paraxylene Adsorptive Separation

How it works

• Large pore zeolite ($\varnothing = 7.4$ Å) with high adsorption capacity

• Preferential adsorption in the pores based on steric hindrance, orientation of isomers and electronic environment

• Commercial Conditions:

<table>
<thead>
<tr>
<th>Process</th>
<th>Simulated Moving Bed (SMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adsorbent Size &amp; Shape</td>
<td>0.4-0.8 mm Spheres</td>
</tr>
<tr>
<td>Operating Temperature [°C]</td>
<td>177</td>
</tr>
<tr>
<td>Operating Pressure [barg]</td>
<td>9</td>
</tr>
<tr>
<td>Desorbent</td>
<td>p-DEB</td>
</tr>
</tbody>
</table>
Paraxylene Adsorptive Separation
ZeoSorb® PX-200: Advantage from binderless Zeolite

Binderless Zeolite Adsorbent provides 100% active Material, i.e. higher selective pore volume (SPV) and thus higher adsorption capacity than binder-containing adsorbents.
Paraxylene Adsorptive Separation
ZeoSorb® PX-200: Key Differentiators

1. PX Selectivity
   Optimized β values
   (selectivities of PX over the other C8 aromatics and the solvent)

2. Adsorption Capacity
   - High selective pore volume (SPV)
   - Low non-selective pore volume (NSPV)

3. Physical Properties
   - Bulk crush strength
   - Attrition
   - Particle size

4. Mass transfer
   - Porosity (micro/macro)
   - Mass transfer coefficient
Paraxylene Adsorptive Separation
ZeoSorb® PX-200 - Performance Testing

Available to Clariant Clients to demonstrate PX recovery and purity
Clariant Products for Aromatics Production

- **Catalytic Reformer**
  - HDT HDMax®
  - Naphtha Pyrolysis Gasoline

- **Extraction**
  - GT-BTX

- **TA/TDP TransMax®**
  - Toluene Methyl. TM™

- **Clay Tonsil®**
  - C6/C7 Raffinate

- **PX Recovery ZeoSorb® PX**
  - Paraxylene

- **Xylene Isomerization ISOXYL®**
  - LE's

- **OX Column**
  - Ortho-xylene

- **Dehepanizer**
  - C11+

- **Clay Tonsil®**
  - Paraxylene

- **Clay Tonsil®**
  - Benzene

- **Toluene Column**
  - Toluene
Xylene Isomerization
ISOXYL® Catalyst Options

**Mixed Xylenes**

**Ethylbenzene (EB)**
C8 aromatics always contain ethylbenzene (EB) in the range of a few percent up to over 20%. EB can’t be separated from xylenes, so it needs to be converted.

**ISOXYL® MPH**
EB Dealkylation

**ISOXYL® EBI**
EB Isomerization
Xylene Isomerization / EB Dealkylation
ISOXYL® MPH - Strong & reliable Performance

- Careful selection of the zeolite and innovative processing steps
- Unique manufacturing technology
- Long-term experience in zeolite R&D and manufacture

- EB Conversion (EBC): 70-80 %
- Xylene Loss (XL): < 1.5 %
- PXATE: > 100 %

- Successfully put into commercial operation
- Expected life time 10 years+
Xylene Isomerization / EBI Isomerization
The all-new ISOXYL EBI-610

Fine balance between protonic sites of the zeolite and the hydrogenation power of the noble metal function results in high EB conversion and excellent selectivity.

- Less hydraulic load on the PX separation section
- Improved plant economics by preserving aromatic rings to an excellent level.

- EB Conversion (EBC) up to 40 %
- C8 Ring Loss (C8RL) down to 2.0 %
- PXATE > 92 %
- EBATE > 60 %
Clariant Products for Aromatics Production

- **Extraction GT-BTX**
- **Clay Tonsil®**
- **TA/TDP TransMax®**
- **Toluene Methyl. TM™**
- **Toluene Column**
- **C8+ A**
- **C6/C7 Raffinate**
- **Benzene Column**
- **Toluene Column**
- **Paraxylene**
- **Leptons**
- **PX Recovery ZeoSorb® PX**
- **Xylene Isomerization ISOXYL®**
- **C11+**
- **Clay Tonsil®**

**Processes and Reagents**:
- **Catalytic Reforming**
- **SHU OleMax®**
- **HDT HDMax®**
- **Naphtha Pyrolysis Gasoline**
- **C8+ A**
- **MeOH**
- **Ortho-xylene**
- **Heavy Aromatics Column**
- **Deheptanizer**
TDP & Transalkylation
TransMax® Catalyst Options

**Toluene-rich Feeds**
TransMax® 302

**Tol./C9+Aromatics Feeds**
TransMax® 501
### Transalkylation of C9+A with TransMax®

#### Key Reactions in Transalkylation

<table>
<thead>
<tr>
<th>Xylenes Formation</th>
<th>Ethylbenzene Formation</th>
<th>Heavy Aromatics Formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tol + Tol $\rightarrow$ Bz + Xyl</td>
<td>ET + Tol $\rightarrow$ EB + Xyl</td>
<td>Tol + ET $\rightarrow$ Bz + A10</td>
</tr>
<tr>
<td>Tol + TMB $\rightarrow$ Xyl + Xyl</td>
<td>ET + ET $\rightarrow$ EB + EX</td>
<td>ET + ET $\rightarrow$ Tol + A11</td>
</tr>
<tr>
<td>ET + Tol $\rightarrow$ Xyl + EB</td>
<td></td>
<td>ET + ET $\rightarrow$ EB + A10</td>
</tr>
<tr>
<td>EX $\rightarrow$ Xyl + C$_2$</td>
<td></td>
<td>Tol + TMB $\rightarrow$ Bz + A10</td>
</tr>
<tr>
<td>TMB + TMB $\rightarrow$ TeMB + Xyl</td>
<td></td>
<td>TMB + TMB $\rightarrow$ Xyl + A10</td>
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<tr>
<td></td>
<td></td>
<td>ET + TMB $\rightarrow$ Tol + A11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PB + Tol $\rightarrow$ Bz + A10</td>
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<td></td>
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<tr>
<td>Benzene Formation</td>
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<td></td>
</tr>
<tr>
<td>Tol + TMB $\rightarrow$ Bz + TeMB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PB $\rightarrow$ Bz + C$_3$</td>
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<td></td>
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<tr>
<td>Toluene Formation</td>
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<td>ET $\rightarrow$ Tol + C$_2$</td>
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<td></td>
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</table>
Transalkylation of C9+A with TransMax®

Benzene Purity and Aromatics Ring Loss

- Hydrogenation of aromatic rings is the primary cause for benzene co-boilers and a prerequisite for ring opening/loss

- TransMax® advantage over other catalysts:
  - Less rigorous and more selective hydrogenation function
  - Zeolites have tailored cracking activity to preserve aromatic rings while ensuring maximum activity for TDP, transalkylation and dealkylation

TransMax® achieves outstanding benzene purity and very low aromatics ring loss
Transalkylation with TransMax®
Challenges & Objectives in TDP/Transalkylation

TransMax® catalysts meet all performance objectives in TDP & Transalkylation
Clariant Products for Aromatics Production

- **Extraction GT-BTX**
- **Clay Tonsil®**
- **TA/TDP TransMax®**
- **Toluene Methyl. TM™**
- **PX Recovery ZeoSorb® PX**
- **Xylene Isomerization ISOXYL®**
- **Dehepanizer**

**Inputs:**
- C6/C7 Raffinate
- Paraxylene
- LE's

**Outputs:**
- Benzene
- Toluene
- Paraxylene

**Processes:**
- Catalytic Reformer
- HDT HDMax®
- SHU OleMax®
- Toluene Column
- Benzene Column
- Xylene Column
- Tonsil®

**Other Notations:**
- Naphtha Pyrolysis Gasoline
- Ortho-xylene
- C11+
- MeOH

**Clariant Products:**
- New Technologies for cost-efficient Paraxylene Production
  - Clariant Products for Aromatics Production
Aromatics Purification
Innovative Clay Catalysts - Tonsil® APT

800 KTA PX Plant

<table>
<thead>
<tr>
<th>Application</th>
<th>Volume [m³]</th>
<th>Life Time Increase [months]</th>
<th>Tonsil® Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reformate Bottom</td>
<td>2 x 235</td>
<td>3 → 5</td>
<td>APT-MX</td>
</tr>
<tr>
<td>BT Treatment</td>
<td>2 x 240</td>
<td>8 → 14</td>
<td>APT-BT</td>
</tr>
<tr>
<td>p-Xylene Rerun</td>
<td>4 x 165</td>
<td>15 → 22</td>
<td>APT-PX</td>
</tr>
</tbody>
</table>

Total Savings > € 1,500,000 per year

Tonsil® APT Series
- Higher Activity
- Longer Service Life
- Higher Selectivity
- Faster Start-up (Low Moisture)
The Clariant Advantage

what is precious to you?
The Clariant Advantage
Cost Efficiency

- All catalysts extensively tested by client’s against the market leaders
- Fully commercial conditions with genuine feed
- All products exceeded or matched the performance of the market leaders
- Clariant products & services excelled in terms of performance-cost ratio
The Clariant Advantage
Technical Service

- Full-scope service for all aromatics facilities, incl. SMB units, by professionals
- On-site assistance for loading and start-up
- Plant optimization
- Regular technical service visits
- On-site assistance for trouble-shooting
- Physical and chemical analysis of used catalyst
- Process simulation (entire complex)
- Catalyst testing in pilot plant
- Adsorbent testing in SMB
The Clariant Advantage
Full-Scope Technology Packages

Clariant does not just sell catalysts but provides comprehensive (full-scope) packages of technologies, products and services:

This offering is peerless in the industry, especially when it comes to cost efficiency.
Disclaimer

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Thank you for your Attention!

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