Do you want to combine experience with innovation?

BASF Phthalic Anhydride Catalysts are the market leading solution for your oxidation process.
BASF Catalysts Introduction

BASF – We create Chemistry

As the world’s leading chemical company, BASF:
- Offers intelligent solutions and high-quality products for most industrial challenges
- Uses new technologies to optimize additional market opportunities
- Combines added value with environmental protection and social responsibility

BASF at a Glance

At BASF, we create chemistry for a sustainable future. We combine economic success with environmental protection and social responsibility. More than 117,000 employees in the BASF Group work on contributing to the success of our customers in nearly all sectors and almost every country in the world. Our portfolio is organized into six segments: Chemicals, Materials, Industrial Solutions, Surface Technologies, Nutrition & Care and Agricultural Solutions.

BASF has companies in more than 90 countries. We operate six Verbund sites and 361 additional production sites worldwide. Our Verbund site in Ludwigshafen, Germany, is the world’s largest chemical complex owned by a single company that was developed as an integrated network. This was where the Verbund principle was originally established and continuously optimized before being implemented at additional sites.

BASF’s Catalysts division, headquartered in Iselin, New Jersey, is the world’s leading supplier of environmental and process catalysts. The group employs more than 5,000, with over 30 manufacturing sites worldwide.

As a global division of BASF SE, Ludwigshafen, Germany, Catalysts offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products including advanced battery materials.

By leveraging its industry-leading research and development (R&D) platforms, passion for innovation and deep knowledge of precious metals, BASF’s Catalysts division develops unique, proprietary catalyst and adsorbent solutions that drive customer success.
BASF Quality and Reputation are Unmatched

BASF’s Chemical Catalysts combine the strength of BASF – with the experience and expertise of our chemists and engineers. Our phthalic anhydride catalysts are valued components of the oxidation process for worldwide chemical manufacturing companies. BASF’s commitment to the phthalic anhydride process and o-Xylene/naphthalene oxidation to phthalic anhydride catalysts results in products and services that meet and surpass customer expectations and requirements.

Important Facts about Phthalic Anhydride at BASF

- BASF has been producing PA for over 140 years
- BASF has been researching PA catalysts for more than 120 years
- The total PA at BASF’s Ludwigshafen (Germany) site since 1873 is more than 4.0 million tons
- Production experience with post reactors since 1980

Phthalic Anhydride Catalyst History

World Consumption of Phthalic Anhydride by End Use – 2018

- 49.0% Plasticizers
- 12.0% Unsaturated polyester resin
- 16.0% Others
- 23.0% Alkyd resins

Source: IHS Markit

World Consumption of Phthalic Anhydride by End Use – 2018

- 49.0% Plasticizers
- 12.0% Unsaturated polyester resin
- 16.0% Others
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- 49.0% Plasticizers
- 12.0% Unsaturated polyester resin
- 16.0% Others
- 23.0% Alkyd resins

Important Facts about Phthalic Anhydride at BASF

- BASF provides phthalic anhydride (PA) catalysts for the production of phthalic anhydride from the oxidation of o-xylene and naphthalene/mixed feed.

- BASF has been producing PA for over 140 years
- BASF has been researching PA catalysts for more than 120 years
- The total PA at BASF’s Ludwigshafen (Germany) site since 1873 is more than 4.0 million tons
- Production experience with post reactors since 1980

1968
Start-up of two commercial Phthalic Anhydride plants at BASF Ludwigshafen of O4-20

1980
First Start-up of O4-20

1993
First installation of O4-20

2000
First installation of O4-20

2002
Acquisition of Wacker’s Phthalic Anhydride catalysts and licensing business

Acquisition of Wacker’s Phthalic Anhydride catalysts and licensing business

2004
Introduction of new Phthalic Anhydride catalyst for naphthalene/mixed feed oxidation O4-20

Introduction of new Phthalic Anhydride catalyst for naphthalene/mixed feed oxidation O4-20

2009
First installation of O4-20

First installation of O4-20

2010
First installation of O4-20 HiFlex with high PA yield and maximum operational flexibility

First installation of O4-20 HiFlex with high PA yield and maximum operational flexibility

2011
First installation of O4-20 HiFlexII with high PA yield and maximum operational flexibility

First installation of O4-20 HiFlexII with high PA yield and maximum operational flexibility

2016
First installation of O4-20 HiFlex with high PA yield and improved PA quality

First installation of O4-20 HiFlex with high PA yield and improved PA quality

2018
First installation of O4-888, with high PA yield and with improved PA quality and first installation of O4-35 with superior PA quality

First installation of O4-888, with high PA yield and with improved PA quality and first installation of O4-35 with superior PA quality

1968
First technical application at BASF Ludwigshafen of O4-20

2000
Introduction of new Phthalic Anhydride catalysts for o-Xylene oxidation O4-40/42

Introduction of new Phthalic Anhydride catalysts for o-Xylene oxidation O4-40/42

2003
Introduction of new Phthalic Anhydride catalysts for o-Xylene oxidation O4-40/42

Introduction of new Phthalic Anhydride catalysts for o-Xylene oxidation O4-40/42

2004
First Start-up of O4-20

First installation of O4-20

2010
First installation of O4-20 HiFlex with maximum operational flexibility

First installation of O4-20 HiFlex with maximum operational flexibility

2018
First installation of O4-20 HiFlex with high PA yield and maximum operational flexibility

First installation of O4-20 HiFlex with high PA yield and maximum operational flexibility

2018
First installation of O4-888, with high PA yield and with improved PA quality and first installation of O4-35 with superior PA quality

First installation of O4-888, with high PA yield and with improved PA quality and first installation of O4-35 with superior PA quality
Organization of the Phthalic Anhydride Catalyst Business

**AMERICAS**
- Iselin, New Jersey
  - Catalysts Division Headquarters
  - Regional Sales
  - Regional Customer Service and Supply Chain
- Sao Paulo, Brazil
  - Sales Office

**EMEA**
- Ludwigshafen, Germany
  - Catalyst Production
  - Catalyst Research
  - Regional Sales
  - Technical Service
- De Meern, Netherlands
  - Sales Office
  - Regional Customer Service and Supply Chain

**ASIA**
- Shanghai, China
  - Oxidation and Dehydrogenation Catalysts Global Business Management
  - Regional Sales
  - Technical Service
  - Regional Customer Service and Supply Chain
- Seoul, South Korea
  - Sales Office
- Mumbai, India
  - Sales Office
- Moscow, Russia
  - Sales Office

Phthalic Anhydride Process

**Permanent Improvement of Process and Catalyst**

**From o-Xylene to Phthalic Anhydride**

**From Naphthalene to Phthalic Anhydride**
Advantages of BASF as a Phthalic Anhydride Catalyst Supplier

BASF offers over 140 years’ experience in Phthalic Anhydride (PA) production and 120 years in PA catalysts research. This legacy forms a strong foundation for continuous innovation and product improvement. Products and services are continually reviewed for alignment with our customers’ needs through regular BASF Phthalic Anhydride Customer Forum meetings.

Delivery of our product to the customer site is just the beginning of our offering. BASF stands behind its products and, through our technical service representatives in Asia, Europe and America, ensures that our products perform and deliver value. We innovate to make our customers successful.

Value Added Customer Service

From order placement through invoicing, BASF’s Customer Service functions as the customer’s voice by:
- Assigning a primary customer service representative
- Providing a Customer Service Network with 3 central hubs
- Addressing customer concerns in the language of the customer

Expert Technical Service

Our technical service staff has extensive professional experience in Phthalic Anhydride catalysts, including hands-on operational expertise in the areas of supervision, startup assistance and catalyst performance optimization. BASF has more than 80 years of experience in the loading and startup supervision of Phthalic Anhydride catalysts.

- o-Xylene and naphthalene/mixed feed oxidation in fixed bed process
- o-Xylene loadings up to 100 g/Nm³
- Supply of complete catalyst filling and measurement equipment on loan basis, including 5-tube, 10-tube and 20-tube catalyst filling machines
- Optimization of catalyst operation condition using portable CO₂ analyzers
- Verification of air flow measurements by total combustion

Main By-Products in Reaction Gas (o-Xylene feed)

| Compound                  | Concentration
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Maleic Anhydride</td>
<td>2.2–4.0 wt.%</td>
</tr>
<tr>
<td>Benzoic Acid</td>
<td>0.4–0.8 wt.%</td>
</tr>
<tr>
<td>Citraconic Anhydride</td>
<td>0.3–0.5 wt.%</td>
</tr>
<tr>
<td>Phthalide</td>
<td>0.01–0.1 wt.%</td>
</tr>
<tr>
<td>o-Toluic Aldehyde</td>
<td>0.005–0.02 wt.%</td>
</tr>
</tbody>
</table>

Typical concentrations in reactor outlet gas (ROG) at 100 g/Nm³ for o-Xylene feed.

Main By-Products in Reaction Gas (naphthalene feed)

| Compound                  | Concentration
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Naphthoquinone</td>
<td>0.03–1.0 wt.%</td>
</tr>
<tr>
<td>Phthalimide</td>
<td>0.01–0.3 wt.%</td>
</tr>
<tr>
<td>Maleic Anhydride</td>
<td>1.8–3.5 wt.%</td>
</tr>
<tr>
<td>Benzoic Acid</td>
<td>0.3–0.7 wt.%</td>
</tr>
</tbody>
</table>

Typical concentrations in reactor outlet gas (ROG) at 80 g/Nm³ for naphthalene feed.

BASF Research & Development

With research and development, we shape the future and develop profitable growth. In 2018, we generated sales of around € 9 billion with products launched on the market in the past five years that stemmed from research and development activities. Optimized processes and intelligent system solutions, along with new and innovative products, make key contributions to the long-term success of our customers as well as ourselves. At BASF, more than 11,000 employees are working worldwide in research and development at approximately 70 locations.

BASF’s Research Verbund covers the central technology platforms, the research and development units in our operating divisions worldwide and at group companies, as well as affiliated companies. In addition, we are currently involved in more than 1,900 collaborative partnerships worldwide with leading universities, research institutes, startup companies, and industrial partners, which add momentum to our research activities around the world.

- BASF leads the world’s chemical industry in expenditures for R&D with more than 2 billion € in investments.
- As the strongest innovation power in the chemical industry, BASF is ranked first in the Patent Asset Index™.
- BASF filed 1,000 new patents in 2019.
Shanghai BASF Process Catalysis R&D Center

- Grand opening in 2019, dedicated R&D center for process catalysts and adsorbents research
- Development of catalysts and adsorbent solutions mainly for Asian Market
- Fast and timely support to our local customers, including BASF PA catalysts customer
  - Catalysts characterization: ICP-OES, XRF, XRD, SEM/TEM, BET, XPS
  - PA composition analysis: PPA, CPA, ROG, light ends, heavy ends analysis, through GC, GC-MS
  - Raw material analysis: o-Xylene and naphthalene analysis through GC, GC-MS, AAS, CHNS/O analyzer

Investing in innovation: BASF expanded its research activities with the new R&D center in Shanghai

Catalyst Research Ludwigshafen

- Inorganic Solids
- Zeolites
- Catalysts for Oleochemicals
- Custom Catalysts
- Amination Catalysts
- Syngas Catalysts

- Fuel Cell Catalysts
- Catalysts for Petrochemicals
- Hydrogenation Catalysts
- Oxidation Catalysts
- Acid/Base Catalysis
- Catalyst Supports

36 Professionals
87 Technicians

International Cooperations with Universities
## Phthalic Anhydride Catalyst Portfolio

### Catalyst Portfolio for o-Xylene Oxidation

<table>
<thead>
<tr>
<th>Phthalic Anhydride Catalyst</th>
<th>O4-68</th>
<th>O4-66</th>
<th>O4-BB</th>
<th>O4-888</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application</strong></td>
<td>Gas phase Oxidation of o-Xylene to PA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Composition</strong></td>
<td>V2O5, TiO2 and Promoters on Ceramic Rings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shape (mm)</strong></td>
<td>Rings, 77*4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Filling Density [kg/l]</strong></td>
<td>approx. 0.93 in 25 mm ID tube</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Air max. [Nm3/h/tube]</strong></td>
<td>4.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Thermal Stability [°C]</strong></td>
<td>up to 500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Load [g/Nm3]</strong></td>
<td>max. 80</td>
<td>max. 100</td>
<td>max. 100</td>
<td>max. 100</td>
</tr>
<tr>
<td><strong>Layers</strong></td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Filling Height [m]</strong></td>
<td>2.2–3.4</td>
<td>3.0–3.7</td>
<td>3.0–3.7</td>
<td>3.0–3.7</td>
</tr>
<tr>
<td><strong>PA-Yield (Reactor Gas) [wt.-%]</strong></td>
<td>114–115</td>
<td>114–115</td>
<td>115–116</td>
<td>115.5–116.5</td>
</tr>
<tr>
<td><strong>Phthalide (Reactor Gas) [wt.-%]</strong></td>
<td>0.02–0.07</td>
<td>0.02–0.1</td>
<td>0.02–0.1</td>
<td>0.02–0.08</td>
</tr>
<tr>
<td><strong>Aromatics (in Off Gas) [mg/m3]</strong></td>
<td>20–40</td>
<td>20–40</td>
<td>20–40</td>
<td>20–40</td>
</tr>
<tr>
<td><strong>Start-Up time [day]</strong></td>
<td>To 80 g/Nm3</td>
<td>18</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>To 100 g/Nm3</td>
<td>–</td>
<td>55</td>
<td>62</td>
</tr>
<tr>
<td><strong>Restart Time [day]</strong></td>
<td>To 80 g/Nm3</td>
<td>1</td>
<td>–</td>
<td>1–2</td>
</tr>
<tr>
<td></td>
<td>To 100 g/Nm3</td>
<td>1</td>
<td>–</td>
<td>1–2</td>
</tr>
</tbody>
</table>

* in combination with post reactor

### Expected Quality of Pure PA by BASF o-x Feed PA Catalysts

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purity (wt.-%)</td>
<td>&gt; 99.9</td>
</tr>
<tr>
<td>Solidification Point [°C]</td>
<td>&gt; 131.0</td>
</tr>
<tr>
<td>Color (Hazen) [APHA]</td>
<td>5–10</td>
</tr>
<tr>
<td>Heat Stability [APHA] (90 min, 250°C)</td>
<td>15–90</td>
</tr>
</tbody>
</table>

**Our portfolio offers innovative solution for every challenge in oxidation.**
For PA producers, BASF's o-Xylene catalysts offer safe operation at maximum capacity up to 100 g/Nm³ feed with superior PA quality guaranteed by expert technical service and long-term commitment in innovation demonstrated in the world’s longest reference list and in-house operation.

O4-68 Catalyst Advantages
- Higher proportion of selective layers per tube
- Hot Spot (HS) remains longer in selective layers
- Higher Phthalic Anhydride yield in 2nd operation year
- Top performance for low loading

O4-66 Catalyst Advantages
- Improved 4-layer catalyst generation
- Improved stability of 1st catalyst layer
- Designed for harsh operation conditions
- Higher Phthalic Anhydride yield in 2nd and 3rd operation year

O4-88 Catalyst Advantages
- Higher yield vs. O4-66
- 3 selective layers
- Patented new active mass
- Easy start-up behavior

O4-888 Catalyst Advantages
- 5 layer catalyst system
- Improved selective layers and active layers
- Excellent product quality

Reference List

China
Nan Ya
Nanjing Libang
Qilu Plasticizers
Shandong Honglein
Shandong Lihuai
Shanghai Huayi
Shijiazhuang Bailong
Tongling Organic
UPC Linyuan
UPC Malaysia
UPC Nanchong
UPC Panjin
UPC Zhenghan
UPC Zhuhai
Zhejiang GST

Korea
Aekyung

Russia
Gazprom

Sweden
Perstorp

USA
Stephan

O4-68

O4-66

O4-88

O4-888

PA-Quality

O-Xylene Feed

PA-Yield

PA-Quality

CL0

CL1

CL2

CL3

CL4

O4-66

O4-88

O4-888

O4-66/68

O4-68

O4-88

O4-888

PA, CO₂

by products

CL0*

CL1*

CL2*

CL3*

CL4*

CL0**

CL1**

CL2**

CL3**

CL4**

* O4-66
** O4-68
Catalyst Portfolio for Naphthalene/Mixed Feed Oxidation

<table>
<thead>
<tr>
<th>Phthalic Anhydride Catalyst</th>
<th>O4-29 HiFlex II</th>
<th>O4-35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Gas phase Oxidation of Naphthalene/Mixed feed to PA</td>
<td></td>
</tr>
<tr>
<td>Composition</td>
<td>V₂O₅, TiO₂, and Promotors on Ceramic Rings</td>
<td></td>
</tr>
<tr>
<td>Air max. (Nm³/h)</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>Thermal Stability [°C]</td>
<td>up to 500</td>
<td></td>
</tr>
<tr>
<td>Feed (Ratio)</td>
<td>Naphthalene Feed: 100–35% o-Xylene: 0–65%</td>
<td>Naphthalene Feed: 100–50% o-Xylene: 0–50%</td>
</tr>
<tr>
<td></td>
<td>Naphthalene: 80 Mixed Feed: 85</td>
<td>Naphthalene: 85 Mixed Feed: 90</td>
</tr>
<tr>
<td>Layers</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Shaple (mm)</td>
<td>Rings, 8<em>6</em>5</td>
<td></td>
</tr>
<tr>
<td>Filling Density [kg/l]</td>
<td>approx. 0.88 in 25 mm ID tube</td>
<td></td>
</tr>
<tr>
<td>Filling Height [m]</td>
<td>2.9–3.5</td>
<td>3.0–3.5</td>
</tr>
<tr>
<td>Phthalic Anhydride Yield (react gas) [wt-%]</td>
<td>Naphthalene: 104.5–105.5 o-X/Naphthalene (50/50): 109.5–110.5</td>
<td>Naphthalene: 104–105 o-X/Naphthalene (50/50): 109–110</td>
</tr>
<tr>
<td>By-products in Reactor Gas</td>
<td>Naphthoquinone [wt-%]: 0.05–1.0</td>
<td>0.03–0.5</td>
</tr>
<tr>
<td></td>
<td>Phthalide [wt-%]: 0–0.05</td>
<td>0–0.03</td>
</tr>
</tbody>
</table>

For PA producers, BASF’s Naphthalene and mixed feed catalysts offer superior PA yield and leading PA quality guaranteed by expert technical service and long-term commitment in innovation demonstrated in the world’s longest reference list.

Expected Quality of Pure PA by BASF Naphthalene/Mixed Feed PA Catalysts

- Purity [wt-%]: > 99.9
- Solidification Point [°C]: > 131.0
- Color (Hazen) [APHA]: 5–10
- Heat Stability [APHA] (90 mm, 250°C): 15–30

O4-29HFII Catalyst Advantages
- Improved 4 layer catalyst generation
- Higher yield vs. O4-29HF
- Up to 65% o-Xylene in feed

O4-35 Catalyst Advantages
- Latest generation 5-layer catalyst system
- Catalyst geometry adjusted for maximum performance
- Superior PA quality
Reference List

**O4-29 HiFlex II**

- China
  - Cixian Sinbo
  - Henan Qing'an
  - Jining Carbon
  - Jiaozuo Grin
  - Kaifeng Junhong
  - Qilu Plasticizers
  - Shandong Hongjin
  - Shijiazhuang Baixi
  - Taixing Union Znd
  - Tangshan Risun
  - Xingtai Risun
  - Zaozhuang JFE

- Korea
  - OCI

- Brazil
  - Elektriz

- USA
  - Koppers

- Czech Republic
  - Deza

**O4-35**

- China
  - Huanghua Xinmuolixing

- Belgium
  - Rain Carbon

Support Technical Services

Customers who utilize our catalysts are offered individualized service agreements for a wide range of technical services. BASF’s dedicated technical service team has extensive experience in oxidation and dehydrogenation catalytic behavior under a variety of operating conditions. This technical team is equipped with a full range of resources to analyze the most complex problems, and has full access to our R&D facility and dedicated R&D personnel. This comprehensive service approach provides the best possible assistance to our customers anytime and anywhere in the world.

Each region in the world is assigned a dedicated BASF technical team:

**Asia Pacific**
- through our PA catalyst global business management in Shanghai

**Europe, the Middle East, and Africa (EMEA)**
- through our technical service team in Ludwigshafen

**Americas**
- through our technical service team in Ludwigshafen

**Features**
- Catalyst selection and performance forecasting
- Loading and start-up support
- Performance evaluation and optimization of current run by using portable COx analyzer
- Analysis of aged catalyst
- Troubleshooting
- Lifetime calculations
- Training of production staff
- Verification of air flow measurements by total combustion
- ROG PA yield calculation

**Customer Support: BASF Phthalic Anhydride Catalyst Package**

BASF provides not only the fitting Phthalic Anhydride catalyst. In addition, we provide top class technological expertise by our experts as well as guidelines for the catalyst’s use. We support our customers even by conducting dedicated experiments in our R&D department, in case that is necessary. Last but not least, we offer in-depth catalyst training covering the whole theoretical background of this technology.
About Us

BASF’s Catalysts division is the world’s leading supplier of environmental and process catalysts. The group offers exceptional expertise in the development of technologies that protect the air we breathe, produce the fuels that power our world and ensure efficient production of a wide variety of chemicals, plastics and other products, including advanced battery materials. By leveraging our industry-leading R&D platforms, passion for innovation and deep knowledge of precious and base metals, BASF’s Catalysts division develops unique, proprietary solutions that drive customer success.

BASF – We create chemistry

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