INDUSTRIAL & PETROCHEMICALS
Catalysts & Services –
Accelerating Your Chemistry®
ACCELERATING
YOUR CHEMISTRY®

Catalytic processes take place behind the scenes, reducing activation energy and accelerating chemical reactions. Yet catalysts never appear in final products. This ability to reduce activation energy while remaining invisible is expressed by our Purple Box.

The purple box symbolizes performance in five dimensions:

TAILORED SOLUTIONS
Your goals, needs and wishes are unique – we’ll develop the right solution for your process.

SPEED
Time is of the essence for our customers – our teams react swiftly and flexibly to your special wishes. Irrespective of whether the catalyst is based on your recipe or ours, we specialize in scaling-up and on producing sophisticated catalysts on a commercial scale.
STRENGTH
Evonik catalysts are always heavy-duty performers – you can count on our strength as well as the power of our catalysts.

LONG LIFE
Efficiency and long-term reliability are decisive for catalytic processes – that’s why Evonik catalysts are always designed for a long service life.

SERVICE
Technical customer service, high throughput screening, metal recovery – Evonik catalysts come with a full service package.
TOGETHER WE BRING CATALYST IDEAS TO LIFE

Catalysts: the No. 1 value generator in the chemical industry. More than 80 percent of all chemical products are manufactured by means of catalytic processes. Expertise in harnessing the power of catalysts is second nature to us – we can help you significantly reduce energy and resource consumption, or develop new products. As an international leading provider of catalytic technologies, we serve the markets:

• Life Sciences & Fine Chemicals
• Industrial & Petrochemicals
• Polyolefins
Evonik, the creative industrial group from Germany, is one of the world leaders in specialty chemicals. Profitable growth and a sustained increase in the value of the company form the heart of Evonik’s corporate strategy. Its activities focus on the key megatrends health, nutrition, resource efficiency and globalization. Evonik’s customers benefit from its innovative products and integrated technology platforms. Evonik is active in over 100 countries around the world. As part of Evonik Resource Efficiency GmbH, the Business Line Catalysts lives up to the principles of resource efficiency. Our products enable and continuously improve production efficiency.

**SALES 2017:** $14.4 billion  
**ACTIVE IN OVER:** 100 countries  
**EMPLOYEES:** more than 36,000

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**EVONIK IS A MEMBER OF**

- the European Catalyst Manufacturers Association (ECMA)
- the Catalyst Manufacturers Association of Japan (CMAJ)
- the Synthetic Organic Chemical Manufacturers Association (SOCMA)
- the Drug, Chemical & Associated Technologies Association (DCAT)
- the American Chemistry Council (ACC)
- the Catalysts Society of Japan (CSJ)
Today, Evonik has eight major catalyst brands for homogeneous and heterogeneous catalytic processes under one roof. This diverse portfolio of catalysts gives us the flexibility to find the most cost-efficient solution for your needs. With its homogeneous and heterogeneous catalysts for batch, semi-batch and continuous processes, Evonik serves the following markets:

**MARKETS & BRANDS**

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OUR MISSION

“Together we bring catalyst ideas to life, creating value by our passion and focus.”

OUR VISION

“To be globally recognized as the preferred partner for major catalyst users, and to develop and attract talented people for our international team.”
We have built our business models around your needs in relation to catalyst solutions.

There are two business models: the product and project business.

**PRODUCT BUSINESS**
- Products from our portfolio
- Evonik proprietary products and production know-how
- Ready to use

**PROJECT BUSINESS**
- Catalysts that are customized in close cooperation with the customer

**TRUE PARTNERSHIP FOR OPTIMIZED CATALYST SOLUTIONS**
In both business models, we leverage our core competencies. We are creative in finding new solutions and are open to ideas that are not obvious. We specialize in scaling up and producing sophisticated catalysts on a commercial scale.

**Our core competencies:**
- Designing robust high performance catalysts
- Producing in commercial quantities
- Delivering on our promises
- Professional project management
Changing markets, innovative technologies and the availability of new raw materials are always posing new challenges but also offering fresh opportunities to the chemical industry.

With Evonik’s catalyst experts you have proficient and experienced support at your side.

The range of catalysis solutions for the Industrial & Petrochemicals market segment is as extensive and varied as the market itself. Evonik is in a position to actively support the development of catalysts right from the initial concept. In addition, thanks to many years of experience in scaling-up catalysts, Evonik can efficiently take catalyst recipes developed by customers to full commercial production. With innovative custom-designed catalysts, customers receive specially tailored – and thus the best possible – solutions.

Raw materials for polyurethane shoe soles are made by means of catalysis.
Evonik’s Petrochemicals customers can avail of specially developed proprietary catalysis solutions for applications such as selective hydrogenation of dienes or acetylene in C3 and C4 hydrocarbon streams, alpha-methylstyrene (AMS) in the Hock phenol process, or acetylene in vinyl chloride (VCM) production. In the area of oxidation reactions Evonik has developed catalysts for producing vinyl acetate monomer (VAM) from ethylene and acetic acid.

SELECTED APPLICATIONS

\[ \text{AcOH} + 0.5 \text{O}_2 \rightarrow \text{AcO} = + \text{H}_2\text{O} \]

VAM

Vinyl acetate monomer (VAM) is the precursor for the production of polyvinyl acetate (PVAc), polyvinyl alcohol (PVOH or PVA), polyvinyl butyral (PVB), ethylene vinyl acetate (EVA) copolymers, and ethylene vinyl alcohol (EVOH) resins. The industrial production of VAM using the Bayer Process involves the gas phase reaction of ethylene with acetic acid and oxygen. This selective oxidation of ethylene is performed by our Noblyst® 8000 series, special palladium and gold catalysts supported on silica.

Benefits:
- Specifically developed solutions supported by Evonik’s own lab test facilities
- Tailored space time yield
- Efficient use of ethylene
- High crush strength and low attrition values
- Long catalyst lifetime
- Evonik track record of more than 25 years at leading VAM producers
AMS

Industrial production of phenol and acetone apply the Hock-process, starting from cumene. One of the byproducts of this process is alpha-methylstyrene (AMS).

AMS can be separated and used as a co-polymer, however, in order to improve efficiency it is most often selectively hydrogenated to cumene and fed back to the oxidation step. Using Noblyst® H14108, a special palladium on alumina catalyst, the hydrogenation process can be run under mild reaction conditions.

Benefits:
- Specifically developed and tailored for the AMS hydrogenation
- Proof of successful operation in more than 10 phenol lines globally with a track record of more than 15 years
- Able to selectively hydrogenate alpha-methylstyrene under mild reaction conditions
- High selectivity towards cumene, thus providing optimized economics of the whole unit
- High activity by tailored catalyst design
- High crush strength, supporting longer catalyst lifetimes
- Resistance towards water washing
C3/C4 OLEFINS

Processing of C3 and C4 hydrocarbon streams requires a selective hydrogenation process (SHP) and/or a complete saturation process (CSP) unit to remove olefinic impurities. Noblyst® H14171 and Noblyst® H14271 are highly active Pd/alumina catalysts for these liquid phase process types. The palladium is highly dispersed predominately in the outer zone of the activated alumina. Owing to its high activity, the catalyst permits operation at low temperatures and high space velocities in the following production processes, e.g.

• 1-Butene Production Process
  This process is used to produce 1-butene from a steam cracker C4 cut. Part of this process is a SHP unit in which diolefins in a raffinate-2 feed (MTBE-feed) are removed by selective hydrogenation. One major benefit of the SHP technology is the ability to selectively convert butadiene to 1-butene while minimizing isomerization to 2-butene.

• Dehydrogenation Process for Propylene Production
  This catalytic process produces propylene from propane. After the dehydrogenation unit the separated propylene stream contains methacetylene and propadiene which are eliminated in a SHP unit.

• Process for MTBE Production
  Isobutylene is used to produce methyl tertiary butyl ether (MTBE). n-Olefins and diolefins remaining after the separation of MTBE are finally saturated to butanes in a CSP unit which can be fed back into the isomerization process.
VCM

Polyvinyl chloride (PVC), used in the construction industry in flooring, cable insulation and window profiles, is based on vinyl chloride monomer (VCM).

REACTION SCHEME

The raw material ethylene is converted to ethylene dichloride (EDC) either by direct chlorination or simultaneous oxychlorination. In the second step the ethylene dichloride is purified to remove side products, subsequently (VCM) and HCl are obtained by pyrolysis (thermal cleavage). In addition to the main products VCM and HCl, traces of acetylene are formed that remain in the HCl recycle stream.
This is where Evonik’s catalyst Noblyst® E39H comes into its own. In a selective hydrogenation process, the unwanted acetylene in the HCl gas is selectively hydrogenated to ethylene, which can then be recycled into the oxychlorination process for conversion to EDC. The advantages here are lower disposal costs, fewer shutdowns, higher VCM quality, and reduced raw materials costs because less ethylene needs to be purchased—in brief, higher added value in resource-conserving and environmentally-friendly VCM production. For higher space velocities we recommend Noblyst® E39K.

**Benefits:**
- High activity (acetylene conversion > 98 percent)
- High ethylene selectivity (60 up to 75 percent)
- Improved selectivity of the oxychlorination process, reduced fouling rates of the EDC cracking furnace resulting in higher EDC purity
- Lower costs for separation and disposal through minimized by-product formation of undesired chlorinated hydrocarbons
- Long catalyst life
- Less downtime
The large amount of catalysts offered by the Catalysts Business Line for Industrial Chemicals reflects just how many industries fall into this category. As in petrochemical applications, exclusively developed catalysts are used here to meet the most varied requirements of our customers. Examples are catalytic system solutions for producing propylene oxide (PO), caprolactam, white oils, toluenediamine (TDA), butanediol (BDO), tetrahydrofuran (THF), sulfolene, plasticizer precursors, aniline, and many other chemicals.

Catalysts used for industrial chemicals contain a broad spectrum of materials, such as precious and nonprecious metals as active components, often supported on substrates with customized acidity or basicity. Increasing the efficiency of the process by means of an optimal combination of activity, selectivity and catalyst lifetime is a prerequisite for value creation.

SELECTED APPLICATIONS

\[
2 \text{NO} + 3 \text{H}_2 \rightarrow 2 \text{NH}_2\text{OH}
\]

**Caprolactam**

Caprolactam is used in the manufacture of nylon-6, a polymer applied in a broad range of products based on high strength materials, ranging from garments to bristles for toothbrushes to automotive gears and even surgical instruments. Caprolactam is synthesized from cyclohexanone, which is converted with hydroxylamine (HYAM) to its oxime.

Treatment of this oxime with acid induces the so called Beckmann rearrangement to caprolactam. Evonik has developed specifically designed catalysts from the Noblyst® P series for the hydroxylamine phosphate oxime (HPO) process which is a production step in many caprolactam manufacturing facilities.

**Benefits:**
- High surface area to boost effect of promoters
- Balance between excellent activity and good filterability
- High selectivity
- High attrition resistance
- Minimized metal leaching by tailored carbon support material
BDO

When it comes to commercial-scale hydrogenation, bulk or precipitated nickel catalysts are often used. Most of these catalysts have a nickel content of between 30 and 60 weight percent. Evonik offers nickel catalysts that have the same or even higher activity with less than 20 weight percent nickel.

The Reppe synthesis for producing 1,4-butanediol, for example, generates the intermediates hydroxybutyraldehyde and 1,4-butenediol, which must be hydrogenated to 1,4-butanediol at high pressures and high temperatures. The Ni/aluminum oxide catalysts have proven successful in this process.

Unlike conventional catalysts, Octolyst® 1000 series requires considerably less nickel: this impregnated Ni/aluminum oxide catalyst displays extremely high activity in the hydrogenation of hydroxybutyraldehyde and 1,4-butenediol.
Propylene Oxide

In the “Hydrogen Peroxide to Propylene Oxide” (HPPO) process, licensed by Evonik and thyssenkrupp, hydrogen peroxide is used as the oxidizing agent to oxidize propylene to propylene oxide with only water as a by-product. This solution requires an upstream facility for the production of H₂O₂, however, unlike other processes, no markets for by- or co-products are needed.

The amounts of waste water and the energy consumption are significantly lower. There could hardly be a cleaner or more efficient direct process. The catalyst system utilized within the HPPO process is based on titanium silicalite-1 (TS-1), a zeolite with MFI structure, in which individual silicon atoms have been replaced with titanium atoms. This catalyst has been proven to be excellent for epoxidation and ammoxidation reactions with hydrogen peroxide.

Evonik has developed a custom catalyst which offers the following benefits.

Benefits:
- Specifically developed and custom tailored for the HPPO process
- High activity as well as high selectivity to propylene
- High crush strength and low attrition values
- Lab and pilot plant test facilities available at Evonik
The hydrogenation of dinitrotoluene (DNT) to toluenediamine (TDA) is an important step in the production of toluene diisocyanate (TDI) which is a key component of flexible polyurethane (PU) foams and other PU products. In the past, the most active precious metal powder catalysts, used in small and medium sized TDA plants, had the worst filtration behavior. However, the best filtering catalyst would deliver lower hydrogenation performance. Evonik has been the first to address this problem and is offering a fast filtering high performing Noblyst® brand catalyst that is suitable for systems using 4 to 20 bar hydrogen and from 100 °C to 140 °C.

Evonik also offers activated base metal catalysts from our Metalyst® MC range designed for large scale DNT hydrogenation systems using more than 10 bar hydrogen and temperatures ranging from 120 °C to 150 °C. These are specifically designed to avoid the formation of takovite while delivering high activity and outstanding TDA selectivity. The buildup of the mineral takovite can lead to a shorter catalyst life, separation issues, and safety problems if not properly controlled.

**Benefits for Noblyst® P series:**
- Reduced tar formation
- Highly active and very selective
- Fast filtration

**Benefits for Metalyst® MC 507:**
- Highly active and very selective
- Takovite avoidance during DNT hydrogenation
- Optimized sedimentation properties
- Very low tar formation
**HMDA**

Hexamethylenediamine (HMDA) is produced by the catalytic hydrogenation of adiponitrile (ADN) and is used for the production of Nylon 6,6 fibers and resins. Nylon 6,6 fibers are commonly used to produce textiles and carpets while the resins have found a broad range of uses in the automotive industry. Since ADN is an alpha-omega dinitrile, there are plenty of possibilities for side products formation and the design of the catalyst needs to take this into consideration. Evonik has a suitable activated nickel catalyst, Metalyst® MC 502 with the following benefits.

**Benefits:**
- Highly active and very selective
- Long lifetime during the hydrogenation of ADN to HMDA
- Optimized suspension / sedimentation properties for the bubble column reactor systems commonly used for HMDA production

**Aniline**

The hydrogenation of nitrobenzene provides many industries with aniline that is further processed to produce mostly rubber processing chemicals, dyes, pigments and methylene diphenyl diisocyanate (MDI). A majority of the MDI worldwide is used to produce rigid foams for the construction, refrigeration, packaging and insulation applications. MDI is also used to a lesser degree for non-foam products such as binders, elastomers, adhesives, sealants and coatings. Although aniline is a bulk chemical there are high purity demands for which Evonik offers a high performance hydrogenation catalyst from the Noblyst® PB000 series as well as fixed bed custom catalysts.
Stearic Acid

Stearic acid manufacturers use selective nickel catalysts such as MONCAT™ 1991 or MONCAT™ 2021 for complete hydrogenation of unsaturated fatty acids. Stearic acid with a negligible degree of unsaturation (I.V. < 0.5), offers stability to the products which are being used in high temperature applications. Fatty alcohol is made from stearic acid and is widely used in the production of detergents, soaps, shampoos, shaving creams etc.

Two routes to saturated free fatty acids
Evonik offers a wide spectrum of production technologies for oil refining at production sites in Germany and the USA. In this application, toll manufacturing is of particular interest to many customers. Regeneration of spent catalysts as well as carrying out individual production steps such as extrusion, impregnation, calcination, reduction and shaping ensures an efficient production process.
CUSTOM SUPPORTS

Most of our customers require unique catalyst solutions. However, this doesn’t stop with the active components but also requires the right choice of support. With many years of experience in customization, we can tailor the optimal support for your process.

Aerolyst®

Aerolyst® is Evonik’s trademark for formed metal fumed oxides for use as catalyst supports or catalysts. The Aerolyst® 3000 series is based on Evonik’s AEROSIL®, a fumed silica with very high purity. Part of the Aerolyst® 7700 series is based on fumed titania. These products have advantages such as a narrow pore size distribution (no micro-pores!), a high pore volume, excellent strength and attrition properties.

HIGH THROUGHPUT PREPARATION AND SCREENING SERVICES

Evonik offers extensive technical support, using high-throughput experiments and catalyst optimization to rapidly identify the most suitable catalyst with the optimal performance for your particular application.
Over the last two decades the demand for custom specific catalysts has increased dramatically. When the need for a custom catalyst arises, we leverage our core competencies in the context of a project. We are creative in finding new solutions and are open to ideas that are not obvious at first glance. Evonik specializes in scaling-up and producing sophisticated catalysts on a commercial scale. A robust and stable production process is crucial to all catalysts, and we know how to design this.

The best catalyst in the laboratory is of no use, if it cannot be produced in commercial quantities. Reliable, delivering on our promises, our professional project management with cross-functional teams makes the project flow smoothly. We are never complacent about our achievements and continually strive for constant self-renewal in our business processes for your benefit.

Project Categories

Joint Development
Catalyst and process needs to be developed; close interaction between the customer and Evonik

Custom Design
Catalyst needs to be developed for existing commercial application

Custom Manufacturing
Catalyst lab recipe exists, but has not yet been produced commercially

Toll Manufacturing
Catalyst and manufacturing process is well defined

Characteristics of a project

• All projects are governed by contracts
• A confidentiality agreement protects each party’s intellectual property rights and allows a free flow of information
• The collaboration contract defines the scope and goals of the project and the commercial conditions
• By definition, all projects run on an exclusive basis

How you benefit from custom catalyst projects

• Allows you to concentrate on your core business
• Provides you with a skilled partner for developing and scaling up new catalysts
• Access to sophisticated catalyst manufacturing equipment
• Offers greater flexibility in the use of catalyst types and quantities
• De-bottleneck your own catalyst production
Overview of Evonik’s production capabilities

- Impregnation/precipitation
- Drying
- Extrusion
- Tableting/pelletizing
- Spray drying
- Powder mixing
- Hot-spray impregnation
- Reduction with hydrogen
- Passivation of pyrophoric catalysts
- Calcination in air, nitrogen and steam
- Regeneration

Our portfolio of custom catalysts is much broader than our proprietary portfolio. In the custom portfolio not only is catalyst composition quite different but also the types of products that we produce for our customers.

Selected types of custom made catalysts

- Special zeolites
- Mixed metal oxide catalysts for selective oxidation
- Superacids
- Solid base catalysts
- Supported heteropolyacids
Evonik has built an extended service package around precious metal recovery and precious metal management. Our services help you to optimize the logistics, purchasing and financing of the precious metals you need.
Evonik supports your supply chain by either selling or leasing the required amount of precious metal for your order. In cooperation with an established network of metal refiners, banks and traders worldwide, we can close your precious metal loop locally.

**Purchasing**
- Spot market orders
- Fixing orders (London fixing plus location charges)
- Limit orders
- Split orders
- Forwards

Please note:
Securities are necessary, e.g. a bank guarantee.

To find comfortable precious metal management solutions, we provide precious metal related services such as:

- Precious metal hotline
- Market statistics
- Cooperation with precious metal firms that have outstanding reputations
- Logistics for precious metal transactions
- Transfers
- Swaps
- Physical shipments
- Determination of the precious metal demand in the precious metal cycle
- Critical (minimum) demand
- Future demand

By consolidating your metal demands we are able to offer competitive precious metal prices, leasing conditions and metal shipping/transfer services.
Spent catalysts containing precious metals are sent to a metals refinery where the precious metal is extracted from the catalyst. The catalyst is destroyed in this process. The metals refinery produces solutions of precious metal salts that are subsequently used in the production of fresh catalysts. This recycling minimizes precious metal losses.

Evonik takes care of the entire precious metal cycle, from management of the precious metal account to coordination of refining activities. This process is transparent to the customer, for whom Evonik is simply a convenient one-stop service point for all his refining needs.

![Diagram of precious metal refining process]

**CALCULATION TOOL**

www.evonik.com/catalysts

On our website we offer a cost calculation tool to help you better understand the economic considerations associated with the use of precious metal catalysts.

You can fill in all parameters of this calculation, such as catalyst price, cost of refining, precious metal losses, precious metal recovery rates and interest on the working capital invested in the precious metals.
SPENT CATALYSTS

Legislation requires the sender of spent catalysts to obey national and international transportation regulations and traffic laws for residual materials and waste. It must be checked, for example, if the residual chemicals in the spent catalyst need to be classified as hazardous or dangerous goods. If necessary, special regulations and permits for packaging and transportation may be required.

The spent catalyst should:

- Be thoroughly washed and steamed and delivered moist with water but solid for handling and shall not contain any excess liquid
- Not be self combustible
- Be marked according to international transportation laws and packed in 60, 120 or 200 l steel or plastic UN-approved drums with metallic lid or in approved pails. Authorization to use other packaging must be agreed to in advance of a shipment.
- Be shipped together with a copy of the completed and signed questionnaire, “Information on Spent Precious Metals Catalyst”, and a Material Safety Data Sheet (MSDS). Furthermore send the completed questionnaire 10 days in advance of dispatch if possible, but in any case before dispatch of shipment.
- Be separated from all materials that are not spent catalyst, but would be combustible, for example, cloths and filters. These materials shall be cleaned and disposed at the customers’ site or if included because of precious metal content, they must be packed and labeled separately. Additional cost or any change in conditions involved with the processing of these special materials will be passed on to the customer.
- Be packed and sent freight prepaid and insured (DDU, Delivered Duty Unpaid, incl. Declaration T1)

Please refer to our detailed Delivery Provisions for Spent Precious Metals Containing Catalysts available upon request from your local sales or customer service contact.
EVONIK RECEIVES a sample of the spent catalyst for the initial analysis

RECEIPT OF SPENT NICKEL after both parties agree on the initial value of the spent catalyst
In alignment with our commitment towards the environment, Evonik has a dedicated facility for recovering nickel from spent catalyst. Evonik purchases your spent catalyst based on the percentage of nickel, where the higher concentrations of nickel receive a higher percentage of nickel LME.

The best results are achieved when the spent catalyst residue contains 10% or more of nickel. This service allows the customer to effectively dispose of the spent catalyst, while recovering some of the nickel value. The availability of this service depends on the local laws and regulations of the customer. Please contact your Evonik representative for further details.

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**BASE METAL MANAGEMENT**

In addition to refining, Evonik takes care of base metal purchasing and financing and associated services. We are well aware of the implications of base metal prices on the overall economic viability of the catalytic process. Therefore, we can offer tailored solutions for integrated metal management and can help you select the cost optimization approach that’s right for you.

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**WEIGHING & SAMPLING**

of spent consignment

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**NICKEL CONTENT**

**ANALYSIS**

to confirm the value of the spent catalyst

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**CUSTOMER**

**RECEIVES PAYMENT**

based on LME* data and the concentration of nickel in the spent catalyst

* London Metal Exchange; www.lme.com
PACKAGING

The standard packaging consists of steel drums with a capacity of up to 200 liters (55 gallons) with two polyethylene inner liners. Approved (UN-1A2) air release valves are incorporated into the lid as required. Our products are also supplied in big bags.

We also provide custom packaging, help you with the safe and correct handling of our products and tailor our logistics to your specific needs.

MSDS

Material Safety Data Sheets

Material Safety Data Sheets (MSDS) can be obtained from your local sales representative or from:

Evonik Resource Efficiency GmbH
Postcode 713/303
Product Safety Department
Rodenbacher Chaussee 4
63457 Hanau-Wolfgang
Germany
sds-im@evonik.com

ESHQ

Environment, Safety, Health and Quality

As a subscriber to the Responsible Care® program, Evonik is committed not only to delivering quality products and services but also to maintaining high health, environmental, safety and security standards in the operation of its plants and distribution of its products. Our sites have ISO 9001 and ISO 14001 certification, and all our US sites are certified in accordance with the RC 14001 standard. Certain products are also Halal and Kosher certified. We take pride in promoting the principles and practices of Responsible Care® by sharing experiences and offering assistance to others who produce, handle transport or dispose of our products.

OTHER BROCHURES

Additional Services

For access to more of our publications please contact your local sales manager or visit our website at www.evonik.com/catalysts
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