JM

Catalysts for chemical processes

A range of high performing and custom catalysts for use in the petrochemicals industries

Johnson Matthey
Inspiring science, enhancing life

Why Johnson Matthey?

We have been leaders in our field for more than 200 years, applying unrivalled scientific expertise to enable cleaner air, improved health whilst making more efficient use of our planet's natural resources. Through continued investment in sound research and development, we are tackling the world's big challenges into our third century and beyond.

Chemical catalysts

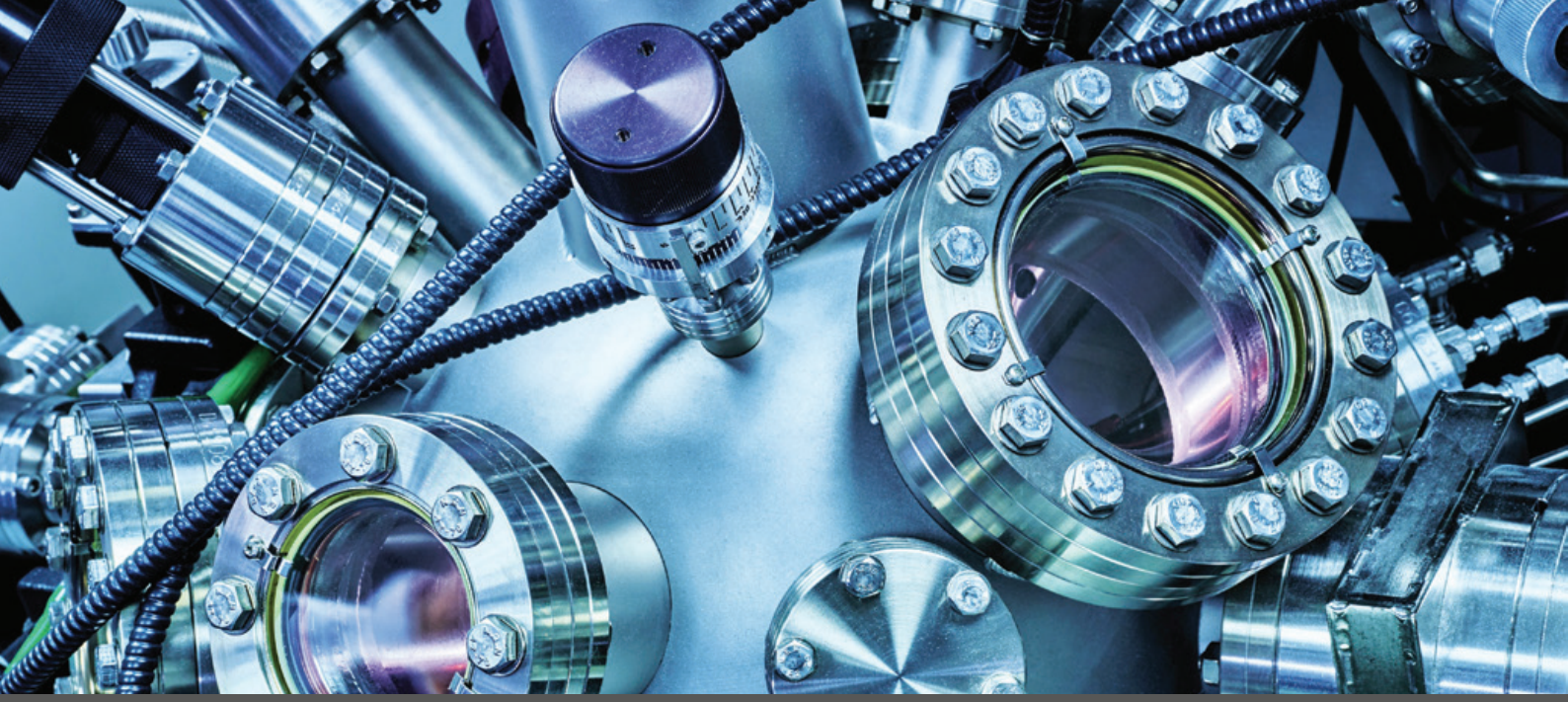
Our range of performance and custom catalysts highlight Johnson Matthey's extensive capabilities and expertise in the chemicals market area. With our dynamic group of dedicated and skilled people and unparalleled technical service, we meet the needs of our customers worldwide, to develop and manufacture the catalysts that optimise chemical processes.

We offer you a comprehensive portfolio of chemical catalysts, plus a range of collaboration models to produce custom-made solutions, available at commercial scale.

Our heritage in chemical processes further enables us to provide practical solutions to maximise the value of your business.

This reputation is further enhanced by our established range of products and technologies:

- PRICAT™
- HTC™
- PURASPEC™
- PURAVOC™
- ACCENT™
- HYDECAT™
- ODORGARD™
- Sponge Metal™
- PURACARE™
- KATALCO™
- AMCAT™



Catalyst development and characterisation

Investment in people and science ensures that Johnson Matthey stays at the forefront of catalyst technology

Catalyst preparation

Johnson Matthey (JM) uses a wide range of preparation methods (precipitation, adsorption, impregnation, coprecipitation) to produce catalysts tailored for specific processes. New catalysts are scaled-up on dedicated equipment, from gram to kilo and kilo to tonne quantities of catalyst.

A wide range of state-of-the-art development equipment is used to transform catalyst formulations into final products, including tableting presses, extruders, granulators and spray dryers.

For catalyst finishing we have a comprehensive range of drying, calcination, reduction and passivation equipment (static, rotating, moving, fluidised bed) operated under a range of conditions.

Catalyst characterisation

JM's material characterisation capabilities include:

- N_2 and Hg porosimetry providing pore volume, pore size distribution, average pore diameter, BET surface area
- Full range of chemisorption techniques for measuring active metal surface areas (e.g. Ni, Co, Cu, Pd, Pt, Ru)
- X-ray diffraction for measuring crystallite sizes and identification of the crystallite phases present
- Scanning Electron Microscopy, Transmission Electron Microscopy
- EPMA: Electron Probe Micro-Analysis
- X-ray fluorescence, ICP, AAS and classical methods for catalyst composition
- Infra-red and Raman spectroscopy, vibrational spectroscopic techniques for measurement of adsorbates on catalytic surfaces
- X-ray Photoelectron Spectroscopy for measuring surface composition of catalysts
- Ammonia and pyridine adsorption and desorption to determine Lewis and Bronsted acid sites
- TGA, DSC, DTA, TPR analysis
- Particle size analysis and sedimentation techniques
- Full range of equipment for measuring strength and attrition of formed catalysts and powders

Catalyst testing

A key strength of JM is our capability and expertise in catalyst performance testing.

Our experience in chemical process technology, combined with world class science and an extensive range of catalyst testing rigs gives us an advantage in testing and delivering optimum catalyst solutions.

We have the capability to test catalyst performance at all stages of the development and scale-up process, from initial screening at milligram scale through to pilot testing at kilogram scale.

Technical service

JM wants its customers to be successful. We continually develop high technology catalysts, the performance of which may be significantly enhanced by optimisation of plant operating conditions.

JM's technical service team are available to provide advice to customers on revised operating conditions, within the plant design limits.

Our highly experienced technical service personnel can assist in many important aspects of process catalyst operations.

The technical service function can assist with:

- Catalyst selection
- Operating conditions and life predictions
- Catalyst loading
- Start-up, shut down and regeneration procedures (on site assistance)
- Routine plant monitoring (technical service site visits)
- Trouble-shooting
- Plant optimisation and revamp studies
- Training
- Establishing basic flow sheets for new applications
- Reactor design (process vessel sketches)
- Chemical and physical analysis of spent catalyst

Custom catalysts

JM recognises that value can often be driven by differentiation. Collaboration with JM on custom catalyst programmes enables our customers and partners to gain an advantage by creating and deploying unique catalyst technology.

Customised collaboration

JM's customer focus and expertise in all aspects of heterogeneous catalyst design, scale-up and manufacturing enables us to accelerate our customers' product development and commercialisation. Our custom collaborations harness the global development and world leading manufacturing capability of the organisation to deliver high quality catalysts with outstanding performance that meet all our customers' needs.

Acting with integrity

Our reputation for reliability and integrity ensures that our customers' IP is safeguarded during every step of the collaboration process: from project initiation to product delivery.

Working together

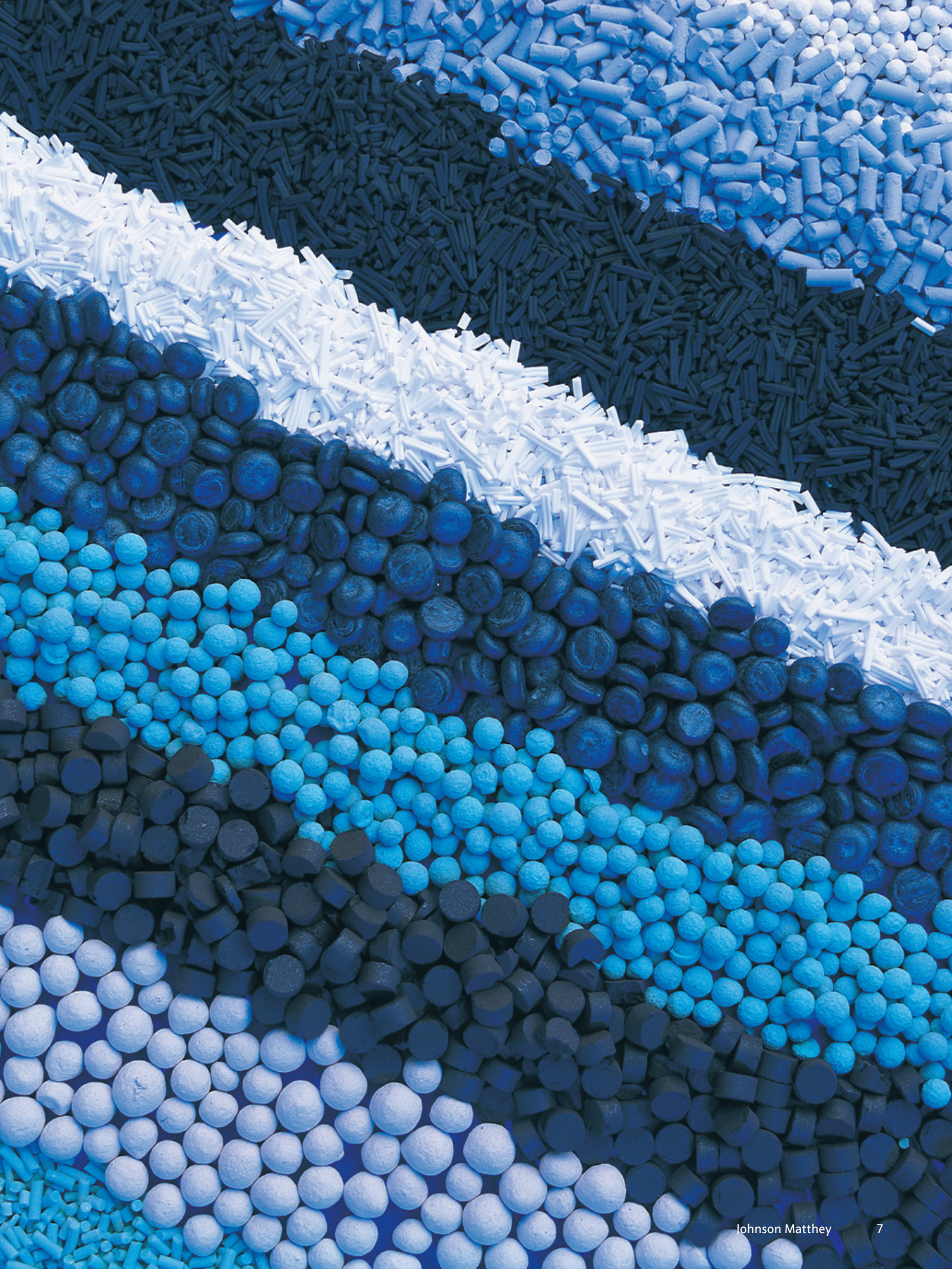
Two projects are rarely the same: flexibility and collaboration are key to our approach in custom projects. We always take the time and care to listen to our customers' non-technical requirements so that we can jointly select the right project model and project management approach. This flexible, collaborative approach ensures that JM continues to be our customers' most valued partner for customised solutions

Project models

Custom Manufacturing	Custom Development	Collaborative Development
JM brings its manufacturing expertise and know-how to deliver your catalyst	JM brings its catalyst design and manufacturing expertise to deliver an improved catalyst into your application	We work closely together to deliver a joint catalyst and application solution

Metals	Formulation	Forming	Finishing:
• Base metals, including but not limited to Ni, Co, Cu, Zn, Cr, Zr, Mg, Mn, K, Ce, Fe, Sn, W • Precious metals: Pt, Pd, Rh, Ru, Ag, Au, Ir, Re • Multi-metallic, including proprietary, mixed base and precious metal recipes	• Precipitation (supported and unsupported) • Impregnation (on a range of supports) • Coating • Alloying	• Precompaction • Tableting / pelleting • Extrusion • Granulating • Spray drying • Encapsulation • Grinding and milling	• Drying • Calcination • Reduction and passivation • Sulphur treatment

Contact your local sales manager to discuss your requirements or contact us via our website.



Olefins

Steam cracking of hydrocarbons is a primary source of olefins. The yield of ethylene and its by-products - propylene, butylenes, butadiene and aromatics - are dictated by the feedstock, plant configuration and cracking severity. We offer catalysts and absorbents suitable for every plant configuration in the olefins value chain to improve the product quality, reliability and cost effectiveness of these essential operations.

We offer high performance **PRICAT** PD catalysts for acetylene conversion for both front-end and tail-end configurations.

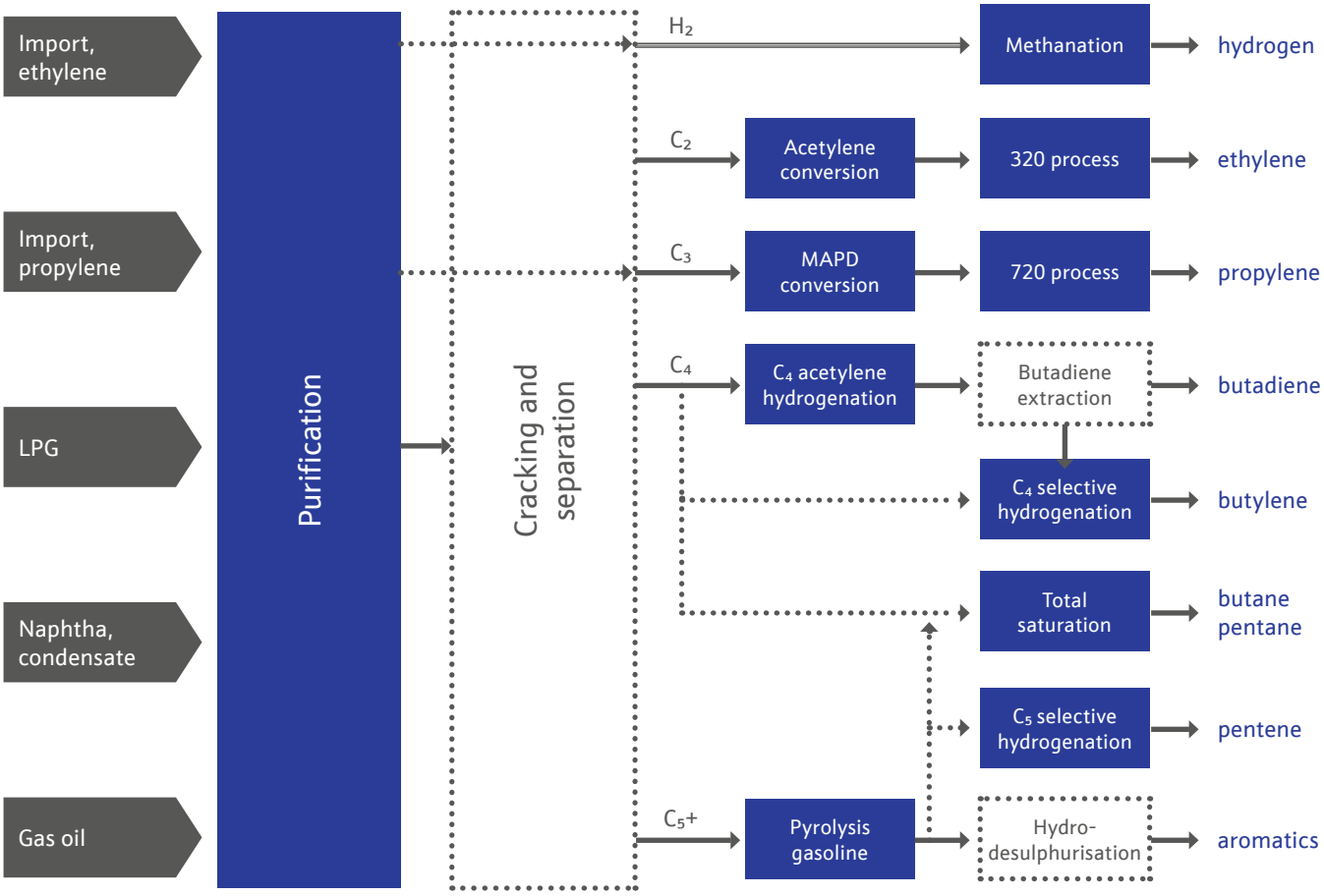
These include;

- Front-end catalysts with tailored offerings for different feeds and CO concentrations
- Tail-end catalysts with dual or single catalyst operation with optimised performance

In our front-end products acetylene is removed whilst ensuring minimal ethylene hydrogenation. In our tail-end products, cycle length is extended through low green oil formation and our range includes high performance offerings delivering high selectivity and high activity in a single catalyst system.

For C_3 processing we provide catalysts for the removal of MAPD (methyl acetylene and propadiene). We offer products for both liquid phase and vapour phase converters, each product being designed to ensure complete MAPD removal whilst avoiding significant propylene hydrogenation and minimising green oil formation.

C_4 and C_5 cuts from an ethylene cracker can be important fractions in the value chain. We offer a range of **PRICAT** PD selective and total saturation catalysts for a range of C_4 and C_5 processes.



■ Blue areas indicate the JM offering

Pygas hydrogenation

Raw pyrolysis gasoline contains a high content of unsaturated hydrocarbons (olefins and aromatics) making it an excellent source of aromatics and high octane gasoline components, but must be hydrotreated before further processing. We offer a comprehensive range of pyrolysis gasoline catalysts as part of our HTC and **PRICAT** PD catalysts. These catalysts, for the removal of acetylenes, dienes and aromatic olefins lead to a number of important benefits:

- Improve the induction period and colour
- Reduce gum content of gasoline blending components
- Reduce fouling in the downstream hydrodesulphurisation unit

We supply nickel and ruthenium catalyst for methanation of CO in hydrogen steam and our **PURASPEC** range is applied to CO removal from ethylene streams.

Alongside our selective hydrogenation catalysts range, we offer products for feedstock and monomer purification. The JM **PURASPEC** range of catalysts and absorbents can be used to remove the full range of impurities (mercury, arsenic, sulphur, chlorides, COS, trace acetylenes, AsH_3, CO and O_2 etc.) from the following streams:

- Gas and liquid feeds ahead the ethylene cracker
- Cracked gas or liquids prior to the selective hydrogenation reactors
- Refinery gases and liquids before polymerisation
- Ethylene cracker products to polymer grade quality
- Recycle gas streams in polymer plants

We supply nickel and ruthenium catalysts for methanation of CO in hydrogen streams and our **PURASPEC** range is applied to remove CO from ethylene streams.

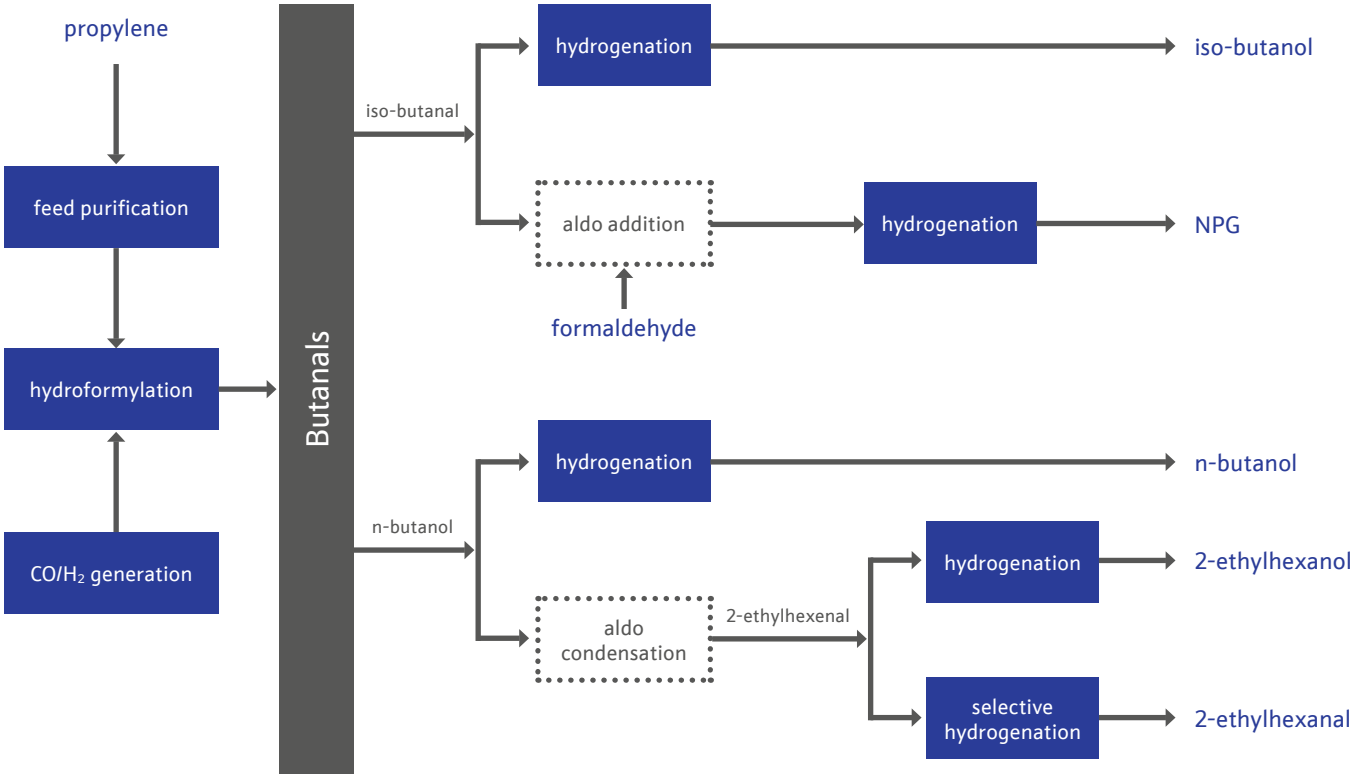
More information on these catalysts and technologies can be found in our ‘olefin processes’ brochure.

Oxo-alcohols

JM offers the complete range of catalysts for the manufacture of oxo-alcohols. Starting from the generation of synthesis gas, hydroformylation and hydrogenation through to final product polishing and esterification. JM supplies catalysts and application know-how for:

- Generation of synthesis gas
- Purification of olefins and hydrogen
- Hydroformulation
- Rhodium scavenging , recovery and refining
- Fixed bed hydrogenation for liquid and vapour phase operations
- Fixed bed liquid phase polishing
- Selective hydrogenation of unsaturated aldehydes
- Downstream applications such as amination and neo pentyl glycol production

We also license the "Johnson Matthey Oxo-Alcohol Process".



Alcohols polishing

In order to improve your alcohol product quality by polishing or finishing we also offer **PRICAT** nickel/silica and **HTC** nickel or cobalt catalysts, for the full range of alcohols, including 1,4-butanediol.

Aldehyde full hydrogenation

We offer a variety of base metal fixed bed hydrogenation catalysts for the full hydrogenation of any aldehyde to the corresponding alcohol. We have an extensive range of **PRICAT** copper/silica, copper/zinc, nickel/silica and **HTC** nickel catalysts for either liquid or vapour phase applications. We can recommend our best choice once feedstock characteristics, process conditions and performance requirements on activity, selectivity and poison resistance are defined.

Aldehyde selective hydrogenation

For the selective hydrogenation of unsaturated aldehydes, such as 2-ethylhexenal to 2-ethylhexanal, we can supply our palladium/alumina catalysts.

Hydroformylation

We offer a complete range of rhodium compounds for hydroformylation processes, such as rhodium chloride, rhodium acetate or the original Wilkinson catalyst $RhCl(PPh_3)3$. We also offer rhodium complexes such as $RhH(CO)(PPh_3)3$ (Rh-42) and $Rh(acac)(CO_2)$ (Rh-50). Our ROPAC catalyst system $Rh(acac)(CO)(PPh_3)$ is well known in the industry.

Neo pentyl glycol (NPG)

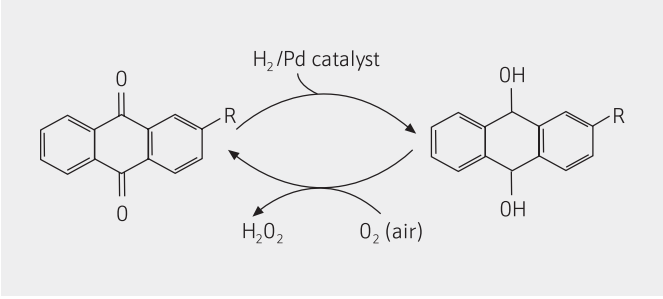
Based on our catalyst know-how in the hydrogenation of hydroxypivalaldehyde to neo pentyl glycol (NPG), we can work together with you in selecting the most appropriate catalyst for both liquid and vapour phase operations.

Oxo-alcohol licensing

JM is a licensor of oxo-alcohol and ester technology. The "Johnson Matthey Oxo-Alcohol Process" can be used to convert a wide range of olefins to the corresponding alcohols. The distinctive feature of the "Johnson Matthey Oxo-Alcohol Process" is that it uses an unliganded rhodium catalyst for the hydroformylation reaction. This was made possible by the development of a highly efficient rhodium harvesting process. Use of unliganded rhodium means that the process can convert a wide range of linear and branched olefins (typically C6 to C14) to give aldehydes and alcohols with minimum by-product formation and therefore a low feedstock usage.

Hydrogen peroxide

Hydrogen peroxide is typically manufactured in a multistep auto oxidation (AO) process with the main step being the catalytic hydrogenation of anthraquinone. The leading technology is based on slurry phase batch systems, but there are an increasing number of plants running the process in fixed bed reactors. JMhas commercialised several catalysts covering both principal technologies.



The recommended catalyst for the slurry system is palladium supported on silica/alumina material. This product has the required activity, product distribution and physical characteristics to carry out the AO process reliably over time. JM has also developed an alternative to the silica/alumina based catalysts using spray-dried silica/alumina support with defined Si:Al ratios. For slurry technologies, which utilise alumina supported catalysts, commercial materials are available in various metal loadings and particle size distributions.

The fixed bed hydrogen peroxide processes also use supported Pd catalysts and Johnson Matthey offers an alumina-based catalyst in spherical shape.

Specialty amines

We offer a wide range of proprietary catalysts for amination of aldehydes, ketones and ammonolysis of alcohols as well as nitrile hydrogenation for both vapour and liquid phase technologies. We can help you choose the right catalyst for your operation.

Catalysts used in these applications include **PRICAT** nickel and cobalt based products, both in tablet and powder form. The **HTC** cobalt range has successfully replaced traditional high cobalt content fixed bed catalysts in several applications. The **HTC** cobalt catalysts are characterised by a highly dispersed active metal phase and an open pore structure, resulting in high activity and selectivity combined with a high physical strength.

Further, we have successfully co-developed and manufactured custom catalysts for the production of specialty amines.

MDI and TDI process catalysts

JM offers a range of catalysts for various nitrobenzene to aniline hydrogenation processes as well as for other chemical reactions in the MDI and TDI flowsheets..

Solvents

For more than 20 years, many customers worldwide have successfully used **HTC** in solvents, fuels, white oils, waxes and other similar applications for de-aromatisation, desulphurisation and removal of undesirable and/or toxic aromatic and olefinic species from solvent streams using hydrogenation.

The catalysts are characterised by a highly dispersed active metal phase and an open pore structure. High metal dispersion is equivalent to small crystallite size and provides a high metal surface area per gram of metal. Catalyst activity is directly linked to metal surface area. Large pores are important to make the metal surface area accessible and minimise diffusion.

The above mentioned features result in high activity, high selectivity and poison resistance, which is nowadays required to turn difficult feeds into low-aromatic and low-sulphur products. The high physical strength and low attrition index ensures a trouble-free operation, even at longer lifetimes, and easy unloading at end of run.

HTC catalysts have been used to produce a wide range of solvents from a variety of hydrocarbon feedstocks including gasoline, kerosene and diesel type fractions. The catalysts commonly reduce aromatic contents from several wt% to less than 50ppm, with tighter specifications achievable as required. These catalysts have also been proven in the manufacture of high quality medicinal white oils, highlighting the unique characteristics of this catalyst range.

Similarly, olefinic solvents can be produced with bromine indices below 10 mg Br2/100g. We have experience of a wide range of feedstocks, both light materials such as hexane or heavier species such as PAO (poly-alpha olefins).

In some special applications, supported precious metal catalysts provide the highest performance. Please, contact us to discuss your requirements.

Fluorochemicals

JM has a long pedigree in fluorochemicals catalysis, our catalysts have been deployed successfully in a range of processes for over 20 years. In addition to continuing to develop and manufacture catalysts for HFC applications JM can also provide catalysts suitable for use in all steps of the latest HFO processes

Chromia catalysts

JM chromia catalysts are used for the vapour phase fluorination of halocarbons with HF. Our range includes both unpromoted and promoted chromia catalysts.

Hydrogenation and dehydrohalogenation

We offer a wide range of hydrogenation catalysts for fluorochemical manufacture by Cl/H exchange, hydrogenation and dehydrogenation. These include both base metal and supported pgm catalysts. Characterised by high activity and selectivity whilst having long operational lifetimes.

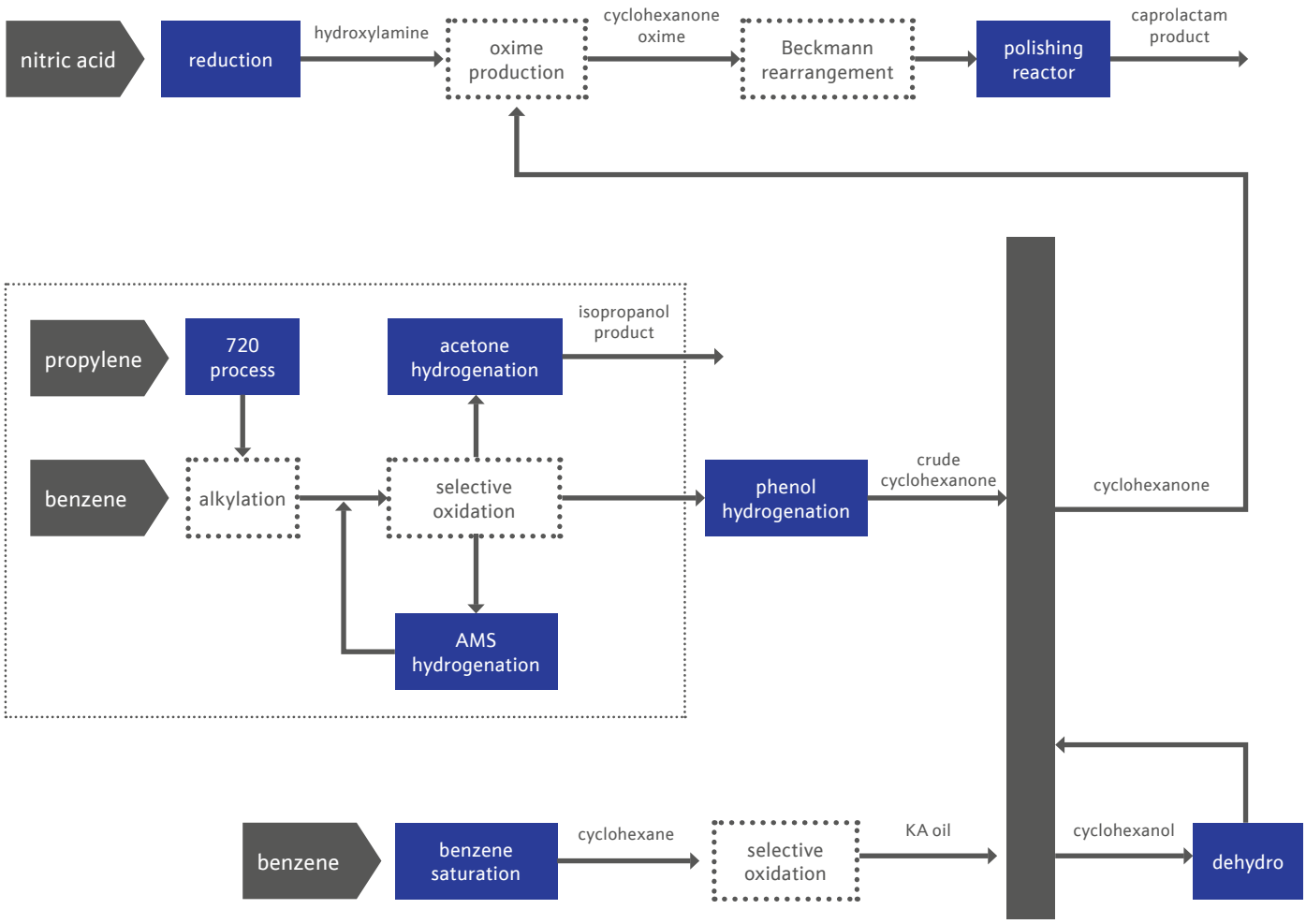
A wide range of fluorochemicals can be produced with these fluorination, hydrogenation and dehydrogenation catalysts, including:

C1's HCFC 22, HFC 32
C2's HFC 134a, HCFC 124, HFC 125, HFC 143a, HFC 152a
C3's HCFC 225, HFC 227, HFC 245, HFO 1234yf

As we have extensive expertise in this area, we are able to customise our proprietary catalysts to meet our customers' specific process needs. With our flexible production assets we are able to manufacture a wide range of custom catalysts in various physical forms.

Caprolactam

Caprolactam is used primarily for the production of nylon 6 fibres and resins. JM offer catalysts and absorbents to improve the product quality, reliability and cost effectiveness of these essential operations in the caprolactam value chain.



Benzene to cyclohexane

In benzene hydrogenation, polishing reactors are required to remove residual benzene. **HTC** nickel catalysts, available in both oxide and reduced & passivated forms, produce high quality cyclohexane at low temperature and high throughput. **PRICAT** platinum on alumina catalysts may also be used and these are supplied as tablets for use in vapour phase tubular reactors.

Cyclohexanol to cyclohexanone

For the dehydrogenation of cyclohexanol to cyclohexanone, JM provide **PRICAT** copper on silica or copper/zinc on alumina catalysts, which offer low phenol and cyclohexene formation and high activity. Furthermore, these catalysts are characterised by their high strength even in the reduced state.

Phenol to cyclohexanone

For the conversion of phenol to cyclohexanone, we offer a range of **PRICAT** palladium on alumina catalysts for use in both fixed bed or stirred tank reactors.

Nitric acid to hydroxylamine

Both palladium on carbon and mixed palladium/platinum on carbon are used for the reduction of nitric acid to hydroxylamine.

Caprolactam polishing

HTC nickel or **Sponge Metal** nickel catalysts can be applied to hydrogenate remaining unsaturated compounds in crude caprolactam. We offer products for both fixed bed and slurry processes.

AMS selective hydrogenation

Phenol production is increased when α-methyl styrene (AMS) is selectively hydrogenated to cumene prior to recycling. JM provide **PRICAT** palladium on alumina catalysts either in tablets or trilobe extrudates. The catalysts give high activity and low isopropyl cyclohexane formation, thus allowing operation at lower temperature, leading to a low rate of coke formation and polymerisation, and a low rate of pressure drop increase across the reactor.

Adiponitrile to hexamethylenediamine

Hexamethylenediamine is mainly used for the production of nylon 6,6 via condensation polymerisation with adipic acid and is currently produced by the hydrogenation of adiponitrile. With our range of **Sponge Metal** nickel catalysts, we can advise you to select the right grade for this reaction.

Environmental catalysts

Environmental concerns about industrial emissions to air and water have been continually growing. In response, JM has targeted key issues by applying our expertise in catalysts and catalytic technology.

Our range of fixed bed catalyst technologies is designed to treat a wide range of gaseous and liquid streams. No competitor can rival its combination of robustness, fit-and-forget operation, economy, effectiveness and environmental compatibility. Yet these technologies can be easily combined with, as well as replace, existing systems.

In the core process, a catalyst converts sodium hypochlorite to brine and a highly reactive oxygen atom, which enhances the oxidation of organic contaminants in waste streams. Our environmental catalysts range uses this process for the following purposes:

HYDECAT

- For destroying waste hypochlorite streams

ODORGARD

- For removing odours and low-level VOCs from air streams

ACCENT

- For removing organics from aqueous systems (COD removal)

Each process can be employed by itself or in combination with one or both of the others, according to individual customer needs.

Some of the environmental catalysts processes are licensed to JM approved engineering companies, who will tailor the application to your particular requirements.

VOC destruction

Our **PURAVOC** range offers a pgm on alumina based fixed bed catalytic technology to remove a broad variety of volatile organic compounds (VOCs) in industrial processes. Our **PURAVOC** catalysts provide excellent conversions at low temperatures. This means that, compared to traditional VOC thermal combustion, **PURAVOC** catalysts give you lower utilities consumption.

PURAVOC catalysts are stable in air at ambient temperature and they can be loaded directly into the reactor. They are supplied pre-activated so no in situ activation is required.

More information on these catalysts and technologies can be found in our **ACCENT**, **ODORGARD**, **HYDECAT,** and **PURAVOC** brochures.

Fats & Oils

Johnson Matthey are market leaders for the supply of catalysts into the fats and oils industry. Our range of **PRICAT** 99 series catalysts are formulated to maximise the desired products and avoid unwanted by-products to maximise efficiency.

For hydrogenation of fats and oils we have a number of products to suit specific customer needs. These include:

- Selective hydrogenation catalysts with optimum selectivity in partial hydrogenation
- Total hydrogenation catalysts
- Catalysts specifically tailored for steep melting curve fats with extremely high selectivity
- Easy to filter catalysts without the need for filter aids
- Excellent activity and good resistance to catalyst poisons
- Rapid distribution of the catalyst in the oil
- Good re-use properties giving high efficiency of catalyst use

In addition to this, our safe and simple to handle products carry the appropriate certifications including suitability for Kosher and Halal applications and free from genetically modified ingredients.

More information on these catalysts and technologies can be found in our Fats and Oils brochure.

Oleochemicals

In oleochemical hydrogenation, even a small gain in efficiency can yield dramatic results. At JM, we supply a range of catalysts to suit whatever hydrogenation system and raw materials you use – all with unparalleled repeatability of performance.

Our **PRICAT** 9932 catalyst achieves high activity in distilled and undistilled fatty acids and has excellent stability against fatty acid dissolution. It distributes quickly into the raw material and has good filtration characteristics for ease of operation. **PRICAT** 9953 delivers many of the benefits of **PRICAT** 9932 and achieves all this with a lower nickel content.

Our **PRICAT** 9955 and 9956 catalysts offer selective hydrogenation for fatty acids, an increasingly important area for oleochemicals. In addition to their excellent stability against fatty acid dissolution and good filtration characteristics, they also deliver high performing selectivity towards polyunsaturate removal and mono - unsaturate retention.

Fatty alcohols is another important oleochemical application. Our base metal **PRICAT** range offers catalysts for fatty alcohol production and polishing, including chrome free alternatives, for those customers working towards reduced chrome in their processes. Please contact us for more information on these products to discuss which catalysts in our **PRICAT** range would be the best for your process.

We can help you select the right catalyst for your process, give advice on process conditions and help you fine tune your process to reach its optimum. We can also provide bespoke catalysts specifically to suit your process. Our catalyst and our comprehensive technical service combine to focus on one objective: to help you gain a distinctive competitive edge.

More information on these catalysts and technologies can be found in our Oleochemicals brochure.

Sponge Metal

Sponge Metal catalysts are used for many of the same heterogeneous catalytic processes as supported precious metal and base metal catalysts. The most common type of reaction is slurry phase, gas-liquid-solid hydrogenation reaction.

Sponge Metal catalysts can be easily separated at the end of the reaction. For slurry phase **Sponge Metal** catalysts, settling, filtration and decantation are common ways to separate the catalyst. Other methods less commonly used in the industry are centrifugation and magnetic separation.

Sponge Metal catalysts are prepared from alloys of transition metals and aluminium. The aluminium is leached from the alloy structure, leaving behind an active metal surface saturated with adsorbed hydrogen. The activated catalysts are stored under water to protect them from oxidation. **Sponge Metal** catalysts are in a fully active form when shipped and require no pre-activation prior to use.

Sponge Metal catalysts are used in the synthesis of pharmaceuticals, agrochemicals, bulk and fine chemicals. They are applied in a number of processes, including:

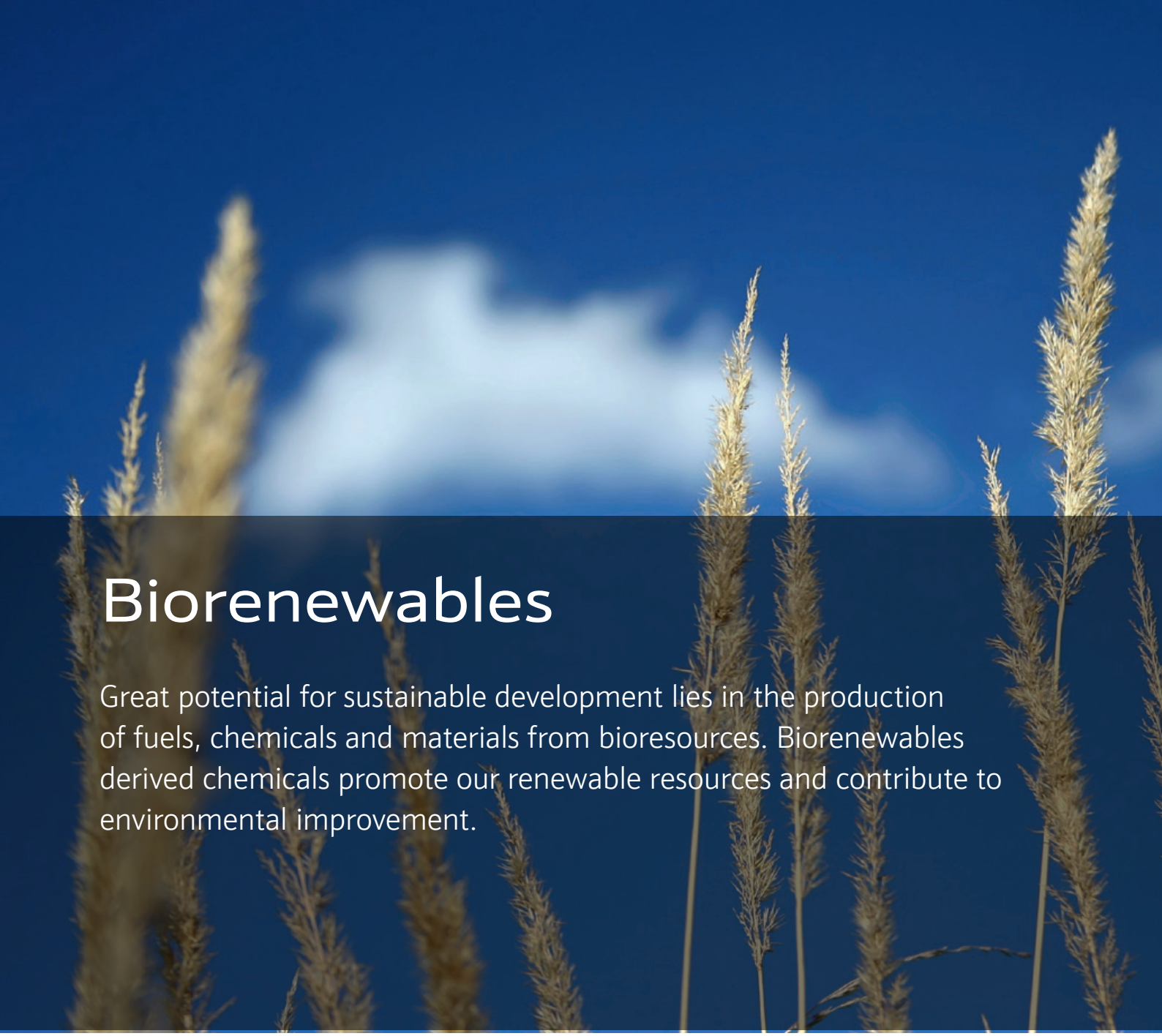
- Polyol hydrogenation
- Hydrogenation of nitriles to amines
- Dehydrogenation of alcohols
- Hydrogenation of nitrile groups to amines
- Carbonyl hydrogenation
- Stereo selective reductive alkylation
- Olefin hydrogenation to alkanes
- Conversion of fatty nitriles to fatty amines

In addition to this, we also offer customised catalysts to meet the specific needs of our customers.

AMCAT specialty encapsulated catalysts

Proprietary **AMCAT** catalysts are activated **Sponge Metal** encapsulated catalysts in which water has been displaced by an aliphatic amine. They offer unique handling and safety properties, as well as being highly effective catalysts.

More information on these catalysts and technologies can be found in our **Sponge Metal** Catalysts brochure.



Biorenewables

Great potential for sustainable development lies in the production of fuels, chemicals and materials from bioresources. Biorenewables derived chemicals promote our renewable resources and contribute to environmental improvement.

Johnson Matthey has extensive experience in developing and manufacturing catalysts to carry out a range of transformations on a variety of bio-sourced feedstocks to produce platform chemicals traditionally derived from fossil based feedstocks.

Examples include:

- Hydrogenation
- Oxidation
- Hydrodeoxygenation
- Dehydration
- Condensation

Leading edge development

Working together with leading centres of academic excellence and industrial partners on the challenges, opportunities and issues of this innovative transition, we have developed a range of high activity and selectivity catalysts robust to conditions of high temperature, high pressure and extreme pH in aqueous environments to deliver efficient transformations of bio-derived molecules into platform chemicals.

Contact your local sales manager to discuss your requirements or contact us via our website.

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