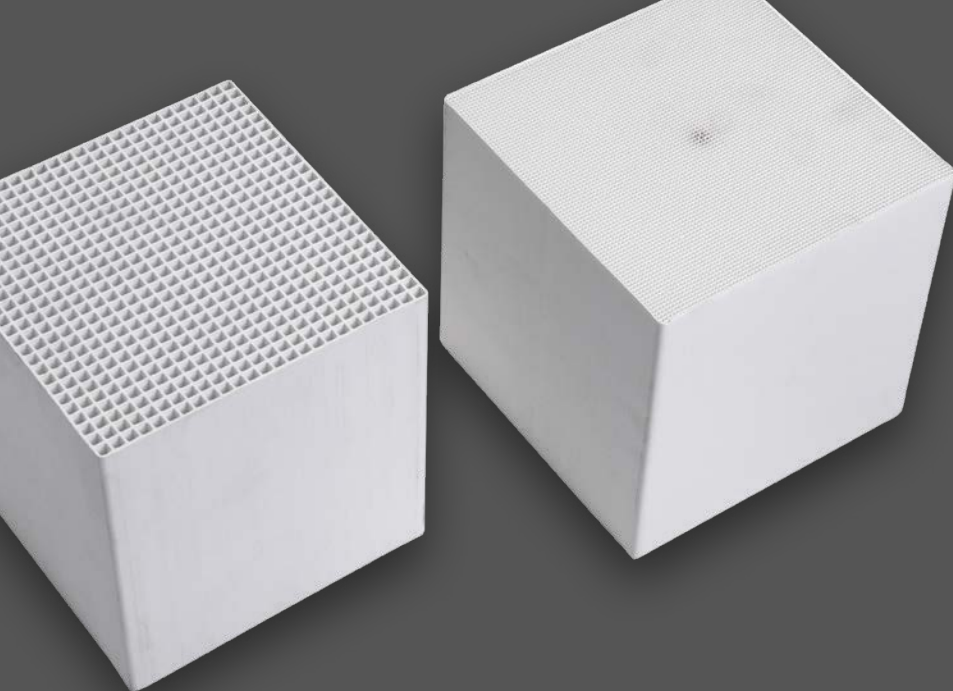




HeraPur® Gas Purification Catalysts

Catalytic Solutions for Gas Purification, Ultra-Purification
and Gas Recycling



WHY HERAPUR® CATALYSTS?

Demanding industrial applications as well as stricter environmental regulations necessitate the implementation of efficient gas pre- and post-treatment technologies and solutions. With the HeraPur® catalyst series, Heraeus offers the means of removing impurities from industrial gases that would otherwise

be detrimental for your downstream applications or for the environment.

Catalysts from the HeraPur® series meet the challenge of converting contaminants from process gases to very low concentrations in the ppm or even ppb range.





THE HERAPUR® CATALYST SERIES

HeraPur® catalysts generally consist of metal oxide supports that are functionalized with precious and/or non-precious metals. A wide range of different carrier materials such as alumina (Al_2O_3), silica (SiO_2), tita-

nia (TiO_2) or zirconia (ZrO_2) are available in a variety of shapes and geometries (tablets, spheres, extrudates, on structured ceramic or metallic supports) to serve a large spectrum of catalytic applications.

OUR STRENGTH: PRECIOUS METAL HANDLING AND MATERIAL KNOW-HOW



Efficient Use of Precious Metals

Pd 46 106.4 Palladium	Pt 78 195.1 Platinum	Rh 45 102.9 Rhodium	Ru 44 101.1 Ruthenium	Ir 77 192.2 Iridium	Ag 47 107.9 Silver	Au 79 197.0 Gold	Re 75 186.2 Rhenium	Non PM
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Catalyst Carrier

- › Alumina (Al_2O_3),
- › Silica (SiO_2),
- › Titania (TiO_2),
- › Zirconia (ZrO_2)
- › Other specialty materials

in a large variety of shapes and geometries

AIR – AND NOBLE GAS ULTRA PURIFICATION FOR TECHNICAL PROCESSES

For various technical processes and applications pure and ultra-pure gases are needed, such as air, N₂, O₂, H₂, He, Ar, etc. To achieve the required qualities, a variety of impurities such as CO, H₂, hydrocarbons and others have to be removed.

Synthetic air, for instance, is a type of industrial gas which is required for countless technical processes in different concentrations and purities. Using Heraeus catalysts in a final purification step ensures a product with extremely low concentrations of undesired constituents. Special catalysts can also be used to treat air and remove traces of CO and hydrogen. In the electronics industry ul-

tra-pure gases, free from CO and hydrogen, are required to produce advanced semiconductors.

Furthermore, oxygen even in traces has to be eliminated from technical gases such as nitrogen, hydrogen and noble gases. In a catalytic reaction with hydrogen in traces or as the main component – the oxygen is converted into water vapour, which then can be easily removed e.g. by adsorption dryers if necessary. In the purified gas residual concentrations of oxygen can be achieved down to the ppb range. This kind of reaction can take place at temperatures far below 100 °C or even at room temperature.

Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options
Air	H ₂	H ₂ O	HeraPur® K-0152	HeraPur® K-0140 HeraPur® K-0240 HeraPur® K-0264 HeraPur® K-0288
	H ₂ , CO	CO ₂ , H ₂ O	HeraPur® K-0180	HeraPur® K-0152 HeraPur® K-02133 HeraPur® K-02137 HeraPur® K-0288
	VOC	H ₂ O, CO ₂	HeraPur® K-02130	HeraPur® K-0152 HeraPur® K-0177 HeraPur® K-0264
O ₂ (also to gain noble gases)	H ₂	H ₂ O	HeraPur® K-0288	HeraPur® K-02133 HeraPur® K-0240 HeraPur® K-0264
	CH ₄	H ₂ O, CO ₂	HeraPur® K-0264	HeraPur® K-02133 HeraPur® K-02141
	N ₂ O	N ₂ , O ₂	HeraPur® K-02141	HeraPur® K-0264
N ₂ and noble gases (He, Ar, etc.)	H ₂	H ₂ O	HeraPur® K-0152	HeraPur® K-0140 HeraPur® K-0240 HeraPur® K-0264 HeraPur® K-0288
	O ₂	H ₂ O	HeraPur® K-02133	HeraPur® K-0152 HeraPur® K-0240 HeraPur® K-0264
	CH ₄	CO ₂ , H ₂ O	HeraPur® K-0264	HeraPur® K-02133 HeraPur® K-02141

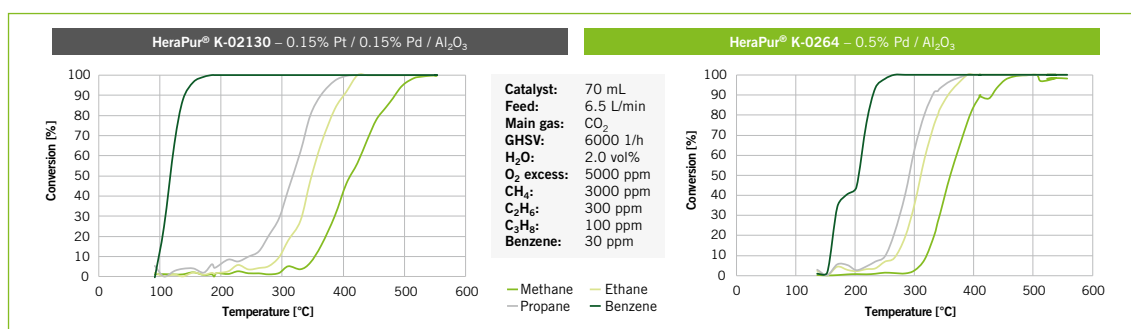
Contact us and we guide you to the most efficient option for your process including type, precious metal loading and recommended operating conditions.

CARBON DIOXIDE PURIFICATION

The food industry in particular, but also other industrial applications, have large requirements for highly purified CO₂. In order to achieve CO₂ in high-purity, the raw gases from natural wells or chemical plants can be treated with catalysts to oxidize the undesirable constituents. Depending on the source of the CO₂, there are many different impurities, such as CO, H₂ and hydrocarbons which

have to be reduced to a few ppm in most cases or, for example highly toxic aromatic compounds, which even have to be reduced to the ppb range.

Heraeus catalysts allow the precise removal of these impurities from carbon dioxide in high quality not only for food grade applications, but for all industries, where highly purified CO₂ is needed.



DELIVERING pure CO₂ – HeraPur® Catalysts experimental data at relevant conditions

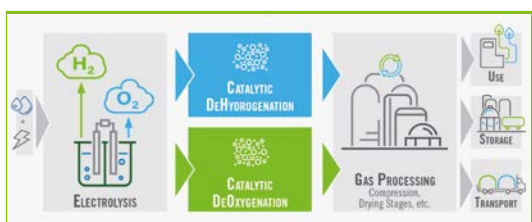
Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options
CO ₂	H ₂	H ₂ O	HeraPur® K-0140	HeraPur® K-0152 HeraPur® K-0240 HeraPur® K-0264 HeraPur® K-0288
	O ₂	H ₂ O	HeraPur® K-0240	HeraPur® K-0140 HeraPur® K-0152 HeraPur® K-0264 HeraPur® K-0288
	Unsaturated or functionalized HCs (alkenes, alcohols, aldehydes, esters, amines, etc.)	H ₂ O, CO ₂ , NO _x , ...	HeraPur® K-0177	HeraPur® K-0152 HeraPur® K-02130 HeraPur® K-0264
	Aromatic HCs	H ₂ O, CO ₂ , ...	HeraPur® K-02130	HeraPur® K-0152 HeraPur® K-0177 HeraPur® K-0264
	Saturated HCs, Aliphates	H ₂ O, CO ₂	HeraPur® K-0264	HeraPur® K-02130 HeraPur® K-02133 HeraPur® K-0240 HeraPur® K-0288
	CH ₄	N ₂ , O ₂	HeraPur® K-0264	HeraPur® K-02133 HeraPur® K-0240

Contact us and we guide you to the most efficient option for your process including type, precious metal loading and recommended operating conditions.

HYDROGEN AND OXYGEN PURIFICATION

Hydrogen Purification

The splitting of water by electrolysis is an efficient technology to produce hydrogen and oxygen. However, the separation of the gases is not perfect. Depending on the electrolysis technology, a certain amount of one gas may slip into the other. To safely process, transport or utilize the gases, these impurities need to be removed.

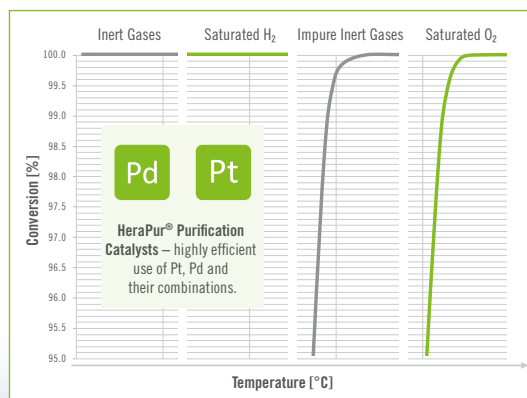


Since decades, Heraeus' gas purification catalysts have reliably fulfilled the task of removing O₂ from H₂ streams by converting it to H₂O – operating at low temperatures and with an efficient use of the applied Platinum Group Metals (PGM). With the emergence of new electrolysis technologies and applications, a new generation of deoxygenation and highperformance dehydrogenation catalysts has been developed.

Hydrogen and Oxygen Purification of Electrolysis

Heraeus Precious Metals provides catalytic solutions for efficient H₂ and O₂ removal from different gas mixtures, as shown in an exemplary diagram below. HeraPur® catalysts are characterized by:

- › Low temperature removal of O₂ or H₂ from hydrogen or oxygen respectively
- › Different compositions based on Pt, Pd or Pt/Pd alloys
- › Low PGM-loadings – especially for electrolysis feeds with low impurity profiles



Exemplary activity profiles of the hydrogen and oxygen purification in different gases

Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options	Application
H ₂	O ₂	H ₂ O	HeraPur® K-0152	HeraPur® K-0140 HeraPur® K-02133 HeraPur® K-0240 HeraPur® K-0264 HeraPur® K-0288	DeHydrogenation
	CO	CO ₂	HeraPur® K-0705H	HeraPur® K-0140 HeraPur® K-0180	(Preferential) Oxidation
	CO	CH ₄	HeraPur® K-04504	HeraPur® K-04502 HeraPur® K-04505 HeraPur® K-04507	(Selective) Methanation
O ₂	H ₂	H ₂ O	HeraPur® K-0288	HeraPur® K-0140 HeraPur® K-0152 HeraPur® K-0240 HeraPur® K-0264	
	CH ₄	H ₂ O, CO ₂	HeraPur® K-0264	HeraPur® K-02133 HeraPur® K-02141	
	N ₂ O	N ₂ , O ₂	HeraPur® K-02141	HeraPur® K-0264	

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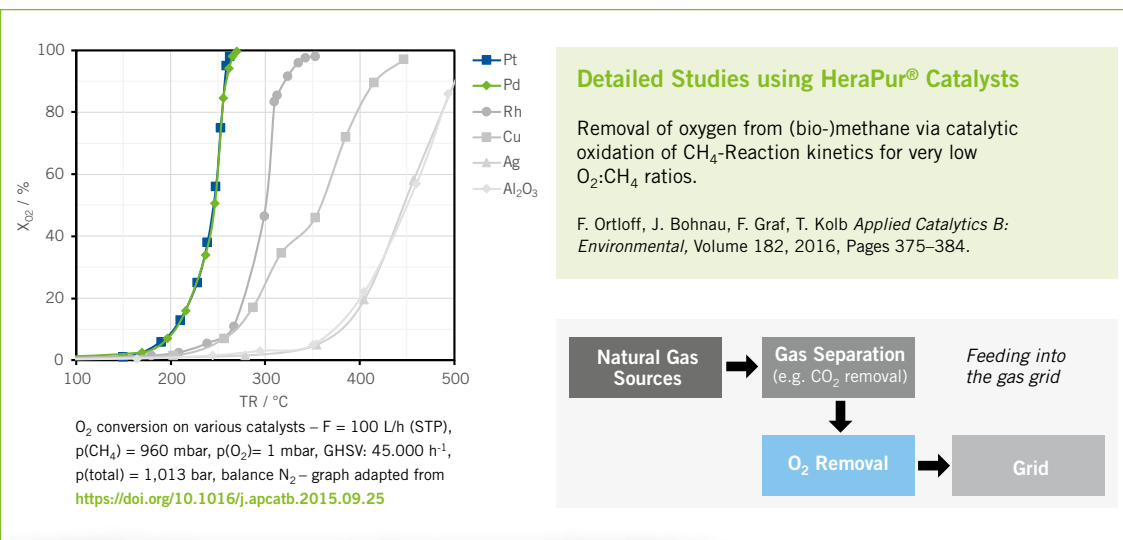
Hydrogen and Oxygen Refining

HeraPur® catalysts can also be used in gas refining and recycling operations. Here process gases of oxygen and hydrogen can contain other unwanted impurities, such as volatile organic compounds (VOCs) and nitrous oxide (N₂O) which can also be successfully removed. HeraPur® catalysts are very effective at preferentially oxidizing carbon

monoxide (CO) to carbon dioxide (CO₂). This technology can be harnessed to purify hydrogen gas streams in fuel cells, where only extremely low CO contaminations are tolerated. It is equally suitable for hydrogen recycling operations. Via an alternate reaction path different HeraPur® catalysts here can also catalytically convert CO to Methane.

METHANE PURIFICATION

HeraPur® catalysts facilitate an energy efficient removal of carbon monoxide (CO), hydrogen (H₂) and oxygen (O₂) from methane (CH₄). This can be applied e.g. in biogas upgrading processes at moderate temperatures and with little byproduct formation.



HeraPur® Catalysts for Oxygen Removal from (Bio) Methane

Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options
CH ₄	O ₂	H ₂ O, CO ₂	HeraPur® K-0264	HeraPur® K-0140 HeraPur® K-0152 HeraPur® K-02130 HeraPur® K-0240 HeraPur® K-0802
	H ₂	H ₂ O	HeraPur® K-0152	HeraPur® K-0140 HeraPur® K-0177

Contact us and we guide you to the most efficient option for your process including type, precious metal loading and recommended operating conditions.

INERT GAS PURIFICATION

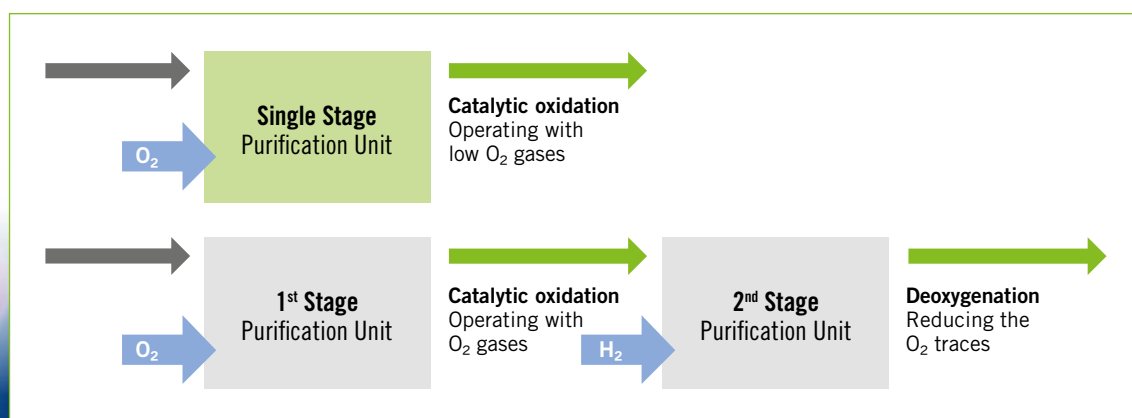
In case inert gases are used in a process as a protective atmosphere large streams of these can be a need of recycling. One example is the treatment of raw materials for plastics, such as in the Solid State Polycondensation (SSP) process for food grade polyester resins. Impurities accumulating in the inert gas here are organic compounds such as aldehydes, glycols and oligomers. Catalytic oxidation is an efficient process to treat the cycled gas stream.

HeraPur® catalysts are designed to be implemented in the purification process even with a very small (stoichiometric) oxygen

excess. After the catalytic process and the drying treatment the purified gas can be directly recycled to the SSP reactor after a prior drying treatment.

Beyond this example Heraeus catalysts are applied to a variety of gas recycling processes and inert gas streams. They can target any organic impurities, provided that they can be oxidized to CO₂ and water under process conditions. The process can either run with little oxygen excess or excess oxygen can be efficiently converted to H₂O then in a two stage process.

Heraeus Catalysts for Gas Recycling Processes



Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options	Application
N ₂	VOC (acetaldehyde and other functionalized and unfunctionalized hydrocarbons)	H ₂ O, CO ₂	HeraPur® K-0163	HeraPur® K-0174 HeraPur® K-0178 HeraPur® K-02131 HeraPur® K-0802	One Stage Process
	VOC (acetaldehyde and other functionalized and unfunctionalized hydrocarbons)	H ₂ O, CO ₂	HeraPur® K-0152	HeraPur® K-0140	Two Stage Process
	O ₂	H ₂ O	HeraPur® K-0264	HeraPur® K-02133 HeraPur® K-0240	Two Stage Process

Contact us and we guide you to the most efficient option for your process including type, precious metal loading and recommended operating conditions.

EMISSION ABATEMENT

Although there are many methods available for the abatement of emissions of volatile organic compounds (VOC) and CO, the most practical and effective technique for their destruction is incineration or oxidation. In this way, the VOC and CO are oxidized at elevated temperatures to products such as CO₂ and H₂O.

The advantage of catalytic oxidation is the lower temperature required in comparison to thermal incineration. For various industrial processes (e. g. chemical production, printing and painting, food processing, electronics, soil and groundwater remediation) this

is a proven and cost-efficient method to control emissions.

Due to the lower operating temperatures, the combustion units can be built with less expensive materials and in simpler fashion, potentially resulting in a longer service-life of the plant and at lower operation and maintenance costs.

For these applications, we offer catalysts with precious metals or base metals as active compounds on bulk material. For large gas flows and in case a low pressure drop is required, of HeraPur® monolithic catalysts can be offered.

Gasfeed	Impurities	Conversion Product	Catalyst Recommendation	Further Catalyst Options
Air	CO, HC	H ₂ O, CO ₂ , ...	HeraPur® K-02130	HeraPur® K-0152 HeraPur® K-0177 HeraPur® K-0264 HeraPur® K-0288 HeraPur® K-0299 HeraPur® K-0802
	Halogenated Hydrocarbons, Dioxins, Furanes	HX, CO ₂ , H ₂ O	HeraPur® K-02130	HeraPur® K-0177 HeraPur® K-02134 HeraPur® K-0299
	O ₃	O ₂	HeraPur® K-0802	HeraPur® K-0803
Analysis Gases	CO, HC	H ₂ O, CO ₂ , ...	HeraPur® K-02146	HeraPur® K-0152 HeraPur® K-0177 HeraPur® K-0264 HeraPur® K-0299

For each application and impurity our HeraPur® catalyst formulations are also available coated on structured ceramic and metallic substrates.



HeraPur® Overview



HeraPur® K-0140

Pt 0.3% / 0.5%

Pellets – Alumina

herae.us/herapur-k-0140



HeraPur® K-0152

Pt 0.1% / 0.3% / 0.5%

Spheres – Alumina

herae.us/herapur-k-0152



HeraPur® K-0163

Pt 0.15%, Rh 0.03%

Spheres – Alumina

herae.us/herapur-k-0163



HeraPur® K-0174

Pt 0.11%, Pd 0.04%

Spheres – Alumina

herae.us/herapur-k-0174



HeraPur® K-0177

Pt 0.3%

Spheres – Alumina

herae.us/herapur-k-0177

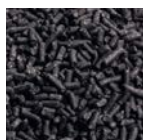


HeraPur® K-0178

Pt 0.3%

Spheres – Alumina

herae.us/herapur-k-0178



HeraPur® K-0180

Ag 5.0%, Pt 0.2%, Pd 0.1%

Titanium Dioxide – Extrudate

herae.us/herapur-k-0180



HeraPur® K-02130

Pt 0.15%, Pd 0.15%

Spheres – Alumina

herae.us/herapur-k-02130



HeraPur® K-02131

Pt 0.15%, Pd 0.15%

Spheres – Alumina

herae.us/herapur-k-02131



HeraPur® K-02133

Pd 0.5%

Spheres – Alumina

herae.us/herapur-k-02133



HeraPur® K-02134

Pt 0.15%, Pd 0.15%

Spheres – Alumina

herae.us/herapur-k-02134



HeraPur® K-02137

Pd 0.5%, Ag 5.0%

Titanium Dioxide – Strangs

herae.us/herapur-k-02137

**HeraPur® K-02141**

Pd 0.6%

Spheres – Alumina

herae.us/herapur-k-02141**HeraPur® K-02146**

Pd 0.5%

Spheres – Alumina

herae.us/herapur-k-02146**HeraPur® K-0240**

Pd 0.1% / 0.3% / 0.5%

Pellets – Alumina

herae.us/herapur-k-0240**HeraPur® K-0264**

Pd 0.2% / 0.3% / 0.5%

Spheres – Alumina

herae.us/herapur-k-0264**HeraPur® K-0288**

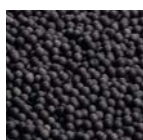
Pd 0.2%, Pt 0.1%

Spheres – Alumina

herae.us/herapur-k-0288**HeraPur® K-0299**

Pd 0.3% / 0.5%

Spheres – Alumina

herae.us/herapur-k-0299**HeraPur® K-04502**

Ru 2%

Spheres – Alumina

herae.us/herapur-k-04502**HeraPur® K-0802**

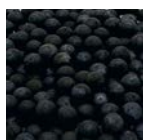
Mn, Cu ~11%

Spheres – Alumina

herae.us/herapur-k-0802**HeraPur® K-0803**

Mn, Cu ~11%

Spheres – Alumina

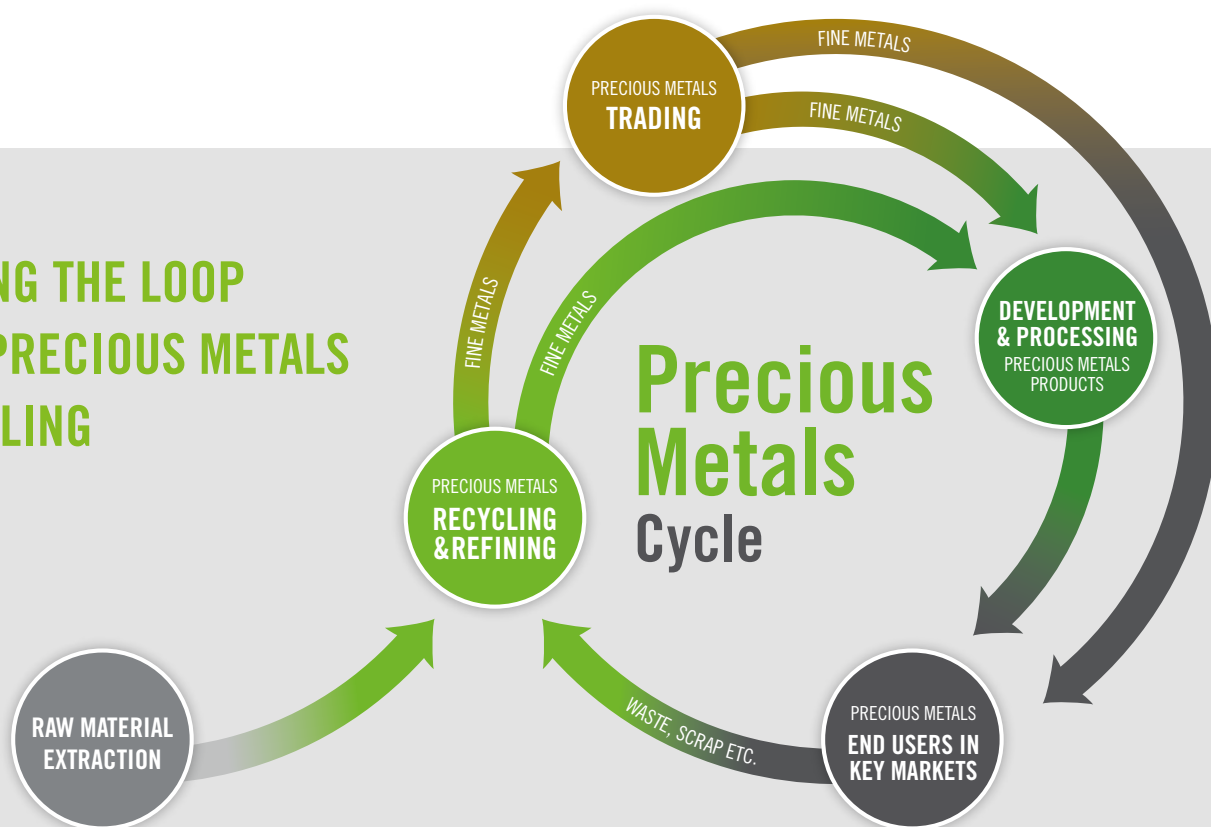
herae.us/herapur-k-0803**HeraPur® K-0705H**

Pt 0.4 %, Co ~10 %

Spheres – Alumina

herae.us/herapur-k-0705h

CLOSING THE LOOP WITH PRECIOUS METALS RECYCLING



As a specialist in the handling of spent precious metal catalysts, Heraeus uses state-of-the-art technologies to pretreat, sample, and refine your valuable materials and ensure high return rates. The reclaimed precious metal can be used again for the manufacture of new catalysts, reducing the demand for primary precious metals.

ABOUT HERAEUS PRECIOUS METALS

Heraeus Precious Metals is one of the world's leading players in the precious metals industry. As part of the Heraeus Group, the company covers the value chain from trading to precious metals products to refining and recycling. It has extensive expertise in all platinum group metals as well as gold and

silver. With about 2,500 employees at 11 sites worldwide, Heraeus Precious Metals offers a broad portfolio of products that are essential for many industries such as the automotive, chemicals, semiconductor, aerospace, pharmaceutical and hydrogen industry.

Heraeus Precious Metals

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