

Essential Ingredients for PVC Production

Trigonox[®], Perkadox[®], Laurox[®], Active[®],
DCloud[®], Ethapol[®] and Noxol[®]

Nouryon

Nouryon Creates Everyday Essentials

Nouryon is your partner in essential solutions for a sustainable future

We are a global, specialty chemicals leader. Markets and consumers worldwide rely on our essential solutions to manufacture everyday products, such as personal care, cleaning goods, paints and coatings, agriculture and food, pharmaceuticals, and building products. Furthermore, the dedication of approximately 7,650 employees with a shared commitment to our customers, business growth, safety, sustainability and innovation has resulted in a consistently strong financial performance. We operate in over 80 countries around the world with a portfolio of industry-leading brands.

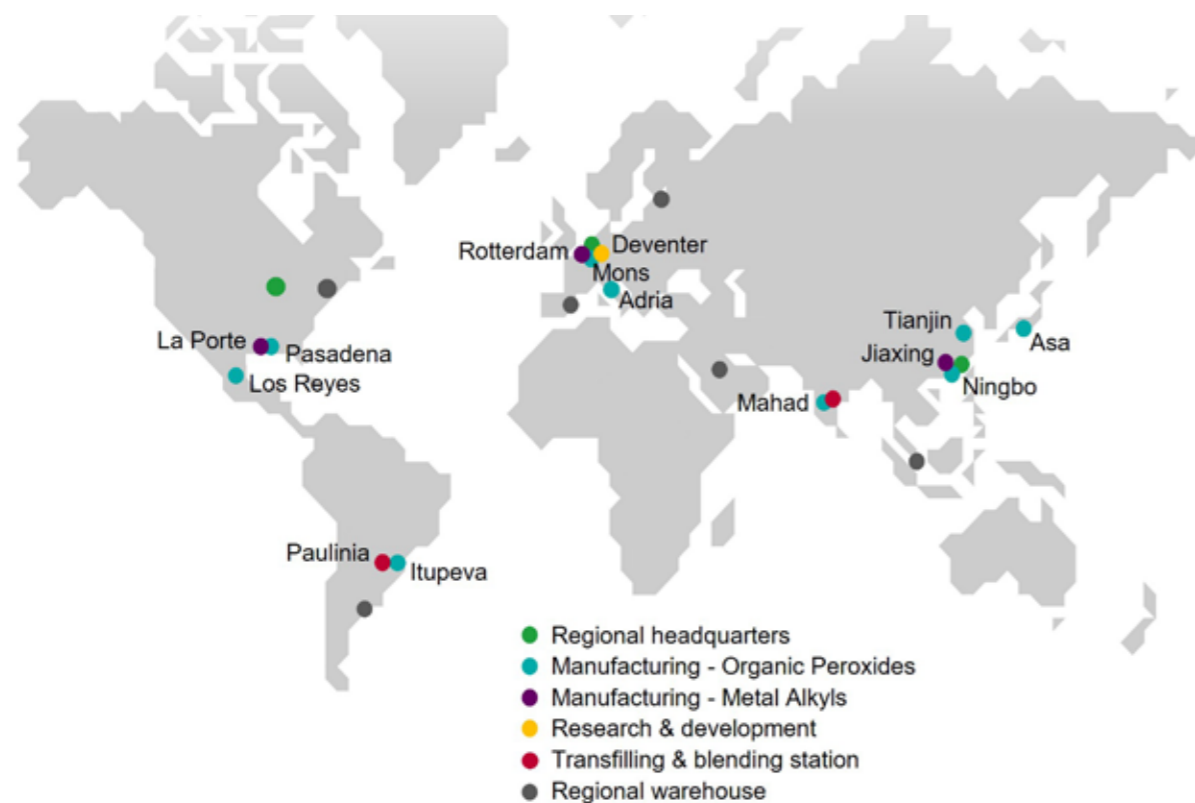
Within our Polymer Specialties business, we produce everyday essentials for the global polymer, recycling and polymer processing industries. We are among the world's leading producers of organic peroxides, metal alkyls and organometallic specialties, which are essential ingredients for the thermo-plastic, composite and rubber industries. We are widely known for our world-class products, including Butanox®, Trigonox®, Perkadox® and Ketjenblack® brands.

As a company of innovation, we have recently introduced new initiators, which have an improved performance in selectivity and HSE profile, including Trigonox® 421 and Trigonox® 301, products for example.

A global partner

Our manufacturing sites and distribution centers are found all around the globe. Our global distribution network allows us to deliver our products to you anywhere in the world. That's how we ensure security of supply and easy access to quality products wherever you are.

All our sites are ISO 9001 and ISO 14001 certified to ensure the highest product quality and strict compliance with environmental regulations. We continually invest in manufacturing techniques, high quality standards, safety, innovation, active technical support and a reliable supply chain.



Enabling the Polymer Cycle

Building on a sustainability driven strategy. We provide essential ingredients to enable the polymer cycle.



Contributing to a Sustainable Future

We partner with our customers, suppliers and employees to deliver innovative solutions, drive progress and create a safe and sustainable today and tomorrow for everyone.

Our 'Commitment to a Sustainable Future,' is based on three pillars:

		
IMPROVE	GROW	ENGAGE
Improve our safety and environmental performance	Innovate to create Sustainable Solutions, enabling customers to be more sustainable	Engage with customers, suppliers, employees, and society to drive progress
Key sustainable development goals: 	Key sustainable development goals: 	Key sustainable development goals: 
		
		

Our effort to **IMPROVE** our environmental performance includes ambitious targets:

Safety ambition: zero injuries, waste, and harm	
2025	
25% carbon emission reduction ⁶	70% low carbon energy ⁷
2030	
Carbon Neutral	10% reduction of water usage and waste generation ⁸
2050	
Net Zero carbon emissions	

⁶ Including carbon emissions from our operations (scope 1) and purchased energy use (scope 2)
⁷ Based on the portion from low carbon sources (biomass, renewable, and nuclear) compared with fossil-based sources as reported by our global manufacturing sites
⁸ Intensity measured on a per tons product basis
⁹ Reflects the percentage of innovation that is focused on sustainability



Essential Ingredients for PVC Production

Polyvinyl chloride (PVC) is everywhere in modern society and in a wide variety of applications, including products we use every day like pipes, windows, siding and flooring. It is produced through the polymerization of vinyl chloride monomer with the help of an organic peroxide initiator. Nouryon is the largest global producer of **polymerization initiators** to produce PVC offering a wide range of products like our well-known Trigonox®, Perkadox® and Laurox® brands.

Trigonox® 187, a special fast peroxide, is used in the **Continuous initiator Dosing (CiD)** technology that increases PVC output, improves process safety and the resin quality.

Ethapol® brand names. A specific Ethapol® (MPG) product is used as an antifoaming agent.

We have a strategic focus on the PVC industry, having global production assets and a dedicated R&D laboratory. Technical support is provided by a technical staff having significant PVC technology experience and know-how.

Moreover, we are a global leader in Noxol® and Everplus® **antifouling agents** which are used to prevent the reactor fouling and polymer buildup in the polymerization process.

Nouryon also offers various **secondary suspending agents**, which are used to control PVC porosity. This includes solvent-based products and aqueous emulsions under Active®, DCloud® and

Polymerization initiators for PVC

Organic peroxides are used as single initiator or in a combination of initiators to optimize the polymerization rate. The most important criteria for selecting the right initiator are peroxide reactivity, physical form and regulatory status. Most solid and liquid peroxides also are available as water-based suspensions and emulsions with improved safety characteristics.

whereas new methanol-free peroxide emulsions have been developed to serve the US PVC industry. Such water-based peroxide formulations are intrinsically safer than solvent based ones.

Organic peroxide suspensions and emulsions are supplied in HDPE cans or in stainless steel and composite IBCs. Bulk transport of peroxide emulsions is carried out by a temperature controlled manifold trailer equipped with multiple stainless-steel IBCs allowing direct transfer to a (refrigerated) storage tank.



Food contact approved water-based peroxide suspensions and emulsions have been developed by Nouryon to serve the European PVC industry,

Your Safety Our Priority

Nouryon is recognized as the global leader in organic peroxide safety. Our proven success in safely handling organic peroxides is due to our long-term commitment to developing and maintaining high safety standards. We at Nouryon always place safety as our top priority.

Sharing our experience in safety is one of the most important resources we offer. Through our safety programs we provide expert advice on the handling of our products including:

- classroom review of safety and handling of organic peroxides
- consultation on storage and dosing facility design
- demonstrations on the safe use, handling and control of organic peroxides

Our Safety Research Laboratory in Deventer, The Netherlands is heavily involved in R&D, ensuring the development of safe products and processes. Studies are carried out, in order to provide a high level of safety in manufacturing, handling and transport of dangerous goods.

In general organic peroxides are thermally unstable compounds, decomposing at relatively low temperatures. However, knowledge of proper handling techniques, carefully designed facilities and thorough training of personnel can overcome the hazards. Personnel who understand and pay proper attention will be able to handle organic peroxides confidently and safely.



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Storage temperatures

SADT: Self-Accelerating Decomposition Temperature

The SADT is the lowest temperature at which self-accelerating decomposition may occur with a substance in the packaging as used in transport. Transportation temperatures are derived from the SADT according to the recommendations by the United Nations Committee of Experts on the Transport of Dangerous Goods.

T_s max.

The T_s max. given in the product list on pages 8-11 is the recommended maximum storage temperature at which the product is stable and quality loss will be minimal.

T_s min.

A minimum storage temperature (T_s min.) is given if phase separation, crystallization or solidification of the product is known to occur below the temperature indicated. We recommend that you store the product above the T_s min. indicated for quality and in some cases safety reasons.

T_{em}: Emergency temperature

The T_{em} is derived from the SADT and is the temperature at which emergency procedures must be implemented.

T_c Control temperature

The T_c is also derived from the SADT and is the maximum temperature at which the product can be safely transported. A T_c is not required if the SADT exceeds 50°C.

Both the T_{em} and T_c are related to safety and do not apply to product quality. To maintain product quality the recommended storage temperatures (T_s min. and max.) have to be observed.

UN Numbers

All products accepted for transport are assigned to generic entry numbers according to classification principles as described in the recommendations by the United Nations Committee of Experts on the Transport of Dangerous Goods. An explanation of all relevant UN numbers is given in Table 1.

Survey of thermal stability

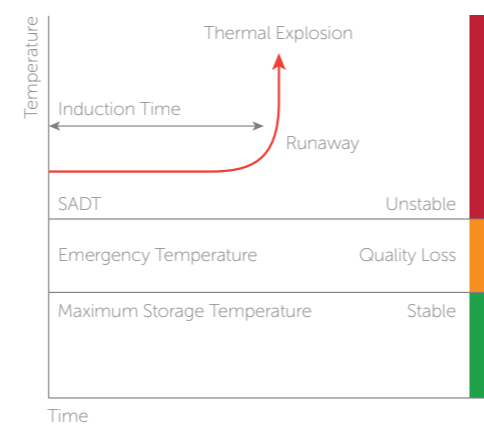


Table 1. Classification of organic peroxides

UN NO.	CLASSIFICATION	NOURYON HAZARD RATING	MAXIMUM CONTAINER SIZE
3103	type C; liquid	High	50 kg (110 lb)
3104	type C; solid		
3113	type C; liquid, temperature controlled		
3114	type C; solid, temperature controlled	Medium	50 kg (110 lb)
3105	type D; liquid		
3106	type D; solid		
3115	type D; liquid, temperature controlled	Low	400 kg (880 lb)
3116	type D; solid, temperature controlled		
3107	type E; liquid		
3117	type E; liquid, temperature controlled	Low	400 kg (880 lb)
3108	type E; solid		
3109	type F; liquid		
3110	type F; solid	Very low	IBC's / Tanks
3119	type F; liquid, temperature controlled		
3120	type F; solid, temperature controlled		
None	Non-dangerous good	No	Unrestricted
SELF-REACTIVE SUBSTANCES			
3234	type C; solid, temperature controlled	High	50 kg (110 lb)
3226	type D; solid	Medium	50 kg (110 lb)
3236	type D; solid, temperature controlled		



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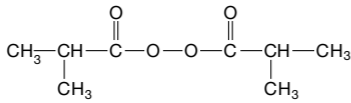
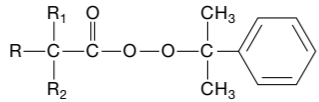
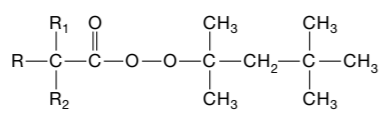
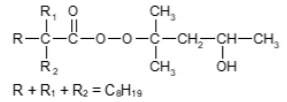
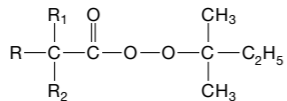
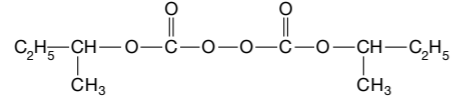
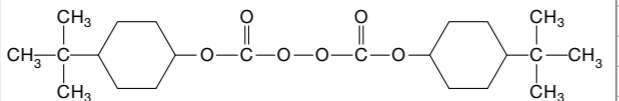
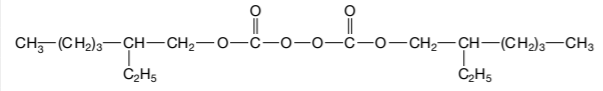
Our PVC Products

Different solutions in diluted peroxide formulations (see tables on page 8-11)

In diluted peroxide formulations the letter 'C' refers to Isododecane which is used exclusively in Europe, Middle East, India and Africa.

In the America's 'odorless mineral spirits' is used and products are indicated with "CH" to distinguish the different solvent.

In Asia our odorless mineral spirits' based products are indicated by "CL".

PRODUCT NAME	CHEMICAL NAME [CAS NUMBER]	GENERAL DATA			Physical form	STORAGE DATA		KINETIC DATA T (°C) FOR T1/2					SAFETY DATA				STANDARD PACKAGE TYPE		
		Molecular weight	Assay (%)	Active oxygen (%)		T ₁ max. (°C)	T ₁ min. (°C)	0.1 h	1.0 h	10 h	A (1/s)	E _a (kJ/mole)	SADT (°C)	T _{em} (°C)	T _c (°C)	UN No.			
TRIGONOX 187-C30	Diisobutyl peroxide [3437-84-1] 	174.2		9.18				57	39	23	3.37E+14	109.06							
TRIGONOX 187-W40		30		2.76	in hydrocarbon solvent	-20								0	-10	-20	3115	HDPE can	
		40		3.68	emulsion in water and methanol	-25	-30							0	-10	-20	3119	HDPE can	
														-5	-15	-25	3119	IBC	
TRIGONOX 99-C75*	Cumyl peroxyneodecanoate [26748-47-0] 	306.4		5.22				75	56	38	3.12E+14	114.59							
TRIGONOX 99-W(E)50		75		3.92	in hydrocarbon solvent	-20								10	0	-10	3115	HDPE can	
		50		2.61	emulsion in water and (m)ethanol	-20	-25							5	-5	-15	3119	IBC	
TRIGONOX 423-C70	1,1,3,3-Tetramethylbutyl peroxyneodecanoate [51240-95-0] 	300.5		5.32				76	57	40	3.98E+14	115.79							
TRIGONOX 423-W50		70		3.73	in hydrocarbon solvent	-15								15	5	-5	3115	HDPE can	
		50		2.66	emulsion in water and methanol	-15	-20							15	5	-5	3119	HDPE can / IBC	
TRIGONOX 193-C75*	Cumyl peroxyneheptanoate [130097-36-8] 	264.4		6.05				79	59	42	1.77E+14	114.27							
TRIGONOX 193-W50		75		4.54	in hydrocarbon solvent	-20								10	0	-10	3115	Bottle	
		50		3.03	emulsion in water and methanol	-20	-25							15	5	-5	3115	HDPE can / IBC	
TRIGONOX 123-C75*	tert-Amyl peroxyneodecanoate [68299-16-1] 	258.4		6.19				81	61	43	1.47E+14	114.38							
		75		4.64	in hydrocarbon solvent	-15	-25							20	10	0	3115	HDPE can	
TRIGONOX SBP	Di-sec-butyl peroxydicarbonate [19910-65-7] 	234.2		6.83				82	63	47	3.19E+15	123.85							
TRIGONOX SBP-C60*		98		6.69	liquid	-20								0	-10	-20	3113	HDPE can / 4x8 lb jug/carton	
TRIGONOX SBPS		60		4.10	in hydrocarbon solvent	-20								0	-10	-20	3113	HDPE can / 4x8 lb jug/carton	
TRIGONOX SBPS-C60*		98		6.69	liquid	-20								0	-10	-20	3113	HDPE can / 4x8 lb jug/carton	
		60		4.10	in hydrocarbon solvent	-20								0	-10	-20	3113	HDPE can / 4x8 lb jug/carton	
PERKADOX 16	Di(4-tert-butylcyclohexyl) peroxydicarbonate [15520-11-3] 	398.5		4.01				82	64	48	7.44E+15	126.39							
		95.5		3.83	powder	20								40	35	30	3114	carton	
TRIGONOX EHP-C75*	Di(2-ethylhexyl) peroxydicarbonate [16111-62-9] 	346.5		4.62				83	64	47	1.83E+15	122.45							
TRIGONOX EHP-W(E)60		75		3.46	in hydrocarbon solvent	-15	-25							5	-5	-15	3115	HDPE can	
		60		2.77	emulsion in water and (m)ethanol	-15	-25							5	-5	-15	3119	HDPE can	
TRIGONOX EHPS		98		4.53	liquid	-20	-25							0	-10	-20	3119	IBC	
TRIGONOX EHPS-C75*		75		3.46	in hydrocarbon solvent	-20	-25							0	-10	-20	3113	HDPE can	
					-15	-25							5	-5	-15	3115	HDPE can		

Secondary suspending agents

We offer a wide range of polyvinyl alcohol (PVA) secondary suspending agents, which are used to control PVC porosity and to improve drying and stripping. This includes solvent based products and aqueous emulsions.

The Active® 45/Ethapol® 55 product range contains solvents. The DCloud® and Ethapol® water-based suspending agents can be charged to a hot PVC reactor. In combination with organic peroxide emulsions they provide excellent PVC characteristics and reduced 'fish eye' levels. In addition, water-based suspending agents are environmentally friendly due to the absence of an organic solvent. Ethapol® MPG product is a secondary PVA, which also has excellent anti-foaming properties. Antifoaming agents are essential for optimal performance of a PVC reactor preventing foaming in both the reactor and PVC stripping sections.

Our suspending agents can be supplied in drums and intermediate bulk containers (IBC's). Please contact one of our experts for more information about our packages.

PRODUCT NAME CHEMICAL NAME (CAS NR.)	PHYSICAL FORM	MAIN APPLICATIONS				
		SOLID CONTENT (%)	DoH*	S-PVC	CO-POLYMERS (VCM/VAM)	E-PVC
SOLVENT-BASED						
Polyvinyl acetate partially hydrolyzed [25213-24-5]						
ACTIVE 45	solution in ethanol and ethyl acetate	40	45	•	•	•
ETHAPOL 55	solution in water and ethanol	40	58.5	•	•	•
WATER-BASED						
Polyvinyl acetate partially hydrolyzed [25213-24-5]						
DCLLOUD 35	emulsion in water	40	36	•	•	•
DCLLOUD 45	emulsion in water	35	46	•	•	•
ETHAPOL MPG	emulsion in water	28	70.5	•	•	•

* DoH = Degree of hydrolysis



Antifouling agents

Nouryon is the world's number one supplier of brands like Noxol® and Everplus® antifouling agents. The products are applied with high pressure steam for coating of the reactor wall or internal parts such as stirrer, baffles, reflux condenser or cooling coils. This coating prevents unwanted PVC formation and deposits.

The Noxol brand is recognized as the worldwide market leader in antifouling. It provides better adhesion to the reactor wall, while its functional groups protect against negative interaction with oxygen. Noxol® is known for its light color and transparency, which are the clearest visual distinctions from all other antifouling agents available in the market.

PRODUCT NAME CHEMICAL NAME (CAS NR.)	PHYSICAL FORM	MAIN APPLICATIONS				
		SOLID CONTENT (%)	S-PVC	CO-POLYMERS (VCM/VAM)	E-PVC	MASS PVC
NOXOL ETH	solution in water and ethanol	20	•	•	•	
NOXOL ETH/S3	solution in water and ethanol	10	•		•	
NOXOL WSW	solution in water	5.5	•	•	•	
NOXOL WSW/D7	solution in water	7	•	•	•	
NOXOL WSW/D9	solution in water	9	•	•	•	
EVERPLUS	solution in water	5.5	•	•	•	•

The antifouling agents can be supplied in bottles, drums and intermediate bulk containers (IBC's). The products are kept under nitrogen atmosphere protecting against oxidation.



Continuous Initiator Dosing (CiD)

Continuous Initiator Dosing is a revolutionary concept which increases PVC production capacity by 20-40% while making the PVC process intrinsically safer. In addition to improving PVC quality and consistency, CiD helps to reduce costs. CiD has already been implemented successfully at several production locations around the world.

In traditional PVC production the reactor is loaded with the raw material VCM monomer and water in the first step of the process. Then the total amount of organic peroxides needed for the polymerization is added. The temperature is increased, and the peroxides initiate the polymerization reaction.

During the reaction, a lot of heat is produced, and the capacity of the reactor is determined by the maximum cooling capacity.

With CiD, the heat production in the reactor is controlled by the quantity of peroxide dosed throughout the polymerization process. To achieve this, a control valve is installed and a special fast peroxide, **Trigonox® 187**, is used. As a result, the cooling capacity is optimized, and the batch time is reduced, increasing the overall capacity. The reaction can be stopped and restarted at any time by simply interrupting or restarting the peroxide dosing.



During the polymerization process a minimum peroxide level is present at any time ensuring intrinsic process safety.

We provide licenses for the use of the patented CiD technology and supports production test runs with mobile initiator dosing units.

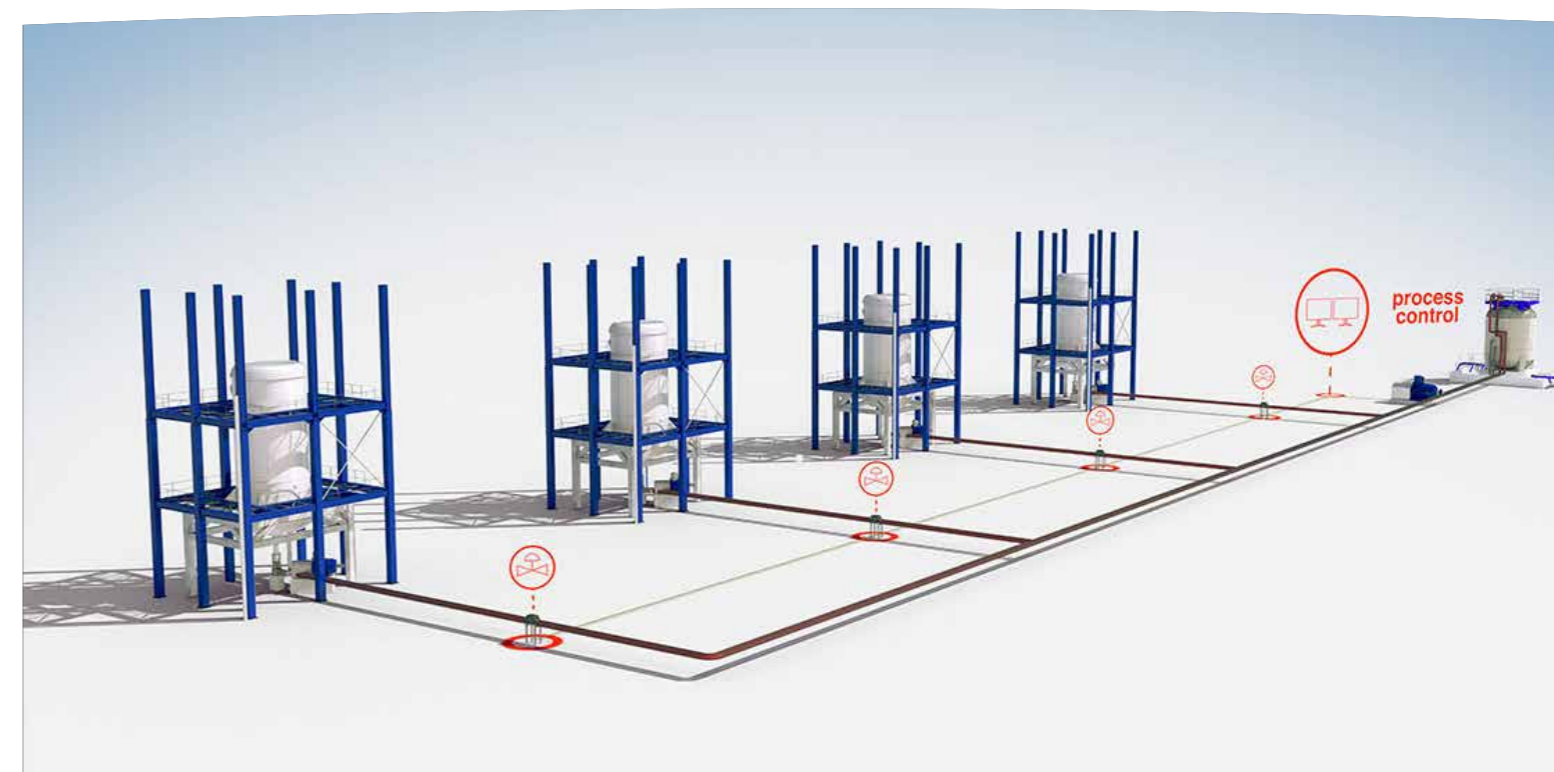
In short, with CiD you can:

- Enhance reactor output by 20-40% with limited investments
- Make your production process intrinsically safer
- Achieve positive effects on product and process consistency
- Improve PVC quality
- Reduce costs

Please contact your Nouryon representative to learn more about CiD.

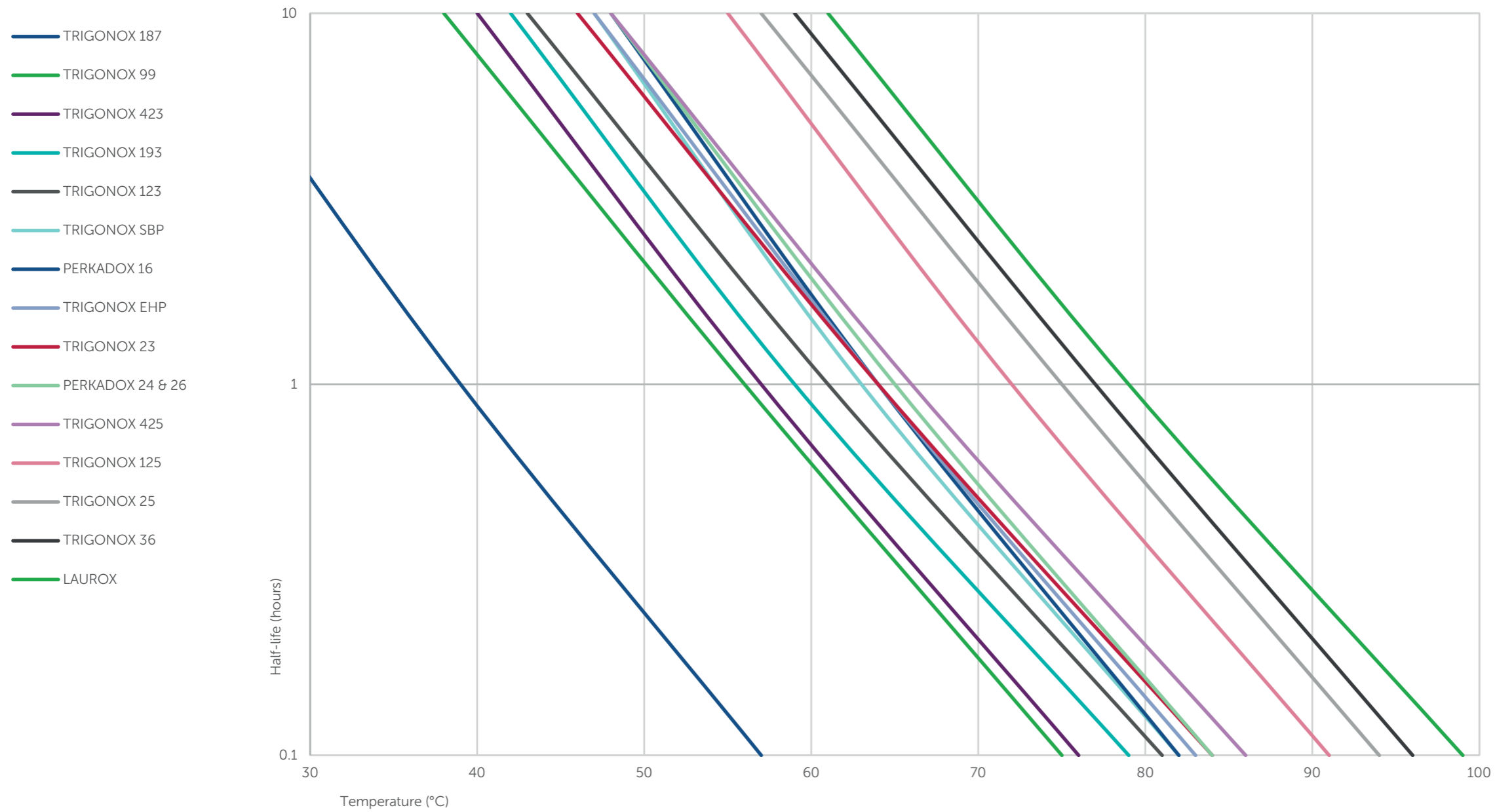


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Half-life Chart/Kinetic Data

The most important characteristic of a polymerization initiator is its rate of decomposition expressed by its half-life ($t_{1/2}$). The half-life is the time required to reduce the original amount of peroxide at a given temperature by 50%.



Kinetic Data

With the exception of hydroperoxides, the half-life is determined by differential scanning calorimetry-thermal activity monitoring (DSC-TAM) of a dilute solution of the initiator in monochlorobenzene. Kinetic data of the decomposition of hydroperoxides in monochlorobenzene are determined titrimetrically.

The tables in this catalog list the temperatures at which the half-lives are 0.1 hour, 1.0 hour and 10 hours.

The half-life can be calculated from the Arrhenius equation

$$k_d = A \cdot e^{-E_a/RT} \text{ and } t_{1/2} = \ln 2 / k_d$$

The Arrhenius frequency factor (A) and activation energy (E_a) are given in the tables on pages 8-11.

The residual concentration of the initiator can be calculated by means of the equation

$$[I] = [I_0] \cdot e^{-k_d t}$$

The initiators in the tables on pages 8-11 are arranged in descending order of activity, based on the 1.0 hour half-life temperature.

k_d = rate constant for the initiator dissociation in s^{-1}
 A = Arrhenius frequency factor in s^{-1}
 E_a = Activation energy for the initiator dissociation in J/mole
 R = 8.3142 J/mole.K
 T = temperature in K
 $t_{1/2}$ = half-life in s

$[I_0]$ = original initiator concentration
 $[I]$ = initiator concentration at time t
 t = time measured from the start of decomposition in s

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Additional information

Product Data Sheets (PDS) and Safety Data Sheets (SDS) for our polymerization initiators are available at [nouryon.com](https://www.nouryon.com)

For information on our antifouling and secondary suspending agents please contact us. On request we also provide specific publications on the use and the safe handling and storage of our products.

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