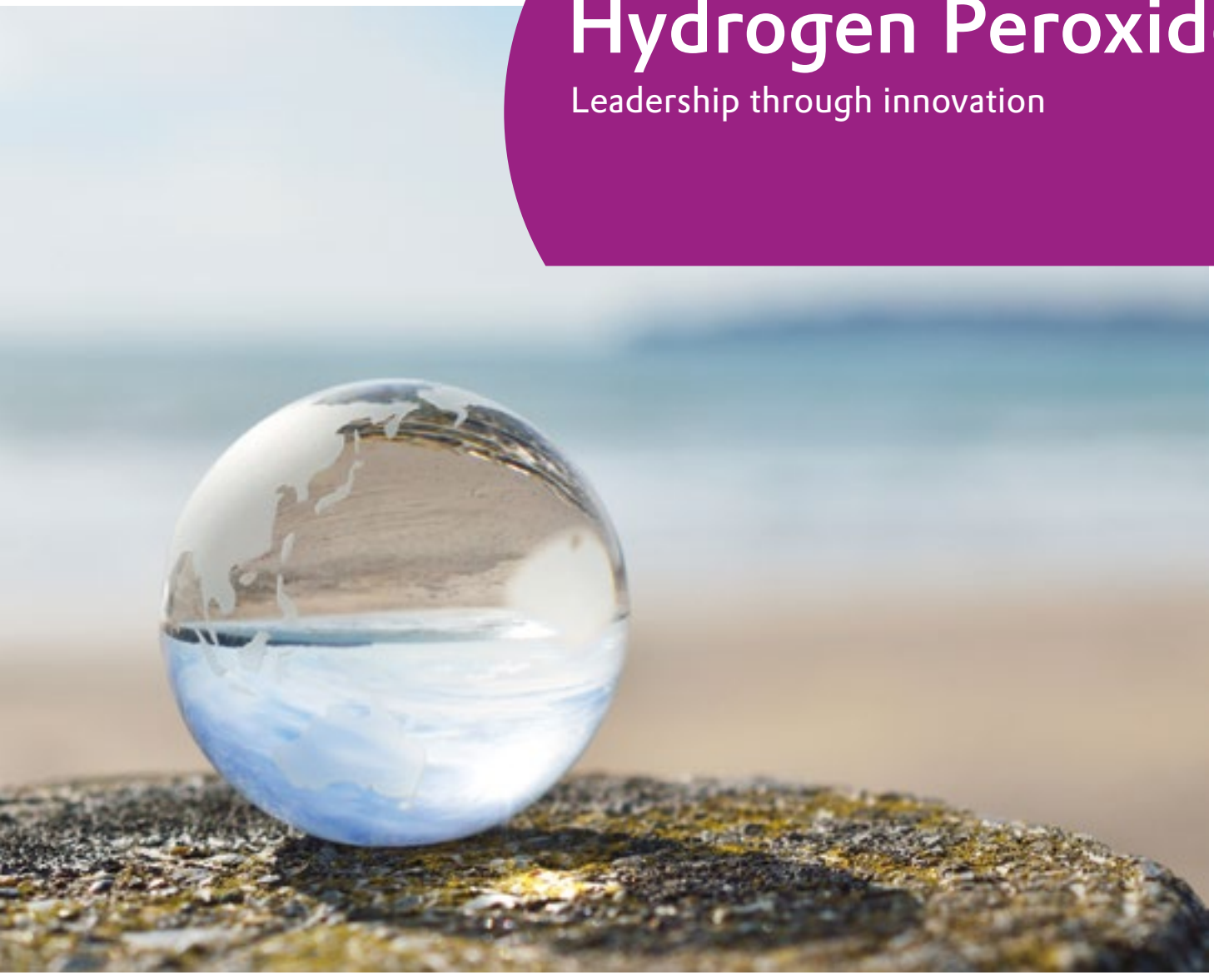
EVONIK INDUSTRIES

Hydrogen Peroxide

Leadership through innovation



Evonik. Power to create.

Content

Evonik is one of the world's largest producers of hydrogen peroxide. Our worldwide capacity (as of 2015) is more than 950 000 tonnes per year. We are the innovative leader in high quality products and services, offering more than a century of worldwide experience to serve the megatrends of the modern society and to deliver an exceptional value for our customers. To ensure optimal supply of hydrogen peroxide to the world market, we operate production facilities at thirteen locations around the world.

Evonik. Power to create.

Pulp and paper

Versatile bleaching agent

In the pulp & paper industry hydrogen peroxide is applied as a versatile bleaching agent in chemical pulp bleaching sequences, in mechanical pulp bleaching (as the only or as the dominant bleaching chemical) as well as in paper recycling with printing ink removal (de-inking). The bleaching conditions can be adjusted within a wide range to suit equipment limitations or a given temperature level.

Chemical pulp

In the bleaching of kraft pulp, the internationally most important pulp type, hydrogen peroxide is one of the chemicals applied in multi-stage processes. Alkaline conditions are required to generate the active bleaching species from hydrogen peroxide, the perhydroxyl anion. Consequently, extraction stages can be used for peroxide addition to boost the effects on extraction and brightness. The application of hydrogen peroxide allows top brightness levels with improved brightness stability, optimized economy through savings in the total chemicals required, low residue of halogenated compounds both in pulp (OX) and in effluent (AOX) and low effluent color. Hydrogen peroxide is applied as the exclusive bleaching agent in sulfite pulp brightening. In single or two-stage processes it allows bleaching to full brightness.

Mechanical pulp

Mechanical pulp, generated by the conventional ground-wood process or modern refining technology (TMP or CTMP, and APMP processes), is bleached with hydrogen peroxide to very high brightness levels. Yield and fiber properties are kept on a very high level. The conventional approach is the application of hydrogen peroxide together with caustic soda as alkali source, sodium silicate for stabilization and buffering and a chelant for the sequestering of heavy metal traces in the wood pulp. Hydrogen peroxide gives high brightness and high brightness stability against aging and yellowing, moderate effluent load and good biodegradability.
For pulp & paper applications Evonik recommends the use of our standard hydrogen peroxide grade – HYPROX®.

De-inked pulp

In paper recycling the removal of printing ink is the most important objective when the fibres are reused in the manufacture of printing papers or tissue grades. Brightness and color removal are secondary targets. Fibre brightening is achieved mainly with H_2O_2. The alkaline conditions of the repulping of wastepaper are ideally suited for a simultaneous application of hydrogen peroxide. Small amounts of hydrogen peroxide are sufficient to improve brightness and prevent alkaline yellowing. In post-bleaching steps, e.g. in a disperser, the brightness is further improved.

Textile bleaching

Mild bleaching agent

Hydrogen peroxide is the bleaching agent for the treatment of natural and synthetic fibers (cotton, wool, silk, linen, rayon). The use of hydrogen peroxide allows not only a high degree of brightness, but also preserves the mechanical properties of the fibers. Similar to pulp bleaching, this process takes place in an alkaline environment. The bleaching liquors have to be stabilized to prevent decomposition reactions due to the presence of trace metals such as copper, iron and manganese, which can often be found in fibers or in water.

Cotton is the main fiber bleached today. Practically all cotton produces nowadays is bleached. About 80 - 90% of all cotton fabrics are bleached with hydrogen peroxide. Typically, bleaching with 0.3 - 0.6 wt% solutions of hydrogen peroxide at a pH of 10.5 - 11.5 is carried out for 1 - 3 hours at a temperature of 90 - 95°C. In the past, sodium hypochlorite was commonly used for cotton bleaching. Hypochlorite bleach was, however, abandoned because of high fiber damage and technical difficulties.

Color-safe laundry bleaches containing hydrogen peroxide have been accepted by consumers as alternatives to bleaches containing hypochlorite. One of its advantages over chlorine-based bleaches is that it does not affect modern dyes. Evonik's hydrogen peroxide grades were proven to yield an excellent bleaching performance in hard surface cleaners, laundry prespot products, carpet cleaners and other color-safe bleaching products. For textile and color-safe bleaching Evonik recommends using HYPROX® hydrogen peroxide products.

Chemical synthesis

Oxidation agent

Hydrogen peroxide is an economical but powerful and environmentally benign oxidizing agent that has found many uses in the chemical industry for the manufacture of organic compounds. Due to its low molecular weight, hydrogen peroxide is a more efficient oxidizing agent on a weight per weight basis than potassium dichromate or permanganate. It is a stable and safe chemical when handled correctly and offers the advantage of being soluble in water, in many organic solvents, or in the substrate itself. Last but not least, hydrogen peroxide has an environmentally benign profile since it decomposes to just water and oxygen.

The various applications where hydrogen peroxide is used as the oxidizing agent of choice include the following examples in chemical synthesis:

- Propylene oxide (alkene epoxidation – HPPO process)
- Organic peroxide initiators (e.g. benzoyl peroxide, lauryl peroxide)
- Epoxidized soy bean oil plasticizers (fatty acid epoxidation)
- Flame retardants (bromination)
- Initiator for catalytic polymerization reactions (free radical source)
- Catechol production (hydroxylation)
- Preparation of pharmaceutical precursors (oxidation)
- Amine oxide surfactants (N-oxidation)
- Herbicide production (S-, N-oxidation)
- Percarboxylic acid production (e.g. peracetic acid)

Depending on the initial quality requirements for chemical synthesis applications Evonik offers both standard as well as high-purity hydrogen peroxide grades, HYPROX® and PERSYNT®.

Environmental applications

Oxidation agent and free radical source

The unique chemical properties of hydrogen peroxide as well as its ecological friendliness predestinate this chemical for an extensive use in a variety of environmental applications. There are numerous examples where hydrogen peroxide helps prevent or reduce negative impacts on the environment.

The advanced oxidation process (AOP) is one of the most commonly applied approaches for waste water treatment. The process uses the oxidation power of hydroxyl radicals, the strongest oxidizing agent known, to decompose toxic substances or to increase their biodegradability. Hydrogen peroxide, being the AOP main component, is the source of the oxidizing species. The AOP process is used successfully to treat various refinery effluents and waste water from chemical or pharmaceutical facilities as well as municipal aqueous wastes.

Hydrogen peroxide is widely used in various technological processes to reduce their environmental impact. Thus, nitrogen dioxide and nitrous oxide emissions from the steel industry, which uses nitric acid in a pickling process, can be strongly reduced. Mercaptans, H_2S and SO_2 removal from effluents or off-gases is achieved by utilization of a wet scrubber with hydrogen peroxide. It is also used to reduce toxicity and odors at paper mills, rendering plants, metal smelters, pharmaceutical, pesticide, chemical manufacturing or petrochemical facilities. Hydrogen peroxide is used as well for dechlorination purposes to prevent corrosion and formation of chlorinated compounds by chlorine producers, chlorine users and chlorinated polymer manufacturers.

Preparation of drinking water is one of the most important environmental applications of hydrogen peroxide. For elimination of harmful microorganisms treatment with ozone is usually used. Hydrogen peroxide is applied in the following step to destroy the ozone residues, so that drinking water can meet the legal high-quality requirements.

Evonik supplies standard as well as high-purity hydrogen peroxide – HYPROX® or CLARMARIN® depending on the quality requirements of the particular application. Hydrogen peroxide of CLARMARIN® grade fulfills the quality requirements of the drinking water directive (DIN EN 902).

Mining

Oxidation agent and oxygen source

Hydrogen peroxide is often used as an oxidant in such metallurgical process steps as ore leaching, concentrate preparation or eluent treatment. Production of gold and uranium exemplifies some important hydrogen peroxide applications in the mining industry. Depending on the ore composition as well as the leaching conditions, utilization of hydrogen peroxide results in savings of eluents and acids, simplifies management of chemicals or waste and improves the overall process control.
In nature uranium occurs in the form of tetravalent or hexavalent oxide minerals (uraninite or pitchblende). Tetravalent uranium has, however, a very low solubility in both acidic or alkaline media. Thus, to achieve an economic uranium recovery, oxidation to the much more soluble hexavalent state is of great importance. Trivalent iron compounds are commonly used to increase uranium's oxidation state. Hydrogen peroxide is applied for regeneration of the active Fe(III) ions in the eluent.
For gold production the most common method used nowadays is the cyanidation process, which involves the leaching of gold containing ores by diluting aqueous cyanide solutions in the presence of lime and oxygen. Depending on the leaching conditions, overall concentration of suspended ore as well as concentration of the oxygen consumers in the ore, hydrogen peroxide can be added to increase the total oxygen concentration in the system and to promote deeper leaching by direct oxidation. On the downstream side hydrogen peroxide is often used for removal of the cyanides from waste water. The cyanide oxidation takes place in a single step, without the formation of toxic intermediates.
For mining applications Evonik recommends the use of HYPROX® – standard grade hydrogen peroxide.

Recycling

Oxidant and bleaching agent

Recycling is the process by which materials are separated from waste destined for disposal and remanufactured into usable or marketable materials. Recycling is often referred to as urban mining, underlining waste as an important raw material. City waste holds, for example, enough precious metals, rare earth elements and other key materials to cover our industrial needs if they were to be completely recovered. Such nonferrous materials as gold, platinum, copper, rare earth and other precious metals are successfully extracted from electronic waste, such as computers or cell phones. More than a third of solid municipal waste is made of paper. Recycling this paper in comparison to paper manufacturing reduces air and water pollution. Worldwide use of recycled paper has doubled over the past 20 years and is expected to grow further. Hydrogen peroxide is applied as an environment-friendly oxidant in many recycling processes. Such processes as de-inking in paper recycling as well as recovery of valuable non-ferrous metals from electronic waste are the most striking examples.

Hydrometallurgical processing of electronic waste from scrapped electronic boards and components resembles the leaching process in the mining industry. A mixture of sulfuric acid and hydrogen peroxide, which is also known as Caro's acid, is used successfully to solubilize metallic copper and other metals to the corresponding salts. Oxidative hydrometallurgical treatment is the most economically method to treat old solar panels for recovering such elements as indium, gallium, selenium, tellurium, cadmium or molybdenum. These can be used for production of new solar panels or for other applications.

For recycling applications, depending on purity requirements, Evonik recommends the use of standard grade or high-purity grades: HYPROX®, PERSYNT® or PERTRONIC®.

Aseptic packaging

Biocide

A lot of foods (beverages, milk, dairy products, sauces and soups) are packaged aseptically in cartons, tubes, bottles and foils. These storage-stable products maintain the required shelf-life and high product quality. To create a sterile environment in the aseptic packaging units various treatment approaches for sterilization of materials and internal machine surfaces are used. In general heat, chemicals, high-energy radiation or a combination are applied. For aseptic packaging equipment sterilizing agents should effectively provide the same degree of protection in terms of microbiological safety which traditional sterilization systems provide. This requirement applies to both the food contact surface of the packaging material as well as the internal machine surfaces constituting the aseptic or sterile zone within the machine. To combine a sterile product with a sterile package various aseptic packaging units have been designed. The most common technological processes using hydrogen peroxide are immersion-bath and spraying. To meet the requirements of the packaging machine manufacturers, Evonik has developed and supplies specialty hydrogen peroxide grades. OXTERIL® 350 Bath and OXTERIL® 350 Spray are tailor-made for the individual immersion-bath or spray process with regards to product stability, residues and packaging line effectiveness. OXTERIL® 350 Combi was designed to be suitable for both aseptic packaging methods. Evonik's OXTERIL® products are approved and recommended by many leading machinery manufacturers and enjoy a wide acceptance by well-known food manufacturers.

Food processing

Bleaching agent and biocide

Hydrogen peroxide is today an important industrial chemical but it is also quite common in nature. In some living organisms hydrogen peroxide is created by certain enzymes as a co-product of biochemical reactions. Nature provides not only the enzymes producing hydrogen peroxide, but also those which break it down into the biologically neutral substances water and oxygen. Decomposition by catalase, an enzyme occurring in all plants, animals and microorganisms opens an easy and natural way for hydrogen peroxide elimination after processing steps. Enzyme catalyzed decomposition is the principal method for removal of hydrogen peroxide residues in food processing (except aseptic packaging) and preparation of food additives.

Due to its remarkable chemical properties and biological degradability hydrogen peroxide is often utilized in food processing applications. It is by far the most widely used peroxygen reagent for bleaching purposes in the food industry. Various types of compounds are bleached with peroxygen – natural oils, waxes, gums, natural sugars and starches. Hydrogen peroxide is used for color adjustment not only for final products, but starting materials also. Foods such as herring, instant tea, starch, cheese whey, tripe or natural fatty acid emulsifiers are treated with hydrogen peroxide to increase whiteness.

Hydrogen peroxide's antimicrobial and fungicidal activity is used for the preservation of aqueous solutions of natural proteins or carbohydrates (collagen of starch) or milk for cheese production. Before cheese making or the further processing of collagen solutions, hydrogen peroxide is removed by catalase. Preparation of various food additives is another application field of hydrogen peroxide. One of the technologically relevant methods of modified starch preparation is its treatment with oxidants, like hydrogen peroxide.

For food processing applications Evonik supplies the high-purity hydrogen peroxide grades PERSYNT® and OXTERIL®. Both grades comply with the purity requirements of the European Pharmacopoeia. OXTERIL® grades fulfill the requirements of the American Food Chemical Codex as well.

Cosmetics and medicine

Bleaching agent and disinfectant

Hydrogen peroxide is used in cosmetics and personal care products as an antimicrobial agent and as an oxidizing agent. It is used, for example, to form dyestuffs during oxidative hair dyeing or to oxygenate stains on teeth to increase whiteness.

In hair coloring the bleaching properties of hydrogen peroxide are used to lighten the hair, which is achieved through oxidative elimination of the brown-black melanins (the principal human hair pigments). Depending on the desired final color shade different bleaching is necessary.

During permanent hair waving, moieties of the amino acid cystein are reduced with mercaptanes, resulting in destruction of the disulfide bonds. After such a treatment the reduced hair is curled and brought into the desired form. To fix the new form mild oxidation by hydrogen peroxide is used.

Hydrogen peroxide as well as carbamide peroxide (urea-H_2O_2 complex) are the primary bleaching components in tooth whitening products such as pastes or gels.

For cosmetic applications Evonik supplies PERSYNT® B7 and PERSYNT® COS, special hydrogen peroxide grades which are designed to meet the high-quality requirements of the cosmetic industry.

Hydrogen peroxide topical solutions (3 wt%) are widely used in medicine as an antiseptic for wound treatment and for soft contact lens disinfection. Hydrogen peroxide is also utilized to disinfect medical equipment, floors, walls or furnishings. Solutions with higher hydrogen peroxide concentration are applied as chemisterilants in specially designed machines for decontamination of heat sensitive medical devices.

For medical applications Evonik supplies high purity hydrogen peroxide grades PERSYNT® and PERTRONIC®.

Space and aeronautics

Propellant

High-concentration hydrogen peroxide has been used as a propellant since the middle of the twentieth century. Current uses include hypergolic bi-propellant engines for launch vehicles and mono-propellant systems e.g. to power satellites. Interest in hydrogen peroxide as an environmentally friendly, non cryogenic propellant is increasing again, especially since it has been made commercially available in a high concentrated (>85 wt%), high-purity form. In a standard liquid-fueled bipropellant rocket engine, the liquid fuel and the oxidant are stored in separate containers. Both of these need to be fed to the rocket engine under high pressure to produce the necessary thrust. This can be achieved by decomposing liquid hydrogen peroxide over a heavy-metal catalyst, resulting in overheated steam and oxygen, which drive the turbo pumps supplying kerosene and liquid oxygen to the rocket engines through impellers and provide herewith the necessary thrust.

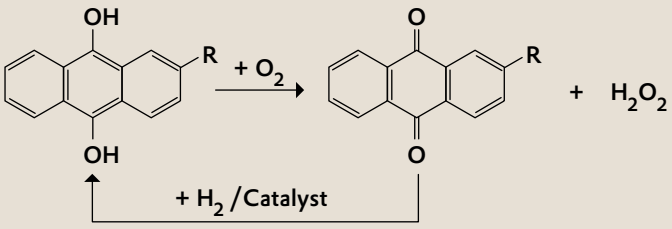
When using hydrogen peroxide in monopropellant engines, the gaseous decomposition products are injected directly into the thrust to generate the required driving force for the vehicle. Monopropellant engines using hydrogen peroxide as the fuel are commonly used for air-independent underwater propulsion applications. PROPULSE® is a high-concentration hydrogen peroxide available from Evonik and is specially designed for propulsion applications.

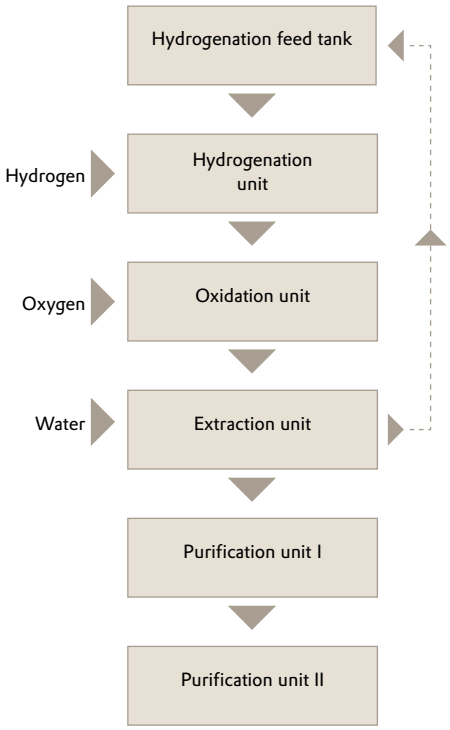
Manufacturing

Evonik uses the anthraquinone autoxidation (AO) process for the production of hydrogen peroxide. Basically the AO-process can be divided into 4 steps:

1. Hydrogenation
2. Oxidation
3. Extraction
4. Purification

The production scheme of the process as well as the brutto chemical reaction are described below.





From the hydrogenation feed tank, the working solution containing quinones enters the hydrogenator, where it is hydrogenated in the presence of catalysts to yield hydroquinones. Before the hydrogenated working solution can be fed to the oxidation step, it passes through a filtration unit for complete removal of the catalyst.

During the oxidation step, the hydrogenated working solution is treated with air. Dissolved hydroquinones are oxidized to quinones and hydrogen peroxide is formed. After the separation of the working solution, the off-gas from the oxidation step passes over activated carbon adsorbers to recover the solvent from the gas stream. Several adsorbers are usually used and regenerated with steam.

The oxidized working solution is treated with water in the extraction column to obtain an aqueous hydrogen peroxide phase. The organic and aqueous phases are separated to obtain a crude hydrogen peroxide solution. The working solution, that leaves the extraction unit, is adjusted to a specific water content before being returned to the hydrogenation feed tank.

Crude aqueous hydrogen peroxide from the extraction stage (H_2O_2 concentration about 40 wt%) is fed into the crude product storage tank via a prepurification unit. From the crude product storage tank, aqueous hydrogen peroxide goes to the concentration unit, where water is stripped off. Here, hydrogen peroxide is freed from impurities and concentrated. The obtained concentrate is used for preparation of our standard commercial grade – HYPROX®.

Specialty grades, OXTERIL®, PERSYNT®, PERTRONIC® and PROPULSE®, are produced in a subsequent purification unit. The purified product is then adjusted to the required concentration and stabilized according to specification, followed by storage in a dedicated tank before shipment.

Product		Industry
HYPROX®	300 350 500 600 700	Pulp & paper; Textile bleaching; Chemical synthesis; Environmental (non biocide); Mining; Metal finishing
HYPROX®AS	350 500 600 700	Active substance for production of biocides
CLARMARIN®	350 500	Environmental (non biocide); Agriculture
PERSYNT®	300 LC 350 LC 500 LC 600 LC 700 LC	Chemical synthesis; Environmental (non biocide); Food processing; Recycling
PERSYNT®	300 Pharma 350 Pharma 300 Steri 350 Steri	Pharma; Medicine
PERSYNT®	350 B7 500 B7 350 COS	Cosmetics
OXTERIL®	350 Bath 350 Spray 350 Spray S 350 Combi	Aseptic packaging
PERTRONIC®	300 350 500 600	Electronics; Recycling
PROPULSE®	825 875 980	Space & aeronautics

Grades

Standard grade:

HYPROX® is a standard hydrogen peroxide grade, which is developed for general industrial use. HYPROX® grade hydrogen proxide is designed for use in the paper industry as a bleaching agent and for the de-inking in wastepaper recycling; in the textile industry as a bleaching agent, oxidizer and de-sizing agent; in environmental protection for the treatment of wastewater, in flue gas and contaminated soil (bioremediation); in the detergent and cleanser industry; in the chemical industry for epoxidation, hydroxylation and other oxidation reactions; for pickling of metal surfaces; as a bleaching agent for oils, waxes, fibres and other natural products.

Specialty Grades:

OXTERIL®, CLARMARIN®, PERSYNT®, PERTRONIC®, PROPULSE® are Evonik's specialty grades, based on hydrogen peroxide of high or highest purity and designed for applications having special quality requirements.

OXTERIL® is a high-purity food grade hydrogen peroxide, which is especially designed for use in the aseptic packaging industry. OXTERIL® grade hydrogen peroxide complies with the requirements of European Pharmacopoeia 7 (ex. concentration), EN DIN 902 and the American Food Chemical Codex 7. OXTERIL® products are approved by the main packaging machine suppliers.
CLARMARIN® is a hydrogen peroxide grade for use in various water treatment applications. CLARMARIN® grade hydrogen peroxide complies with the quality requirements of EN DIN 902 and is recommended to be used for drinking water preparation.

PERSYNT® is a high-purity hydrogen peroxide, which is optimized for food treatment, fine chemical synthesis as well as for use in the cosmetic and pharma industries. PERSYNT® grade hydrogen peroxide complies with the requirements of European Pharmacopoeia 7 (except for concentration) and EN DIN 902.
PERTRONIC® is the electronic hydrogen peroxide grade and meets the requirements of the electronic industry concerning purity and stability.
PROPULSE® is a high-concentration hydrogen peroxide grade and was specially developed for use in space rocket launches as well as mono-propellant in various underwater marine vessels.

Please contact your regional sales manager for information about a particular product, which would suit your application best and to obtain further technical as well as commercial information. Also please feel free to check for additional regionally available grades and products.

Important physico-chemical properties of aqueous solutions of hydrogen peroxide (1)

H_2O_2 concentration (2)	%(wt.)	0	30	35	50	60	70	100
	$g(H_2O_2)$ / kg		300	350	500	600	700	
	$g(H_2O_2)$ / l		332	395	596	742	899	
	mol/l		9.8	11.6	17.5	21.8	26.4	
	mol%		18.5	22.2	34.6	44.3	55.3	
Active oxygen content	%(wt.)	0	14.1	16.5	23.5	28.2	32.9	47.1
Molecular weight	g/mol	18.015						34.015
Density at 20 °C	g/ml	0.998	1.111	1.131	1.195	1.241	1.289	1.450
Density at 30 °C	g/ml		1.105	1.124	1.187	1.232	1.279	
Density at 40 °C	g/ml		1.098	1.118	1.179	1.223	1.267	
Density at 50 °C	g/ml		1.091	1.110	1.171	1.214	1.260	
Density at 60 °C	g/ml		1.084	1.103	1.163	1.205	1.251	
Density at 70 °C	g/ml		1.077	1.095	1.154	1.196	1.241	
Density at 80 °C	g/ml		1.069	1.087	1.145	1.186	1.231	
Freezing point	°C	0	-26	-33	-52	-56	-40	-0.4
Boiling point at 1013 mbar.	°C	100	106	108	114	119	125	150
Boiling point at 2026 mbar.	°C		132	135	145	152	158	
Boiling point at 3039 mbar.	°C		147	150	161	168	176	
Total vapor pressure	10^{-3}MPa		3.333	3.200	2.400	1.867	1.467	0.370
	mm. Hg.	31.6	25	24	18	14	11	2.77
H_2O_2 partial vapor pressure at 30° C	10^{-3}MPa		0.033	0.040	0.080	0.120	0.173	0.370
Pressure at 30 °C	mm. Hg.		0.25	0.3	0.6	0.9	1.3	2.77
Specific heat at 25°C	J*g/K	4.2	3.6	3.5	3.3	3.2	3.1	1.35
Refractive index, n25D at 25°C		1.3325	1.3519	1.3554	1.3661	1.3734	1.3814	1.4067
Viscosity at 20°C	MPa*s	1.00	1.11	1.12	1.18	1.21	1.23	1.25
Surface tension at 20°C	mN/m	72.8	74.2	74.5	75.7	76.4	77.3	80.4

1) The tabulated values, which are given above, describe physico-chemical properties of salt-free pure aqueous solutions of hydrogen peroxide in water.

2) Hydrogen peroxide concentration can be expressed in weight percent, gram of 100%-age hydrogen peroxide in 1 kg solution, gram of 100%-age hydrogen peroxide in 1L solution and as molar concentration or molar fraction of hydrogen peroxide in solution. The tabulated values for $g(H_2O_2)/l$ and mol/l are given for the solution temperature of 25°C.

Physico-chemical properties

Hydrogen peroxide (H_2O_2) is a colorless water-soluble liquid. The molecule of hydrogen peroxide is asymmetrical and strongly polarized. A high tendency to form hydrogen-bond networks causes higher viscosity than water. Because of free electron pairs on both oxygen atoms, the H_2O_2-molecule tends to form donor-acceptor compounds. Pure hydrogen peroxide is primarily of scientific interest only. Its aqueous solutions, however, are widely used in many industrial branches for various applications. Important physical properties of hydrogen peroxide and its aqueous solutions are summarized in the table on the left side.

The molecular structure as well as oxygen's oxidation state define the chemical properties of hydrogen peroxide. The oxygen atom, being in the oxidation state I, allows hydrogen peroxide to participate in both oxidation as well as reduction reactions. Although hydrogen peroxide is well known as a strong oxidizing agent, its reduction properties play an important role in some applications. Typical chemical reactions, in which hydrogen peroxide is involved, are oxidation and reduction reactions, formations of other peroxygen or adduct compounds. In contrast to many other red-ox agents, hydrogen peroxide introduces no additional substances other than water into the reaction system and an excess can be easily decomposed into water and oxygen, not interfering thereby with subsequent reaction steps. Hydrogen peroxide is often regarded as a true "green chemical". Despite its high reactivity, pure hydrogen peroxide is a stable substance and, if kept under optimal conditions, can be stored for years. The most important factors increasing the rate of decomposition a high pH value, high temperatures, UV-irradiation, presence of transition metal salts and all kinds of impurities. Decomposition of hydrogen peroxide

$$2\,H_2O_2 \longrightarrow O_2 + 2\,H_2O$$

is a quite complex process, which involves formation of various free radicals. In some applications (soil remediation) the induced instability is intentionally caused and used.

Packaging and storage

Depending on customer, grade, region and other requirements, the shipment of hydrogen peroxide is made in small to large containers. For consumers of large quantities, the installation of a storage tank is recommended. Common forms of packaging for hydrogen peroxide are:

- Plastic canisters: 60 liters with content of 65 kg
- Plastic drums: 200 liters/220 kg, or 55 gallons/500 lbs
- IBC (Intermediate Bulk Container) 1000 - 1200 kg
- 2.5-tonne and 5-tonne containers for rail or road transport
- Road tanker, capacity about 25 tonnes
- Railroad car, capacity 28 - 68 tonnes
- Overseas ISO container, capacity 15 - 20 tonnes

Please check with your regional representative about the availability of desired grades and packaging systems.

Hydrogen peroxide containers should be stored in roofed, fireproof rooms where they can be kept cool and protected from sunlight. It is important that the hydrogen peroxide is protected against all types of contamination. Therefore, the containers should be stored unopened and in an upright position without blocking the breather vents. With proper storage in the original containers or in tank installations, the product can be stored safely for a long period of time without noticeable losses in concentration (typically less than 1% relative per year).
Through the use of a tank installation, efficient and economical storage together with an inplant supply to points of consumption is possible. For construction of storage tanks, pure aluminum and $AlMg_3$ can be used. Polyethylene (up to 60 % by weight H_2O_2) or stainless steel are preferred today owing to reduced corrosion problems.
Aluminum and stainless steel tanks can be installed horizontally or vertically, but for static reasons polyethylene containers must be installed only vertically. For safety reasons, it is advisable to install larger storage containers in a dedicated area. Stainless steel has proven most effective for piping. Before initial filling, the storage tank and all parts in a hydrogen peroxide storage tank installation must be suitably cleaned and passivated.
Storage tanks, intermediate containers, as well as dosing and reaction vessels must be fitted with venting equipment. In addition, hydrogen peroxide must not remain trapped in pipes between valves because decomposition at such points could lead to pressure build-up. If ball valves are used, a vent hole must be drilled into the ball.
We at Evonik are happy to make available our extensive experience in the planning and construction of tank installations to our customers. Our Engineering Department carries out the planning, design, construction and initial filling, including prior cleaning. As the smallest unit 6 cubic meter tank installations are normally built which permit delivery of the product in 5 - tonne containers. In general, such an installation is economically feasible for an annual requirement of at least 20 - 30 tonnes.

Labeling and transportation

Hydrogen peroxide solutions with concentration higher than 8 % by weight are dangerous substances, e.g. according to Global Harmonized System (GHS) and the European Regulation No. 1272/2008. They must be labeled and handled correspondingly.

Please refer to our Material Safety Data Sheet for details.

Classification of aqueous H_2O_2 solutions according to the European Regulation No. 1272/2008

30 % ≤ H_2O_2 < 35 %		
Hazard statements	H302	Harmful if swallowed
	H318	Causes serious eye damage
	H332	Harmful if inhaled
Prevention statements	P264	Wash hands thoroughly with soap and water after handling
	P280	Wear protective gloves, and clothing; eye and face protection
35 % ≤ H_2O_2 < 50 %		
Hazard statements	H302	Harmful if swallowed
	H315	Causes skin irritation
	H318	Causes serious eye damage
	H332	Harmful if inhaled
	H335	May cause respiratory irritation
Prevention statements	P261	Avoid breathing dust, fume, gas, mist, vapors, spray
	P280	Wear protective gloves, and clothing; eye and face protection
50 % ≤ H_2O_2 < 70 %		
Hazard statements	H272	May intensify fire; oxidizer
	H302	Harmful if swallowed
	H314	Causes severe skin burns and eye damage
	H318	Causes serious eye damage
	H332	Harmful if inhaled
	H335	May cause respiratory irritation
	H412*	Harmful to aquatic life with long lasting effect
Prevention statements	P210*	Keep away from heat, sparks, open flames, hot surfaces No smoking
	P261	Avoid breathing dust, fume, gas, mist, vapors, spray
	P280	Wear protective gloves, and clothing; eye and face protection
70 % ≤ H_2O_2		
Hazard statements	H271	May cause fire or explosion; strong oxidizer
	H314	Causes severe skin burns and eye damage
	H318	Causes seriouse eye damage
	H302	Harmful if swallowed
	H332	Harmful if inhaled
	H335	May cause respiratory irritation
	H412	Harmful to aquatic life with long lasting effects
Prevention statements	P210	Keep away from heat, sparks, open flames, hot surfaces No smoking
	P261	Avoid breathing dust, fume, gas, mist, vapors, spray

* Only for H_2O_2 ≥ 63%

Regulations for surface transport

Hydrogen peroxide up to a concentration of 8% by weight is not subject to any transport regulations. For higher concentrations, the following classifications apply:

Concentration of H_2O_2	8% < H_2O_2 < 20%	20% ≤ H_2O_2 ≤ 60%	H_2O_2 > 60%
Orange panel	50	58	559
UN-No.	2984	2014	2015
IMDG-Code, RID/ADR	5.1; 2984; PG.III	5.1, 2014; PG.II	5.1; 2015; PG.I
Labels	5.1	5.1 + 8	5.1 + 8

National regulations may differ from one country to another, and are being revised continually. Customers who want to transport hydrogen peroxide within particular national boundaries should refer to the applicable national regulations.

Safety aspects

Safety has always been one of Evonik's main concerns. As we have clearly committed ourselves to the Responsible Care Program of the chemical industry, we strive for the highest possible level of safety within our own plants and laboratories as well as those of our customers. In this chapter we have summarized the safety risks related to hydrogen peroxide, its handling and storage. Today, many risks are rather unlikely because a globally accepted technical standard exists. However, everybody should be aware of the risks and understand the necessity of certain precautions while working with hydrogen peroxide.

Hydrogen peroxide is a clear colorless liquid, which resembles water. Therefore, spilled product or hydrogen peroxide in unlabeled containers could erroneously be regarded as water. Hydrogen peroxide is corrosive to the skin and eyes as well as to metal surfaces. It is a strong oxidizing chemical and, therefore, tends to react rapidly, sometimes even violently with various substances.

Hydrogen peroxide solutions themselves are not flammable. Highly concentrated hydrogen peroxide, however, can ignite inflammable materials, and the oxygen released by decomposition additionally promotes the combustion. Even at low concentrations, ignition can occur under unfavorable conditions after a gradual concentration of the hydrogen peroxide due to evaporation of water.

Vapors can explode if the hydrogen peroxide concentration in the vapor phase is higher than 26 mol% (40 % w/w). Explosions are ignited by sparks, contact with a catalytically active material, or – at temperatures above 150 °C – even by catalytically non-active materials.

At normal pressure, such vapour compositions can only occur if the hydrogen peroxide concentration of the liquid is 74 wt %w/w or higher and the temperature of the liquid is higher than 100 °C.

Explosive and shock-sensitive mixtures can be formed if concentrated hydrogen peroxide comes into contact with organic compounds. According to data in the literature, there is a general risk of detonations if the content of hydrogen peroxide in the resulting mixture is 25 % by weight or above. In any case, appropriate safety precautions must be taken to avoid critical conditions.

Handling

As a consequence of the properties of hydrogen peroxide and the safety aspects outlined in the previous chapters some basic rules for the handling of hydrogen peroxide are summarized as follow:

Rule	Comment
Everybody working with H_2O_2 should be trained to do so.	It is our policy to avoid safety risks and incidents wherever possible. Therefore, all personnel should be familiar with all necessary precautions and properties of this chemical.
Use dedicated equipment only.	It is the easiest way to avoid unintended contamination and compatibility problems.
Only carefully pre-cleaned drums, tubes, pumps and other equipment should be used.	Even with dedicated equipment it is essential to make sure, that all surfaces which come into contact with H_2O_2 are cleaned carefully.
Avoid any contamination!	Any contamination with impurities like metal salts, dust, rust, wood, equipment or others is likely to accelerate the decomposition process.
Avoid higher pH-values!	Like contamination, a pH-value of 5 or above will increase the decomposition reaction. Any alkali products or caustic solutions have to be avoided.
Protect hydrogen peroxide from heat, direct sunlight and UV radiation.	Heat, light and radiation can also slightly increase the decomposition process.
Never return H_2O_2 to its original container.	H_2O_2 taken out of its original storage container or tank should never be returned. The risk of unintended contamination of the whole storage volume is just too high.
Make sure that Personal Protective Equipment (PPE) is used and emergency showers are available nearby!	Every person involved in handling of H_2O_2 has to wear its PPE (goggles, gloves etc). It is necessary to have immediate access to emergency showers and eye wash stations in case an incident occurs.
Have water hoses available in case of an emergency.	Besides water for personal safety it is always the method of choice to have plenty of water available for dilution or cooling in case of an emergency.
Never confine hydrogen peroxide in drums, tanks, tubes etc.!	H_2O_2 always tends to develop overpressure. Therefore, it is mandatory to have pressure relief equipment installed in every part of your system.
Keep storage temperature under surveillance.	Increasing temperature is an excellent indicator for problems in a tank.
Make sure that only compatible working materials are used.	The most common compatible materials are glassware, polyethylene, polyvinylchloride, Teflon, stainless steel, pure aluminum.
Avoid any contact with inflammable material and organic substances.	H_2O_2 is a reactive agent and a strong oxidizer. It is very likely that it reacts with combustible, inflammable or oxidizable materials, possibly resulting in a violent reaction.

In case of any doubt or question feel free to contact your Evonik representative for further help.

First aid

Instructions

Contact with skin	Wash affected skin with plenty of water. Remove all contaminated clothing immediately. In case of burns or shock, seek medical attention.
Contact with eyes	Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
Ingestion	Drink plenty of water. Seek medical attention.
Inhalation	Move the victim out into the fresh air – wear a respirator. In case of suffocation, seek medical attention.
Leak or spill	Drench with water. Wash the liquid off all contaminated surfaces with plenty of water. Do not absorb in sawdust or other combustible materials. Do not attempt to recover spilled liquid. Drench with water only.
Fire	Cool the tank from outside with water to avoid higher temperatures for the stored material. Fires where hydrogen peroxide is involved directly or indirectly should be extinguished with water.

Response statements according to European Regulation No. 1272/2008

30 % ≤ H_2O_2 < 35 %	
P301+P312	IF SWALLOWED: Call a POISON CENTER or doctor if you feel unwell.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P310	Immediately call a POISON CENTER or doctor.
35 % ≤ H_2O_2 < 50 %	
P301+P312	IF SWALLOWED: Call a POISON CENTER or doctor if you feel unwell.
P302+P352	IF ON SKIN: Wash with plenty of soap and water.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
50 % ≤ H_2O_2 < 70 %	
P370+P378	In case of FIRE: Use water for extinction.
P301+P330+P331	IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
H_2O_2 ≥ 70 %	
P371+P380+P375	In case of major FIRE and large quantities: Evacuate area. Fight fire remotely due to the risk of explosion.
P301+P330+P331	IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353	IF ON SKIN (or hair): Remove/Take off immediately all contaminated clothing. Rinse skin with water/shower.
P304+P340	IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing.
P305+P351+P338	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

Disclaimer

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Reference to trade names used by other companies is neither a recommendation, nor does it imply that similar products could not be used.

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