Phosphates: the power suppliers for skin and hair

published in Kosmetik International 2017 (10), 56-58

Life without phosphorus, that is unthinkable! Plants solubilize phosphate-containing rocks and soils with the help of their acids and then resorb the phosphoric acid contained therein. Humans ingest the element via food chain.

From a chemical viewpoint, phosphorus (P) is related to nitrogen (N). In contrast to the gaseous and inert nitrogen, the solid phosphorus is very reactive and only occurs naturally in the form of its oxygen compounds (phosphoric acid salts).
Phosphoric acid is an inorganic acid and used as acidifying agent (E 338) in food such as cola beverages. In combination with metals, the acid forms three different types of salts: phosphates, hydrogen phosphates and dihydrogen phosphates. Mixtures of these salts often are used as buffers in aqueous media. Buffers are brine solutions with a pH level that remains stable after addition of acids or bases (pH level: measuring unit for acidic or alkaline character). Buffers are important components in cosmetic products particularly in cases where acids or bases form during storage – for instance through saponification or urea hydrolysis. Such acids or bases - in the case of urea, ammonia forms – are balanced by buffers, in other words, they stabilize the preparations.

No radical chain reactions

Another important feature of phosphoric acid is the indirect anti-oxidant effect. It is called indirect effect because it is not caused by direct reaction with atmospheric oxygen or free radicals as in the case of vitamin C or vitamin E. On the contrary, phosphoric acid forms insoluble salts or inactive complexes with heavy metals such as iron. Traces of iron ions are ubiquitous and also find their way into the cream jar, at the latest, when the cream has been taken out with the fingers. They are the main triggers for the formation of highly reactive hydroxyl radicals that are responsible for the rancidification of unsaturated fatty acids. The underlying radical chain reaction is initiated by reaction of iron with oxygen in the presence of high-energy radiation as e.g. sun light. The same type of radicals form in the skin after iron ions get in contact with hydrogen peroxide (Fenton reaction). This is why physiological phosphoric acid salts also are beneficial for skin care purposes. In the INCI they are listed with the terms disodium phosphate (sodium salt) and potassium phosphate (potassium salt).
Phosphoric acid and phosphates occur in human body cells in dissolved form. An insoluble salt is the calcium-rich hydroxylapatite which forms our bone substance and also is contained in our dental enamel. Manganese ammonium diphosphate, a violet pigment (CI 77 742) and manganese phosphate, a red pigment (CI 77 745) also are insoluble salts.
The salts of fluorophosphoric acid are used for the oral care and particularly for tooth pastes for caries prevention. Examples are ammonium-, sodium-, potassium-, and calcium monofluorophosphate. The fluorine content in the preparation should not exceed 0.15%. Additional restrictions apply for children younger than 6 years.
Acidic phosphoric acid esters form by linkage of long-chain fatty alcohols with phosphoric acid. Cetyl phosphate can be mentioned as an example here. Cetyl alcohol alias hexadecanol is a natural co-emulsifier. The phosphate group makes it a strong anionic emulsifier that is neutralized and activated with sodium or potassium hydroxide solutions. The emulsifier is listed in the INCI with the terms Sodium Cetyl Phosphate or Potassium Cetyl Phosphate.

Components of cell membranes

Natural phospholipids also belong to the phosphoric acid esters; they are physiologically significant substances that, among others, build up cell membranes and intracellular membrane structures. Phosphatidylcholine is gained from soya lecithin or egg lecithin and used to produce liposomes that, regarding their external shape and size, are similar to living cells. Water-soluble (hydrophilic) substances can be encapsulated into liposomes. Phosphatidylcholine-based liposome membranes fuse with the barrier membranes of the skin which they fluidize; in this way they boost the penetration of the encapsulated material. Phosphatidylcholine also is a base material for biodegradable lipid-containing nanoparticles. Phos-

phatidylcholine gained from soya lecithin with its high content of essential fatty acids is an appropriate remedy for the prevention and treatment of acne. Egg-lecithin based phosphatidylcholine only has minor significance for cosmetic products.
Phosphatidylglycerol-derived cardiolipin (CL) has two phosphatidyl groups and is a component of the intracellular membranes of mitochondria. CL abnormalities lead to disorders of the metabolism and serious diseases.
Related to the phospholipids are sphingolipids that perform various functions in living cells. Among them are sphingomyelins which, in common with phosphatidylcholine, also have a phosphocholine group. Enzymes (phosphatases) cleave phosphoric acid esters into their base components. To some extent, the enzymes work in a substrate-specific way; thus, during apoptosis of the skin cells, the sphingomyelinase („SMase") transfers the membrane active intracellular sphingomyelins into the barrier-active ceramides of the horny layer with elimination of a phosphocholine residue. Concerning the phospholipids, the phospholipases C and D cleave off the phosphocholine group or other phosphate residues while leaving behind the diglycerides (esters of glycerin with two long-chain fatty acids).
Phosphoric acid can form chains by linkage of two phosphoric acid molecules and elimination of water. In this way, diphosphoric acid will form with its specific salts (diphosphates). Diphosphates and triphosphates (formed of 3 phosphoric acid molecules) are high-energy compounds due to their P-O-P-linkages. Adenosine triphosphate (ATP) is a nucleotide consisting of an ester of triphosphoric acid with ribose (monosaccharide) and a glycoside bond with the purine base adenine.

This creates energy

ATP is the main energy supplier in cells. Energy is released when phosphate groups one by one are gradually enzymatically cleaved or in other words, when adenosine diphosphate (ADP) and adenosine monophosphate (AMP) are formed from ATP. The released energy then initiates energy-consuming processes. ATP is formed in the power plants of cells, the mitochondria, among others, with collaboration of coenzyme Q_{10} (ubiquinone-10) which is used as a cosmetic active agent; in its reduced form it is a strong antioxidant.
Similar to ATP, also the other nucleotides such as guanosine triphosphate (GTP), uridine triphosphate (UTP) and cytidine triphosphate (CTP) participate in the energy supplying processes in cells. Nucleotides also serve as signal transducers in biochemical processes. Also cyclic phosphates such as cAMP and cGMP participate in the process. Nucleotides also are components of ribonucleic acids (RNA) in which they are bonded together via phosphate groups. Ribose in desoxyribonucleic acids is replaced by desoxyribose and uracil by thymine.
Diphosphoric acid is doubly esterified with ribose and a significant structural element of the coenzymes that participate in redox reactions of the body. Nicotinamide adenine dinucleotide, abbreviated NAD, occurs in reduced form (NADH) and in oxidized form (NAD^+). The situation is similar with nicotinamide adenine dinucleotide phosphate (NADP) in which an additional phosphate group is bonded to the ribose group.
Since phosphor compounds are essential for biological processes, non-physiological phosphor-containing chemicals can have inhibiting and destructive effects on biological regulatory circuits. Various pesticides, above all herbicides and insecticides belong to this group. They can occur as residues in herbal and animal extracts. But they can also occur in recycled plastics (jar and dispenser materials). Phosphorous substances can also be found in combat agents, cytostatics and fireproofing agents. Predominant are aromatic phosphoric acid esters, thiophosphoric acid esters (sulphur-containing), thio- and flourophosphonates as well as phosphoric acid amides.

Phosphorus also is contained in...

Phosphonic acids are components of herbal and animal organisms as well as of bacteria and fungi. Characteristic is their direct carbon-phosphorus bond (C-P). The synthetic representatives are strong complexing agents; etidronic acid alias 1-hydroxyethane 1,1-diphosphonic acid (HEDP) is used in hair care products and soaps (maximum content of 0.2%) and serves as a water softening agent. Phosphonic acids have antioxidative effects as they scavenge heavy metals similar to phosphoric acid. Simple phosphonic acids are degraded by bacteria while more complex structures are very inert. Diphosphonates are used in the treatment of osteoporosis patients.

Dr. Hans Lautenschläger