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DEFINITIONS OF TERMS RELATING TO DEGRADATION, AGING, AND RELATED CHEMICAL TRANSFORMATIONS OF POLYMERS

(IUPAC Recommendations 1996)

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Definitions of terms relating to degradation, aging, and related chemical transformations of polymers (IUPAC Recommendations 1996)

Abstract: Chemical reactions of polymers are very important from the points of view of chemical modifications of polymers to improve properties and changes in structure and physico-chemical properties in the course of synthesis, processing, application or the action of chemicals or micro-organisms. However, terminology has developed only on *ad hoc* bases in different professional communities. Hence, this document presents an alphabetical list of terms relating to degradation, aging, and related chemical transformations of polymers, and defines a self-consistent terminology for the field to aid communication and avoid confusion. Some of the general definitions are modified by one or more prefixes or adjectives describing type or cause. Definitions of basic terms such as aging, degradation, and stability have notes appended relating to specific cases. Thus, for example, definitions of different types of aging (such as artificial, cosmic, ground, or radiation aging) are covered by notes under the general term "aging". Adjective-modified terms that are frequently used by themselves are defined separately; biodegradation, photostabilizer, and chain-terminating antioxidant are typical examples. An index is appended at the end of the document for the reader's convenience.

INTRODUCTION

Chemical reactions of polymers are of great importance. First, chemical modifications of polymers have been used widely to improve their properties. Second, owing to physical and chemical factors such as abrasion, heat, light, radiation, or the action of chemicals or micro-organisms, all polymers tend to undergo spontaneous changes in structure and physico-chemical properties in the course of synthesis, processing and application. These types of transformations are extremely important from economic and environmental points of view; however, their terminology has developed only on an *ad hoc* basis and the development of a self-consistent terminology for the field will greatly aid communication and alleviate confusion.

This document presents an alphabetical list of terms relating to degradation, aging, and related chemical transformations of polymers; an index is appended. The general definitions in this document are often modified by one or more prefixes or adjectives describing type or cause. Thus, definitions of basic terms (such as aging, degradation, and stability) have notes appended relating to specific cases. For example, artificial, cosmic, ground, and radiation aging are covered by notes under the general term "aging". Prefix- or adjective-modified terms that are frequently used by themselves are defined separately; biodegradation, photostabilizer, and chain-terminating antioxidant are typical examples.

	Term	*Definition*
1	ablation	Removal of surface layers of polymers through heat generated by external forces, such as by the action of high-speed hot-gas flow or a laser beam.
2	ablator	A substance that forms a protective surface on a space craft or a missile, and is consumed in an ablation process.
3	abrasion	Removal of surface material from a solid, particularly through the frictional action of solids, liquids, or gases.
4	aging	Processes that occur in a polymeric material during a specified period of time, and that usually result in changes in physical and/or chemical structure and the values of the properties of the material. *Notes* 1. Thermodynamic processes that produce reversible changes in the physical structure of a polymeric material are termed physical aging. 2. If desired, the term aging may be qualified. For example, aging by the action of water or aqueous solutions is termed aqueous aging; aging by the direct or indirect effect of living organisms is termed biologically-induced aging; aging in extraterrestrial space or under conditions that simulate outer-space is termed cosmic aging; aging through contact with ground or soil is termed underground aging; aging caused by the action of an oxidizing agent, especially oxygen, is termed oxidative aging; aging induced by the combined action of light and oxygen is termed photo-oxidative aging, by the action of heat and oxygen thermo-oxidative aging, by the action of heat alone thermal aging, and by the action of visible or ultraviolet light photochemical aging.
5	antagonism	The opposing action of two or more agents that results in an effect smaller than would be expected from the individual action of each. *Note* Used especially for antioxidants and stabilizers.

6	anti-fatigue agent	An agent used to inhibit the fatigue of a polymer.
7	antioxidant	A substance that inhibits or retards oxidation. *Notes* 1. Antioxidants acting under specified conditions may be referred to as thermal antioxidants, photo-antioxidants, mechano-antioxidants, etc. 2. See also chain-terminating antioxidant.
8	antiradiant	An additive that protects a polymer against ionizing radiation.
9	ashing	A process in which a polymer is burned to a powdery residue.
10	autoxidation	Oxidation in which the intermediate products increase the rate of reaction. *Note* Autoxidation is usually the result of chain-reaction with air or oxygen, and the intermediate products are usually peroxidic in nature.
11	biodegradation	Degradation of a polymeric material caused, at least in part, by a biological process. *Notes* 1. See also degradation. 2. Usually biodegradation takes place through enzymatic processes resulting from the action of bacteria or fungi. 3. Biodegradation of a polymer is sometimes desirable.
12	carbonization	Transformation of an organic polymer into a material that consists largely of carbon.
13	chain-terminating antioxidant	An antioxidant capable of interrupting autoxidation by reacting with the propagating free radicals to form inactive products or products of reduced activity. *Note* Chain-breaking antioxidant is also used as a synonym for chain-terminating antioxidant.

14 cracking

The formation of cracks in a polymeric material.

Notes

1. Cracking by the action of chemicals, ozone, oxidizing agent, solvent (liquid), ultraviolet or other electromagnetic radiation is termed chemical cracking, ozone cracking, oxidative cracking, solvent cracking, UV cracking or radiation cracking, respectively.
2. See also environmental stress cracking.

15 crazing

Formation of cavities, when a polymer is stressed, which contain load-bearing fibrils spanning the gap between the surfaces of each cavity.

Note

One of the dimensions of a cavity is usually less than a few micrometers.

16 degradation

Chemical changes in a polymeric material that result in undesirable changes in the values of in-use properties of the material.

Notes

1. In some cases, degradation is accompanied by a lowering of molecular weight.
2. Causes of degradation may be specified by prefixes or by adjectives preceding the term degradation. For example, degradation caused by exposure to visible or ultraviolet light is termed photodegradation; degradation induced by the action of oxygen or by the combined action of light and oxygen is termed oxidative degradation or photo-oxidative degradation, respectively; degradation induced by the action of heat or by the combined effect of chemical agents and heat is termed thermal degradation or thermochemical degradation, respectively; degradation induced by the combined action of heat and oxygen is termed thermo-oxidative degradation.

17 denaturation

A change in the native conformation of proteins or nucleic acids resulting in loss of their biological activity.

Note
Denaturation is caused by factors such as heating, change in pH, or treatment with chemicals.

18 durability

The ability of a polymeric material to retain the values of its properties under specified conditions.

19 environmental stress cracking

Cracking caused by the combined actions of (i) mechanical stress and (ii) chemical agents or radiation or both.

Notes
1. Environmental stress cracking is also called stress cracking.
2. See also cracking.

20 environmentally degradable polymer

A polymer that can be degraded by the action of the environment, through, for example, air, light, heat, or micro-organisms.

Notes
1. The degradation of an environmentally degradable polymer after use is sometimes desirable.
2. A controlled-degradable polymer is a polymer designed to degrade into products at a predictable rate. Such products are usually of lower molecular weight than the original polymer.

21 fatigue

The process of progressive, localized, permanent, structural change occurring in a material subjected to fluctuating external stimuli.

Note
Mechanical stimuli such as stresses and strains may produce cracks or fracture in a material. Loss of function of a photo-chromic material resulting from cyclic irradiation may also be considered fatigue.

22 fire retardant

An additive that increases the fire resistance of a material.

Notes
1. A fire retardant is sometimes called a flame retardant.
2. The ability of a material to resist fire is called fire retardancy or flame retardancy.

23 heat endurance

The ability of a polymer to retain its function under the application of heat.

24 inhibitor

A substance that stops a chemical reaction.

Notes
1. See also retarder.
2. In a general chemical terminology, the term inhibitor is defined as "a substance that diminishes the rate of a chemical reaction" (IUPAC Compendium of Chemical Terminology, 1987, p.199).

25 lifetime

The time during which a polymer keeps a fraction of its original property values to such an extent to be useful in an intended application.

26 metal deactivator

A complexing agent that deactivates or reduces the ability of metal ions to initiate or to catalyze the degradation of a polymer.

27 peroxidation

The process of the formation of a hydroperoxide or peroxide by oxidation.

28 peroxide decomposer

An agent that transforms peroxides into stable compounds without the formation of free radicals.

Note
A decomposer for hydroperoxides is termed a hydroperoxide decomposer.

29 photosensitizer

A substance that permits or enhances the initiation of a photochemical reaction.

Note
The process involved is called photosensitization.

30 photostabilizer

An additive used to protect a polymer from photodegradation.

Note
A photostabilizer is also called light stabilizer or photoprotective agent.

31 pyrolysis

Thermolysis, usually associated with exposure to a high temperature.

Notes

1. IUPAC Compendium of Chemical Terminology, 1987, p.324.
2. Thermolysis is defined as the uncatalyzed cleavage of one or more covalent bonds resulting from exposure of the compound to an elevated temperature, or a process in which such cleavage is an essential part (IUPAC Compendium of Chemical Terminology, 1987, p.424).
3. Self-sustained pyrolysis in which the reaction is sufficiently supported, once initiated, by the exothermic heat of reaction is termed auto-pyrolysis.

32 retarder

A substance that decreases the rate of a reaction.

Note

See also inhibitor.

33 sensitizer

A substance that permits or enhances the initiation of chemical change in a polymeric material.

34 stability

The ability of a polymer to maintain the values of its properties over a specified period of time.

Note

Particular types of stability may be specified by adjectives preceding the term "stability". For example, the ability of a polymer to resist biologically induced aging or biodegradation is termed biological stability; the ability of a polymer to resist the action of chemicals, light, ionizing radiation, or heat is termed chemical stability, photostability, radiation stability, or thermal stability (or thermostability), respectively; the ability of a polymer to resist oxidation is termed oxidative stability; the ability of a polymer to resist to the combined action of light and oxygen or oxygen and heat is termed photo-oxidative stability or thermo-oxidative stability, respectively.

35 stabilization

Treatment of a polymer to improve its stability.

Notes
1. Stabilization by introducing certain additives to a polymer or by modifying the chemical structure of polymer molecules may be termed chemical stabilization.
2. Stabilization achieved through physical (e.g. mechanical or thermal) treatment may be termed physical stabilization.

36 stabilizer

An additive that increases the stability of a polymer.

Note
Additives used for specific purposes are termed UV stabilizers, photostabilizers, thermal stabilizers, etc.

37 weak link

The chemical bond in the main chain of a polymer molecule that is most susceptible to scission.

38 wear

Loss or deterioration of a polymer due to continued use, friction, or exposure to other natural destructive agencies.

Note
See also abrasion. Wear due to frictional action may be termed abrasive wear.

39 weathering

Exposure of a polymeric material to a natural or simulated environment.

Notes
1. Weathering results in changes in appearance or mechanical properties.
2. Weathering in which the rate of change has been artificially increased is termed accelerated weathering. Weathering in a simulated environment is termed artificial weathering.
3. The ability of a polymer to resist weathering is termed weatherability.

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