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A Primer on Polymer Nomenclature: Structure-Based, Sourced-Based, and Trade Names

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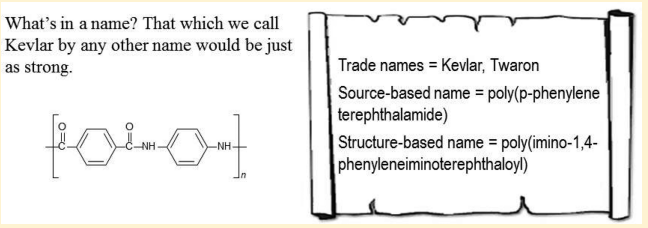
ABSTRACT: Polymer nomenclature is important because it is part of the language of polymer science and is needed for polymer identification, reference, and documentation. A primer on polymer nomenclature is provided herein for people new to the field or for instructional use. Both structure-based and source-based nomenclatures, together with trivial and trade names, are described. Source-based nomenclature is commonly used by polymer scientists for polymers where the starting monomers are known. The structure-based approach is especially helpful when the chemical structure of a polymer is well-defined; it is part of the recommendations from the International Union of Pure and Applied Chemistry and Chemical Abstracts Service. Appropriate illustrations of these approaches are provided.



KEYWORDS: *Second-Year Undergraduate, Upper-Division Undergraduate, Graduate Education/Research, Continuing Education, Polymer Chemistry, Communication/Writing, Polymerization, Nomenclature/Units/Symbols*

Polymers are materials with high molecular weights and typically consist of many repeating units.[1,2] In general, polymers can be grouped as natural or synthetic. Natural polymers include polynucleotides, polypeptides, polysaccharides, lignin, condensed tannins, and polyterpenes. Synthetic polymers are produced via reactions where one or more types of monomers are joined together; they may result from chain-growth or step-growth polymerizations. Both natural and synthetic polymers often have properties that render them useful in different contexts and applications. Some natural polymers such as DNA, RNA, and proteins are essential for life. Many synthetic polymers are important in diverse applications and are produced commercially on a very large scale.

In view of the importance of polymers, it is useful to have a consistent polymer nomenclature.[3−9] Currently there are at least four approaches to name a polymer: (1) source-based nomenclature, (2) structure-based nomenclature, (3) common or trivial names, and (4) trade names.

SOURCE-BASED APPROACH

In the source-based approach,[6,7,10−12] a polymer is named on the basis of the monomer from which it is prepared. Generally, the name of the polymer is generated by using the prefix "poly" followed by the name of the monomer in parentheses. For a simple monomer of one-word name, the parentheses are sometimes omitted but are preferred. Thus, a polymer made from ethylene is called poly(ethylene). Likewise, polymers made from propylene, styrene, and vinyl chloride are called poly(propylene), poly(styrene), and poly(vinyl chloride), respectively (Figure 1). These four polymers currently have the largest commercial sales volume. Copolymers are named with a connective term "*co*" between the monomer names. Thus, a copolymer of ethylene and vinyl chloride is called poly(ethylene-*co*-vinyl chloride).

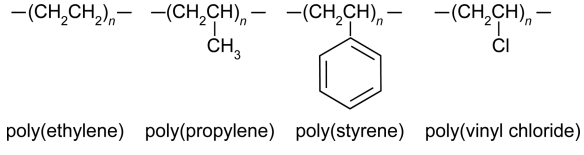
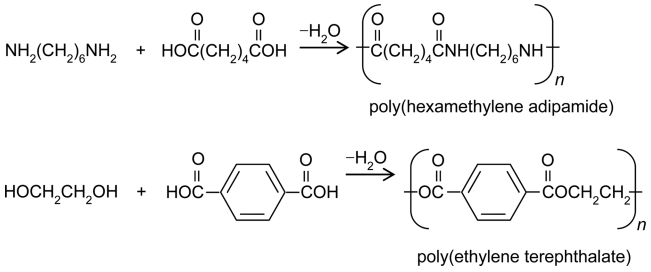


Figure 1. Structures and source-based names for four common polymers.

Scheme 1. Reactions and Source-Based Names for Two Step-Growth Polymers



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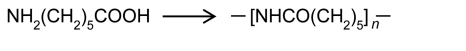
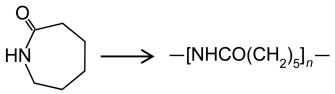
Scheme 2. Two Possible Source-Based Names for Nylon 6, Depending on the Reaction Pathway Involved

1. Reaction of 6-aminocaproic acid



6-aminocaproic acid poly(6-aminocaproic acid)

2. Ring opening polymerization of ε-caprolactam



ε-caprolactam poly(ε-caprolactam)

Step-growth polymers can be likewise named. For example, the product of the reaction between 1,6-hexanediamine and adipic acid is called poly(hexamethylene adipamide). The polymer derived from ethylene glycol and terephthalic acid is called poly(ethylene terephthalate) (Scheme 1).

The advantage of the source-based approach is that it is intuitively obvious and is especially useful when the starting monomer is known. Many of the source-based names are commonly accepted and frequently used in everyday speech by polymer scientists and in most research articles. It is also the preferred nomenclature in most textbooks of polymer science.[1,2,13−15] Conceptually, it is the easiest for students to grasp and provides a direct reflection of polymer structure. A disadvantage is that sometimes different names can arise from the same chain structure. An example is given below for Nylon-6, which can have two different source-based names because they are prepared from two different reaction pathways (Scheme 2).

STRUCTURE-BASED APPROACH

In the structure-based approach,[6,7,16−18] the name is chosen by first identifying the preferred repeat unit in a polymer, called the constitutional repeat unit (CRU) by the International Union of Pure and Applied Chemistry (IUPAC) and the structural repeating unit (SRU) by Chemical Abstracts Service

Table 1. Comparison of Three Approaches to Polymer Names and Common Abbreviations

source-based name	structure-based name(s)[a]	trade names	abbreviation(s)
Poly(ethylene) or poly(ethene)	Poly(methylene)	Alathon, Eltex, Finathene, Fortiflex, Hostalen, Lupolen, Marlex, Novapol, Paxon, Petrolene, Spherilen (high density)	HDPE
		Alkathene, Borstar, Dowlex, Dynex, Lupolen, Novapol, Petrothene (low density and linear low density)	LDPE/LLDPE
Poly(propylene) or poly(propene)	1. Poly(1-methylethylene) 2. Poly(1-methyl-1,2-ethanediyl)	Celstran PP, Eltex P, Escorene PP, Fortilene PP, Profax, Propylux, Novolen	PP
Poly(styrene)	1. Poly(1-phenylethylene) 2. Poly(1-phenyl-1,2-ethanediyl)	Dylene, Dylite, Lustrex, Styrofoam, Styron, Styropor, Polystyrol	PS
Poly(vinyl chloride)	1. Poly(1-chloroethylene) 2. Poly(1-chloro-1,2-ethanediyl)	Advex, Benvic, Fiberloc, Formolon, Geon, Novatemp, Vinoflex	PVC
Poly(acrylonitrile)	1. Poly(1-cyanoethylene) 2. Poly(1-cyano-1,2-ethanediyl)	Orlon, Acrilan, Dralon, Crumeron	PAN
Poly(methyl methacrylate)	1. Poly[1-(methoxycarbonyl)-1-methylethylene] 2. Poly[(1-methoxycarbonyl)-1-methyl-1,2-ethanediyl]	Acrylite, Degalan, Diakon, Elvacite, Lucite, Plexiglas, Paraglas	PMMA
Poly(chloroprene)	1. Poly(1-chloro-1-butenylene) 2. Poly(1-chloro-1-butene-1,4-diyl)	Neoprene, Baypren	
Poly(isobutylene)	1. Poly(1,1-dimethylethene) 2. Poly(1,1-dimethyl-1,2-ethanediyl)	Oppanol, Vistanex	PIB
Poly(ethylene oxide)	1. Poly(oxyethylene) 2. Poly(oxy-1,2-ethanediyl)	PolyOx, Carbowax	PEO, PEG
Poly(acetylene) or poly(ethyne)	1. Poly(vinylene) 2. Poly(1,2-ethenediyl)		PAc
Poly(ethylene terephthalate)	1. Poly(oxyethyleneoxyterephthaloyl) 2. Poly(oxyethane-1,2-diyloxyterephthaloyl) 3. Poly(oxyethanediyloxycarbonyl-1,4-phenylenecarbonyl)	Arnite, Crystar, Dacron, Hostaphan, Kodar, Mylar, Rynite, Terphan, Terylene, Valox	PET
Poly(hexamethylene adipamide)	1. Poly[imino(1,6-dioxohexamethylene) iminohexamethylene] 2. Poly(iminoadipoylimino-hexane-1,6-diyl) 3. Poly[imino(1,6-dioxo-1,6-hexanediyl) imino-1,6-hexanediyl]	Nylon-66, Akulon, Antron, Baylon, Capron, Danamid, Durethan, Gelon, Maranyl, Technyl, Ultramid, Vydyne, Zytel	PA 66
Poly(ε-caprolactam) or poly(6-aminocaproic acid)	1. Poly[imino(1-oxohexamethylene)] 2. Poly[imino(1-oxo-1,6-hexanediyl)]	Nylon-6, Akulon, Baylon, Capron, Danamid, Durethan, Gelon, Technyl, Ultramid	PA 6
Poly(bisphenol A carbonate)	1. Poly(oxycarbonyloxy-1,4-phenyleneisopropylidene-1,4-phenylene) 2. Poly[oxycarbonyloxy-1,4-phenylene-(dimethylmethylene)-1,4-phenylenediyl]	Makrolon, Lexan, Merlon, Calibre, Orgalon, Sinvet, Xantar	PC

[a]Names listed as "1." reflect the 1975 IUPAC recommendations;[11] those listed as "2." or "3." are compatible with the CAS and 2008 IUPAC recommendations.[5]

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(CAS). The CRU usually contains subunits, which are divalent groups that can be named using IUPAC nomenclature for organic compounds. The name of the CRU is given by using the following rules of seniority (i.e., priority) for subunits: heterocyclic rings > acyclic heteroatoms > carbocyclic rings > chains with carbon atoms. For a CRU with carbocyclic rings, the subunit with the greatest number of rings takes precedence, followed by the largest rings, and then the greatest number of atoms common to rings. For a CRU with carbon chains, the one with the longest chain takes precedence, followed (in decreasing seniority) by the chain with the most unsaturation, the lowest locant for a double bond, the lowest locant for ring attachment, the largest number of substituents, the lowest locant for a substituent, and finally the alphabetical order of substituents. The CRU is named by citing the names of the subunits in the order where they appear in the CRU, including their substituents (if present). The polymer name is simply given as poly(CRU name).

With the rapid growth of the polymer field, the structure-based nomenclature has been evolving. According to IUPAC rules approved in 1975,[16] chain-growth polymers like poly(ethylene), poly(styrene), and poly(vinyl chloride) are called poly(methylene), poly(1-phenylethylene), and poly(1-chloroethylene), respectively. Step-growth polymers like Nylon-66 and poly(ethylene terephthalate) are called poly[imino(1,6-dioxohexamethylene) iminohexamethylene] and poly(oxyethyleneoxyterephthaloyl), respectively. In the revised IUPAC rules developed since 2002[6,17] (and similar to the nomenclature used by CAS), the five polymers poly(ethylene), poly(styrene), poly(vinyl chloride), Nylon-66, and poly(ethylene terephthalate) can be called poly(methylene), poly(1-phenyl-1,2-ethanediyl), poly(1-chloro-1,2-ethanediyl), poly(imino(1,6-dioxo-1,6-hexanediyl)imino-1,6-hexanediyl), and poly(oxyethane-1,2-diyloxyterephthaloyl), respectively. More examples are shown in Table 1.

The structure-based approach is especially useful if the chemical structure of the polymer is well-defined. This approach is also more systematic and easier for the purpose of information management, classification, and retrieval. Thus, this approach is part of IUPAC and CAS recommendations. Weaknesses are that sometimes a name can become rather long and it is not always easy to visualize a structure from a name.

COMMON AND TRADE NAMES

Many polymers have common or trivial names for historical reasons or due to common usage.[1−6] Some of these names that have been incorporated into source-based nomenclature include poly(ethylene), poly(propylene), poly(styrene), starch [poly(α-1,4-glucopyranose)], cellulose [poly(β-1,4-glucopyranose)], poly(acrylic acid) [poly(2-propenoic acid)], and poly(methacrylic acid) [poly(2-methyl-2-propenoic acid)].

Polymers that are commercialized often have trade or brand names, and some of them have passed into common usage. These include Bakelite (phenol formaldehyde resin), Formica (melamine formaldehyde resin), Nylon-66 (polyamide from adipic acid and 1,6-hexanediamine), Nylon-6 (shown above), Kevlar and Nomex (aramid fibers), Orlon [poly(acrylonitrile)], and Saran [poly(vinylidene chloride) and its copolymers]. Moreover, poly(tetrafluoroethylene) is called Teflon in plastic and coating applications, Viton in elastomeric applications, and other names. Poly(ethylene terephthalate) is known as Dacron in textiles and Mylar in films, among other names.

In the literature and in common usage, abbreviations are sometimes used for polymers. Some abbreviations are noted in Table 1, together with source-based, structure-based, and some trade names.

Further information on polymer nomenclature is given in the references.[3−12,16−18] Descriptions of polymer nomenclature have also been given in a number of polymer textbooks.[1,13−15] Readers interested in more detailed comparisons of source-based and structure-based nomenclature may consult two useful papers by Wilks.[19,20] Extensive lists of trade names of commercially available polymers are available on the web; three of them are given in the references.[21−23]

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Notes

Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

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