

Polymer Nomenclature in Industry*

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Received May 19, 1969

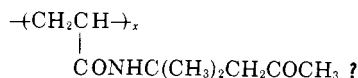
Much confusion exists in industry at present with respect to basic nomenclature of polymers, units, and terminology. Certain remedies have been suggested, including greater use of systematic nomenclature, development of generic terms and abbreviations for plastics, certain changes in viscosity nomenclature, and particularly in definitions of some very basic terms.

Nomenclature: "A system or set of names or designations used in a particular science...and formally adopted or sanctioned by the usage of its practitioners; a set of chemical names that may be systematic...or not and that aims to tell the composition and often the structure of a given compound."¹

According to the standards of this definition, nomenclature practice in the polymer industry ranges from satisfactory to deplorable. In general, scientific communications emanating from industrial research laboratories reflect the best current standards, such as they are,^{2,3} but inevitably suffer from the same inherent problems already described in the other papers of this symposium. There is no need to repeat these shortcomings here. On the other hand, the trade and patent literature often depart grossly from best nomenclature practice.

Even a cursory look at trade journals and manufacturers' literature will reveal repeated use of such terms as "impact styrene," "melamine," "PVC-PVA copolymer," "EVA," "acetal copolymer," "polyvinyl dichloride," "propylene-vinyl," "epoxy," "fiber glass," and "polyethylene glycol" to designate various specific polymers. It is true that these are quite understandable to polymer practitioners; few would be puzzled by them and even fewer would, unfortunately, be shocked by this obvious flouting of elementary rules of polymer nomenclature.

On the other hand, what about the ubiquitous "vinyl?" To the plastics engineer, it may mean poly(vinyl chloride), poly(vinyl chloride-co-vinyl acetate), or plasticized poly(vinyl chloride-co-vinyl acetate)—not identical, but at least closely related materials; however, to the paper chemist and others using latexes, the term is much more likely to mean a polymer consisting predominantly of vinyl acetate—an entirely different species! How is the reader, especially the "outside" reader, to know which of these is meant? And to cite an example from recent industrial literature, how could anyone, without recourse to the structural formula or systematic name, know that "polydiacetone acrylamide" stands for



* Presented before the Division of Polymer Chemistry, 156th Meeting, ACS, Atlantic City, N. J., September 11, 1968.

Another unfortunate tendency is to utilize a well-known trademark as a shortcut for the generally more complicated generic name, and for the certainly more cumbersome systematic name.

It may seem surprising, in view of this widespread use of questionable terminology, that any sensible communication is possible in the polymer industry. The major reason why this primitive nomenclature—one "sanctioned by the usage of its practitioners" but certainly not by "formal adoption"—has endured is the small number of polymers in commercial use; the overwhelming preponderance of U.S. production of plastics is accounted for by only about two dozen classes of materials⁴ and the number of other polymers having some commercial importance probably does not exceed one hundred at this time, excluding the various grades. Consequently, it has been relatively easy to learn the jargon of the industry. This situation is changing rapidly, however, as hundreds of new polymers reach the market,⁵ and demands for more precise expression are sure to become more insistent. As a minimum, one may hope that the simple poly(monomer) system be used now by writers for the trade literature. There is also no reason why the new structure-based system devised by the Polymer Division³ could not be phased in gradually, at least for the simpler cases: It is no more difficult to write or to say poly(cyanoethylene) than polyacrylonitrile.

Patent literature has been generally more acceptable from the nomenclature point of view than the trade publications. U.S. patent practice permits description of materials as "reaction products of A and B"; this is, in fact, but a variation of the well-known system of naming polymers based on their source. Patent attorneys must by necessity avoid ambiguity and, although they do not always use what we consider best nomenclature, terms such as "styrene" instead of "polystyrene" are rarely, if ever, seen in patents.

GENERIC NAMES AND ABBREVIATIONS

Because there is a genuine need in industry and commerce for short, clearly understood terms, rather than the nomenclaturally correct but often ponderous systematic names, generic names as well as abbreviations have come into widespread use. There should be no objection

to this practice, provided there exists uniformity in usage, which is unfortunately not the case with plastics.

The rubber industry has long employed both generic terms, such as neoprene and butyl rubber, and abbreviations, such as SBR and NBR, that are generally understood.⁶ Governmental regulations⁷ have brought order to the textile industry, previously plagued by a bewildering confusion of terms, by requiring the use of a system of generic terms. Unfortunately, the plastics industry is still in need of such a set of generic terms and abbreviations enjoying wide acceptance. The American Society for Testing and Materials has made certain recommendations in this direction, and these deserve serious study and possible acceptance.^{8,9}

UNITS

A further confusion exists in industrial literature with respect to units. Among numerous examples, one may cite the lack of consistency found in viscosity-molecular weight relationships. It is not at all unusual to see values reported for M and a in the Mark-Houwink equation, $[\eta] = KM^a$, without the units, solvent, or temperature being specified. The units are especially a source of ambiguity, since practice varies greatly: in the U.S. and Great Britain, $[\eta]$ is usually expressed in dl./g.; in the older German literature in l./g.; in more recent German literature and in the IUPAC Report² in ml./g. The name for $[\eta]$ can be either "intrinsic viscosity" (not really a viscosity), "limiting viscosity number" (not really a number, since it has the dimensions of reciprocal concentration), or Staudinger index, which further compounds the confusion. Perhaps $[\eta]$ could be expressed simply in *staudingers*, a new unit, just as we have newtons, hertz, and torricellis. My preference would be to have staudingers correspond to dl./g.

Most industrial and patent literature still makes use of the antiquated English units for weights and measures. Often English and metric units are used together. ASTM has begun to introduce the *Système International d'Unités* ("SI units") and it is hoped that this will be followed by its prompt and universal acceptance.

TERMINOLOGY AND DEFINITIONS

Perhaps most astonishing is the fact that there are no widely accepted definitions for such basic terms as "monomer," "homopolymer," "copolymer," etc.; for example, IUPAC,² ASTM,⁸ and several reference books¹⁰⁻¹³ give different interpretations for "copolymer." The IUPAC definitions have been criticized¹⁴ on the ground that they do not always permit a clear-cut choice between homopolymerization and homopolymer on one hand, and copolymerization and copolymer on the other.

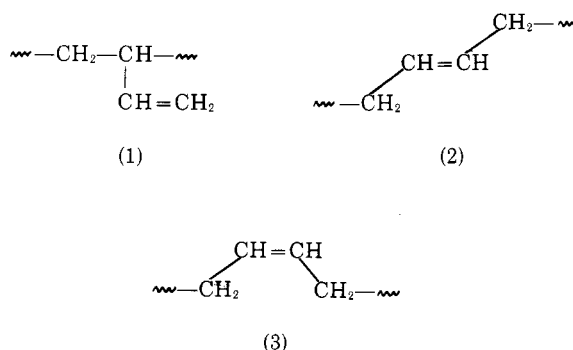
The IUPAC considers that "...in homopolymerization the number of molecular species contributing to the polymer structure is the minimum number required for the types of reactants employed. In ordinary addition polymerizations, this minimum number is one; in most condensation polymerizations, it is two.... A homopolymer is a (high) polymer, consisting of molecules containing (neglecting the ends, branch junctions, and other minor irregularities) either a single type of unit or two or more

chemically different types in regular sequence."² There are, therefore, different criteria for the reaction and the resulting polymer.

Clearly, the intent of the IUPAC is to consider a polymer such as poly(ethylene terephthalate) a homopolymer, even though it is derived from two monomeric substances. Unfortunately, the IUPAC definition is not always a reliable guide. One difficulty lies in the very ambiguity of the expression "minimum number required for the types of reactants employed." In the case of terephthalic acid and ethylene glycol, each reactant is, in principle, capable of reacting alone to give a polyanhydride and a polyether, respectively. In that sense, the minimum number is one. By contrast, for condensation between the two substances, the minimum number is two. Could it not be said, then, that the "minimum number" depends not so much on the type of reactant, as IUPAC specifies, but rather on the type of reaction?

Another serious difficulty arises in the classification of addition polymers. Styrene and maleic anhydride may be coreacted to give a polymer with a strictly alternating structure. Since the two monomers are present in the product in a regular sequence, the polymer is a homopolymer by IUPAC definition. The process of reaction, on the other hand, is a copolymerization, since each monomer is capable of reacting by itself, and "the minimum number" for this type of reactant is one. It should be pointed out that, strictly speaking, the classification of the reaction changed abruptly from homopolymerization to copolymerization in 1961, when the homopolymerization of maleic anhydride was first discovered.¹⁵ Prior to that time, the anhydride was believed to be capable only of polymerization with other vinyl-type monomers and the "minimum number" was, therefore, two. Here, again, emphasis on the type of reaction rather than reactants would obviate the confusion.

An equally unsatisfactory situation prevails in the case of butadiene polymerization. Here "the minimum number" is one. The product, however, may have several chemically different units such as 1, 2, and 3 present in irregular sequence. According to the IUPAC rules, the process of preparation should be classified as a homopolymerization, but the product would have to be considered a copolymer.



Since I find it difficult to accept that a copolymerization can give a homopolymer or a homopolymerization a copolymer, I have recently proposed the following definition:¹⁴ Homopolymerization may be defined as any process where-

in a single monomer reacts to form a polymer. A homopolymer is the product resulting from such a process.

Copolymerization would then be defined in an analogous fashion as any process wherein more than one monomer reacts to form a polymer. In this way, poly(ethylene terephthalate) would be considered a copolymer formed by copolymerization, polybutadiene a homopolymer formed by homopolymerization, and the styrene-maleic anhydride copolymer's classification would not depend on the fortuitous discovery that maleic anhydride is more reactive than originally thought.

This type of discussion is not simply an exercise in semantics. Patentability and certain other legal questions of vital interest to industry frequently hinge on exactly such definitions of basic terms. A recent celebrated case involved the question of whether, in polycondensates derived from ethylene glycol and terephthalic acid, the replacement of small amounts of terephthalic acid by isophthalic acid changed the homopolymer nature of the product.¹⁶ Another case, in which I served as witness, hinged on whether a polydisperse polymer is a compound. Widely accepted definitions are, therefore, truly a great unfulfilled need. The International Standards Organization (ISO) and IUPAC have recently undertaken a critical re-examination of the definitions of about two dozen key polymer terms, and their reports will be awaited with great interest.

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ERRATA

In the article "Simple Representations of Structural Formulas of Zirconium Compounds" by Warren B. Blumenthal [*J. CHEM. Doc.* 9, 135 (1969)], the structures at the end of column 1, page 135, for nitrogen at coordination No. 3 and 4 are in error. The correct representations are shown below.

Correct Representations

