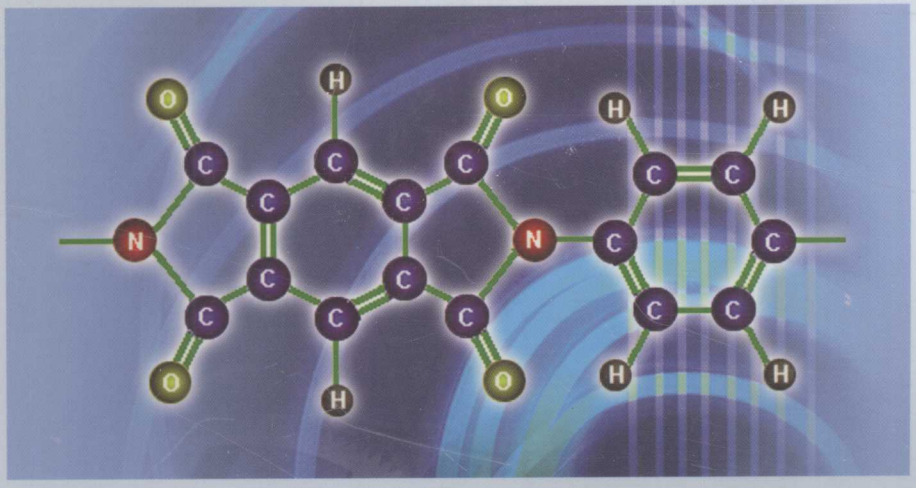
Brief Guidance to Polymer Science in English

高分子科学英文导读

主　编　高振华
副主编　朱丽滨　刘海英



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前　言

材料工业尤其是复合材料是21世纪的朝阳工业。高分子材料是材料工业的重要组成部分，也是科技发展中的一个热点，国内外对高分子材料的研究开发十分活跃，发展又十分迅速。该专业涉及化学、化工、材料、轻工、物理、机械等许多领域，因此高分子材料与工程的专业外语必然会涉及上述各学科领域，相关专业词汇量巨大。据编者依照近年出版的与高分子科学相关的英语辞典估算，常用的关于高分子科学的英文词汇在50 000条以上；再加上化学、化工、材料、机械等学科领域，相关词汇量在100 000条以上。因此，使得从事该专业的科研人员、教师等在阅读相关专业英语资料时需要的词汇量很大，对于该专业本科学生和研究生等初学者更是难以应对。为此作者针对高分子科学专业本科生的专业外语学习需要选编了本书。

在本书编撰期间，正是编者在加拿大访问研究期间，借助于魁北克Forintek Canada Corp.（加拿大林产工业技术研究院）图书馆、Laval大学图书馆和McGill大学图书馆关于高分子科学方面丰富的馆藏以及他们的对外开放，使本书的资料收集和选材极为丰富。该书所收集的内容都是选自英、美国家的高分子科学教材和期刊杂志的原文，经过整理和选剔，使该书的内容通俗易懂，又具有一定的深度，因此该书既可作为高分子科学的专业外语，也可用于非高分子科学专业介绍高分子科学知识的双语教学资料和自学资料。本书还收录了有关高分子科学的一些基础知识，如高聚物命名、化工词缀、常数等，使本书在某种意义上成为一本小工具书，因此也适于相关科研工作者和教学人员作为参考资料。

本书分为四部分，Part A是高分子科学导读，共32课，内容涉及高分子化学Lesson 1 ~ Lesson 13)、高分子物理（Lesson 14 ~ Lesson 23）和高分子成型加工与应用（Lesson 23 ~ Lesson 32）；Part B是以高分子化学为主并涉及高分子科学基础知识，主要是服务于聚合物命名，内容涉及该专业常见无机化合物、期刊杂志、缩写等内容，还收集了常见聚合物结构与单体结构名称，以增加学生的知识面；Part C主要介绍一些常用单位、常数、词缀等的英语表达；Part D是1996年IUPAC推荐使用的涉及高分子科学的基本名词解释。

全书约30万字。其中，Part A 高分子科学导读的 Lesson 1 ~ Lesson 22 课由高振华编写，Lesson 23 ~ Lesson 32、Part B、Part C 由朱丽滨编写，Part D 和全书词汇表由刘海英整理编写。同时衷心感谢东北林业大学材料科学与工程学院顾继友教授和加拿大林产工业技术研究院复合材料部王向明博士对本书编写的大力支持并提出了许多建设性建议。

由于编者英语水平有限，书中难免有不妥之处，真诚地希望读者能提出宝贵意见。

编　者

2005年4月于哈尔滨

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Part A Brief guidance to polymer science

Lesson 1 The primary definitions of polymer science

It was not until 1930's that the science on the polymers, the high-molecular-weight compounds that are so important to man and her modern science and technology, began to emerge and came to exploding later on.

The polymer, or called macromolecule sometimes, is concerned with the non-biological one in this book, which are primarily the synthetic materials used for plastics, fibers, elastomers, etc. Today, these high-molecular-weight compounds are really indispensable to human, being essential to his clothing, shelter, transportation, and utilization, as well as to the conveniences and luxuries of modern living[①].

A polymer is a large molecule built up by the repetition of simple chemical units via covalent bonds. Sometimes the repetition is linear but more often that is branched or interconnected to form three-dimensional network. The repeating unit of the polymer is usually equivalent or nearly equivalent to the monomer, or the beginning material from which the polymer is formed, while the structural unit represents the residue from the monomeric compound(s) employed in the preparation of the polymer. Usually, there is a direct correspondence between the monomer(s) and the structural unit(s). Two illustrative examples of units occurring in linear polymer are shown in Fig. 1 - 1.

In the first example of polypropylene, the repeating unit, structural unit and the monomer from which it is derived possess identical atoms occupying similar relative positions. In the last example of polyhexamethylene adipamide there are two types of monomeric reactants, and these give rise to two supplementary structural units which make one repeating unit. In polymers containing a single structural unit, the structural unit ordinarily is also the repeating unit.

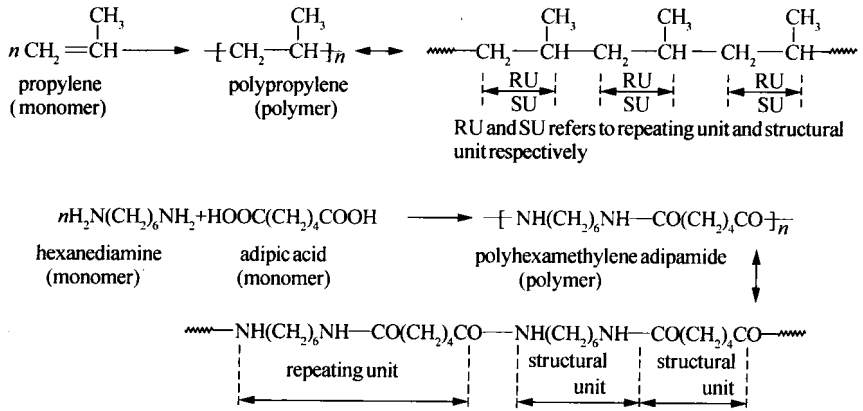

Fig. 1 – 1 Two different linear polymers, their monomer, repeating unit, structural unit and their structural formulas and diagrams.

The length of the polymer chain is defined by the number of repeating units in the chain, which is called the degree of polymerization (DP), i.e., the number represented by n in Fig.1 – 1. It is sufficient to mention here that the hazards of ambiguity can be avoided by referring to the average degree of polymerization, provided that the manner of averaging is specified. Unless stated otherwise, the term average degree of polymerization refers to the ordinary average obtained by dividing the total number of structural units by the total number of molecules, i.e., the number average degree of polymerization[②]. The molecular weight of the polymer is the product of the molecular weight of the repeating unit and the degree of polymerization. Using polypropylene as an example, the polymer has a degree of polymerization 150, then its molecular weight is $150 \times 42 = 63\,000$. Most polymers used as plastics, rubbers or fibers have molecular weight between 10 000 and 1 000 000. Similarly, the average molecular weight, the number average molecular weight to be more accurately, represents the mass of the sample divided by the number of moles it contains. Where no confusion is likely to arise[③], the qualifying adjective average may be omitted.

In the preceding discussion the term polymer has been used in the general sense of a substance that has one or two structural units and one repeating unit. Polymeric substance containing two or more structural units combined more or less in random sequence is the distinguished by the term copolymer. A linear copolymer composed of two units or monomer A and B, for instance, can be represented as following:

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—B—B—A—B—B—B—A—A—B—A—

The structural units may occur in random sequence or in regular sequence. If the units alternate with perfect regularity, the substance is preferably regarded as a polymer of repeating unit —AB—. For example, the polyhexamethylene adipamide in Fig. 1 – 1 affords this type. Although these substances might be looked upon as "*copolymer*" of diamines and dibasic acids structural units, it is preferable to classify them as polymers in which the repeating unit consists of one residue from each of the two reactants④.

The processes of polymerization were divided by Carothers and Flory into two groups known as condensation and addition polymerization. In more precise terminology, it divided into step-reaction and chain-reaction polymerization that is commonly used in every textbook on polymer science. The step-reaction polymerization is quite analogous to condensation between low-molecular-weight compounds. In polymer formation the condensation takes place between two functional group of molecules to produce one larger molecule, with the possible elimination of a small molecule such as water, ethanol and hydro-chloride. The chain-reaction polymerization involves chain reactions in which the chain carrier may be an ion or a reactive substance with one unpaired electron called a free radical. The free radical is capable of reacting to open the double bond of the alkene monomer and add to it. In a very short time, a few seconds for instance, many more monomers add successively to the growing chain.

The nomenclature of polymeric substance is based the repeating unit of the polymer. The IUPAC⑤ rules of nomenclature give a detail and expatiatory but precise description that is seldom used by most people. The popular nomenclature of polymer are as follows. In the case of addition polymers or in other cases where the polymer is synthesized from a single monomer species the prefix "poly-" is added to the name of the monomer. For example, the ethylene polymerizes to give polyethylene, styrene to give polystyrene and vinyl chloride forms polyvinylchloride that sometimes is written as poly (vinyl chloride). Reacting two types of monomer together makes some condensation polymers, which form an alternating sequence in the polymer chain. The polymer formed from the reaction between hexanediamine and adipic acid is then termed polyhexamethylene adipamide (see Fig. 1 – 1). However trade names or trivial names are often used to describe particular polymers, as that the polymer condensed from diamine and dibasic acid is call polyamide or Nylon. "*The common monomers*

and polymers" in Part B of this book gives the most kinds of polymer and their monomers and nomenclature.

Words and expressions

polymer	['pɔlimə]	n. 聚合物，高聚物
macromolecule	[ˌmækrəu'ɔlikju:l]	n. 巨型分子，高分子
elastomer	[ilæstəmə]	n. 弹性体
indispensable	[ˌindis'pensəbl]	adj. 不可缺少的，绝对必要的
covalent bond		n. 共价键
branched	[brɑ:ntʃid]	adj. 支化的，分岔的
interconnected	[ˌintə:kə'nektid]	adj. 相互连接的
repeating unit		n. 重复单元
monomer	['mɔnəmə]	n. 单体
structural unit		n. 结构单元
propylene	['prəupili:n]	n. 丙烯
polypropylene	[ˌpɔli'prəupili:n]	n. 聚丙烯
hexanediamine	[hekˌseindai'æmi:n]	n. 己二胺
adipic acid	[ə'dipik'æsid]	n. 己二酸
polyhexamethylene adipamide	[ˌpɔliheksə'meθilin ə'dipˌæmi:d]	n. 聚己二酰己二胺，聚酰胺－66，尼龙－66
reactant	[ri:'æktənt]	n. 反应物
supplementary	[ˌsʌpli'mentəri]	adj. 额外的，补充的，追加的
degree of polymerization		n. 聚合度
ambiguity	[ˌæmbi:gju:iti]	n. 含糊，不明确
molecular weight		n. 相对分子质量
diamine	[dai'æmi:n]	n. 二元胺
terminology	[ˌtəmi'nɔlədʒi]	n. 术语学
dibasic acid		n. 二元羧酸
step-reaction polymerization		n. 逐步聚合反应
chain-reaction polymerization		n. 链式聚合反应
free radical		n. 自由基
alkene	['ælki:n]	n. 烯烃
nomenclature	[nəu'menklətʃə]	n. 命名，命名法

expatiatory	[ekspeiʃiitəri]	adj. 冗长但详述的
ethylene	['eθili:n]	n. 乙烯
polyethylene	[ˌpɔli'eθili:n]	n. 聚乙烯
styrene	['stairi:n]	n. 苯乙烯
polystyrene	[ˌpɔli'staiəri:n]	n. 聚苯乙烯
vinyl	[vainil, 'vinil]	n. 乙烯基
chloride	['klɔ:raid]	n. 氯化物
polyvinylchloride	[ˌpɔli'vainiklɔ:raid]	n. 聚氯乙烯

Phrases

be essential to…	v. 对……必要的
to give rise to…	v. 引起……，使……发生
be looked upon…	v. 认为……，看做……
provided that…	conj. 倘若……
in the case of…	adv. 在……情况下
be analogous to…	v. 与……类似

Notes

①Today, these high-molecular-weight compounds are really indispensable to human, being essential to his clothing, shelter, transportation, and utilization, as well as to the conveniences and luxuries of modern living. 译做：如今，这些高分子物质已成为人们衣食住行所不可缺少的部分，并给予现代生活以便利和充分的享受。

luxuries 原指奢侈品，使人愉快、舒服但非必需的东西，此处与后面的 living 配合，转译为充分享受的（生活）。

②Unless stated otherwise, the term average degree of polymerization refers to the ordinary average obtained by dividing the total number of structural units by the total number of molecules, i.e. , the number average degree of polymerization. 译做：若非特指，平均聚合度一般是指聚合物结构单元总数为其总分子数平均的结果，也即数均聚合度。

Unless stated otherwise，直译做“除非指出……否则……”，是一个常用的省略语；i.e. 是“that is…”的缩写，译做“也即”、“也就是”，在科技写作和科技论文中常被用到。

③Where no confusion is likely to arise…，译做：在不产生歧义的情况下……

④Although these substances might be looked upon as "*copolymer*" of diamines and dibasic acids structural units，it is preferable to classify them as polymers in which the repeating unit consists of one residue from each of the two reactants. 译做：虽然这些物质（指聚酰胺）看似由二元胺和二元酸两个结构单元构成的"共聚物"，但两个单体通过反应后构成了其重复单元，因此尚不能将之归分为均聚物。

A is preferable to B，译做"A 比 B 更可取或更好"。

⑤IUPAC 是"Internaltional Union of Pure and Applied Chemistry（国际纯粹化学和应用化学联合会）"的缩写。

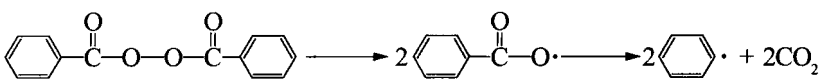
Lesson 2 Radical Chain polymerization

The processes by which unsaturated monomers are converted to polymers of high molecular weight exhibit the characteristics of typical chain reaction, which the active center responsible for growth of the chain is associated with a single polymer molecule through the addition of many monomer units[①]. Thus polymer molecules are forming from the beginning, and almost no intermediate is found between monomer and polymer of higher molecular weight. Of several postulated types of active center, three have been confirmed experimentally, the free radical, the cation and the anion. The related case discussed in the paper focuses on the free radical polymerization.

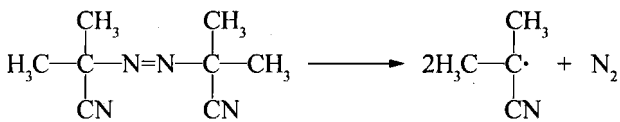
The free radical chain mechanism, first suggested by Taylor and Bates to explain the polymerization of ethylene, was proposed independently by Staudinger in 1920s to offer an explanation for the general characteristics of vinyl. Folry gave the conclusive results, in 1937, that radical polymerization proceeds by and requires the steps of initiation, propagation, and termination of chain reaction, however the chain transfer occurs almost in all radical polymerization. All that will be introduced as follows:

1. Generation of free radicals

An impressive number of substances are capable of generating free radical, an intermediate having an odd number of electrons through an unpaired electron[②]. They can be generated by many ways including thermal or photochemical decomposition of some peroxides or diazo compounds. Two compounds that are commonly used to produce radicals for polymerization are the thermal decomposition of benzoyl peroxide:



and of azobisisobutyronitrile:



The stability and reactivity of radicals varies widely with the chemical structure and species. For instance, primary radicals are less stable but more reactive than secondary radicals, which are in turn less stable than tertiary ones[③]; and the phenyl radical is more reactive than the benzyl radical; the allyl radical is quite unreactive, and so on. The final and conclusive evidence for the free radical mechanism is afforded by detection in the polymer of radical fragment from the initiator.

2. Reaction of chain initiation

The process of chain initiation may be considered to involve two steps, the first being the generation of a pair of free radicals R· decomposed from the initiator I, as follows:

$$I \longrightarrow 2R\cdot \qquad (2\text{-}1)$$

and the second the free radicals adds to the double bond of vinyl monomer with regeneration of chain radical:

$$R\cdot + CH_2{=}\overset{X}{\underset{|}{C}}H \longrightarrow R{-}CH_2{-}\overset{X}{\underset{|}{C}}H\cdot \qquad (2\text{-}2)$$

Not all of the radicals released in step (2 - 1) necessarily yield chain radicals according to (2 - 2); some of them may be lost through side reactions. As a result, initiator efficiency is aroused, which can be estimated by comparing the amount of initiator decomposed with the number of polymer chains formed. Most initiators in typical vinyl polymerization have efficiencies between 60% and 100%.

3. Reaction of chain propagation

The chain radical formed in step (2 - 2) is capable of adding successive monomers to propagate the chain which may be represented by:

$$R{-}CH_2{-}\overset{X}{\underset{|}{C}}H\cdot + CH_2{=}\overset{X}{\underset{|}{C}}H \longrightarrow R{-}CH_2{-}\overset{X}{\underset{|}{C}}H{-}CH_2{-}\overset{X}{\underset{|}{C}}H\cdot \xrightarrow{+CH_2=CHX}$$

$$R{-}CH_2{-}\overset{X}{\underset{|}{C}}H{-}CH_2{-}\overset{X}{\underset{|}{C}}H{-}CH_2{-}\overset{X}{\underset{|}{C}}H\cdot \xrightarrow{+CH_2=CHX} \cdots\cdots \qquad (2\text{-}3)$$

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