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Introductory concepts of Polymer and their functionality

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Abstract:

This chapter discusses the basic concepts and definitions of polymer. There are many types of polymers exist in our nature. Much of the terminology in current use in polymer science has technological origins, and some meanings may therefore be understood by convention as well as by definition. Some of these terms are included in this chapter since a full appreciation of the behavior and potential of polymeric materials requires acquaintance with technical developments as well as with the more academic fundamentals of the field. An aim of this chapter is to provide the basic understanding and vocabulary for further independent study in both areas.

Keywords: monomer, polymer and Functionality

Introduction:

Some basic concepts and definitions of terms used in the polymer literature are reviewed in this chapter. Much of the terminology in current use in polymer science has technological origins, and some meanings may therefore be understood by convention as well as by definition. Some of these terms are included in this chapter since a full appreciation of the behavior and potential of polymeric materials requires acquaintance with technical developments as well as with the more academic fundamentals of the field. An aim of this book is to provide the reader with the basic understanding and vocabulary for further independent study in both areas. Polymer technology is quite old compared to polymer science. For example, natural rubber was first masticated to render it suitable for dissolution or spreading on cloth in 1820, and the first patents on vulcanization appeared some twenty years later. About another one hundred years were to elapse, however, before it was generally accepted that natural rubber and other polymers are composed of giant covalently bonded molecules that differ from "ordinary" molecules primarily only in size. (The historical development of modern ideas of polymer constitution is traced by Flory in his classical book on polymer chemistry [1, 2], while Brydson reviews the history of polymer technology.) Since some of the terms we are going to review derive from technology, they are less precisely defined than those the reader may have learned in other branches of science. This should not be cause for alarm, since all the more important definitions that follow are clear in the contexts in which they are normally used.

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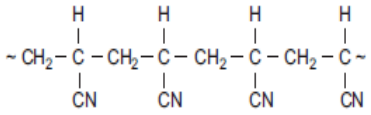
Typesof Polymers and Polymerization

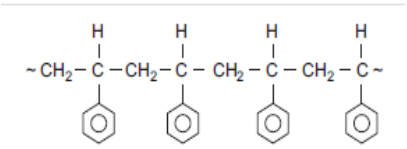
Monomer

Monomer is a basic unit of polymer in other word we can say that, monomer is a molecule that combines with other molecules of the same or different type to form a polymer[3]. Acrylonitrile, CH_2=CHCN, is the monomer for polyacrylonitrile, which is the basic constituent of "acrylic" fibers.



Polymer

The term polymer in Greek means 'many parts' and designates a large molecule or a macromolecule made up of smaller repeating units. Polymers can be found all around us, from the strand of our DNA, which is a naturally occurring biopolymer, to polypropylene which is used throughout the world as plastic. Polymers can be naturally found in plants and animals (natural polymers) or can be human-made (synthetic polymers). Different polymers have a number of unique physical and chemical properties, due to which they find usage in everyday life. Polymers generally have molecular weights greater than about 5000 but no firm lower limit need be defined since the meaning of the word is nearly always clear from its use. The word macromolecule is a synonym for polymer. Thus the structure of polystyrene shown in bellow-



Classification of Polymers Based on the Structure of the Monomer Chain

This category has the following classifications:

Linear Polymers

The structure of polymers containing long and straight chains falls into this category. PVC, i.e., polyvinyl chloride, is largely used for making pipes, and an electric cable is an example of a linear polymer.

Branched-chain Polymers

When linear chains of a polymer form branches, then such polymers are categorized as branched chain polymers. For example, low-density polythene.

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Cross-linked Polymers

They are composed of bifunctional and trifunctional monomers. They have a stronger covalent bond in comparison to other linear polymers. Bakelite and melamine are examples of cross-linked polymers.

Properties of Polymers

Physical Properties

- As chain length and cross-linking increase, the tensile strength of the polymer increases.
- Polymers do not melt, and they change state from crystalline to semi-crystalline.

Chemical Properties

- Compared to conventional molecules with different side molecules, the polymer is enabled by hydrogen bonding and ionic bonding resulting in better cross-linking strength.
- Dipole-dipole bonding side chains enable the polymer for high flexibility.
- Polymers with Van der Waals forces linking chains are known to be weak but give the polymer a low melting point.

Optical Properties

- Due to their ability to change their refractive index with temperature, as in the case of PMMA and HEMA: MMA, they are used in lasers for applications in spectroscopy and analytical applications.
- Optical properties are also a very important property of glass. Optical properties can be divided into three categories: refraction, absorption, and transmission of light. Because of the excellent optical properties, development of optical glasses with appropriate refractive index and dispersion characteristics is possible which plays a very important role in many areas like: nano-science, medical science, astronomy, and biology.
- The refractive index of a glass increases with increasing electron density. Therefore, the glasses containing low atomic number ions and a low electron density exhibit low refractive indices. In alkali silicate glasses, refractive indices increase with the increase of alkali oxide concentration.

Polymerization

Polymerization is a chemical reaction in which the product molecules are able to grow indefinitely in size as long as reactants are supplied[4.5]. Polymerization can occur if the monomers involved in the reaction have the proper functionalities.

Functionality

The functionality of a molecule is the number of sites available for bonding to other molecules under the

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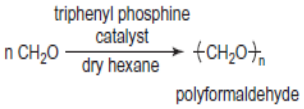
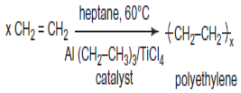
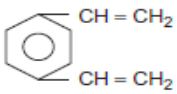
specific conditions of the polymerization reaction. A bifunctional monomer can be linked to two other molecules under appropriate conditions. Examples are





A polyfunctional monomer can react with more than two other molecules to form the corresponding number of new valence bonds during the polymerization reaction. Examples are divinyl benzene



in reactions involving additions across carbon_carbon double bonds and glycerol or pentaerythritol ($C(CH_2OH)_4$) in esterifications or other reactions of alcohols.

If an a-functional monomer reacts with a b-functional monomer in a non-chain reaction, the functionality of the product molecule is a+b-2. This is because every new linkage consumes two bonding sites. Production of a macromolecule in such reactions can occur only if a and b are both greater than 1[6.7].

The following points should be noted-

1. Use of the term functionality here is not the same as in organic chemistry where a carbon carbon double bond, for example, is classified as a single functional group.
2. Functionality refers in general to the overall reaction of monomers to yield products. It is not used in connection with the individual steps in a reaction sequence. The free radical polymerization of styrene, for example, is a chain reaction in which a single step involves attack of a radical with ostensible functionality of 1 on a monomer with functionality 2. The radical is a transient species, however, and the net result of the chain of reactions is linkage of styrene units with each other so that the process is effectively polymerization of these bifunctional monomers.
3. Functionality is defined only for a given reaction. A glycol, HOROH, has a functionality of 2 in esterification or ether-forming reactions, but its functionality is 0 in amide-forming reactions. The same is true of 1, 3- butadiene.

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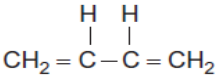

This may have a functionality of 2 or 4, depending on the particular double bond addition reaction.

4. The condition that monomers be bi- or polyfunctional is a necessary, but not sufficient, condition for polymerization to occur in practice. Not all reactions between polyfunctional monomers actually yield polymers. The reaction must also proceed cleanly and with good yield to give high-molecular-weight products. For example, propylene has a functionality of 2 in reactions involving the double bond, but free-radical reactions do not produce macromolecules whereas polymerization in heptane at 70C with an Al $(CH_2CH_3)_2CI/TiCl_3$ catalyst does yield high polymers.
5. Functionality is a very useful concept in polymer science, and we use it later in this book. There are, however, other definitions than the one given here. All are valuable in their proper contexts

CONCLUSION

In polymers, monomers are bonded by different molecular interactions. The nature of these interactions yields polymers of varying elasticity, tensile strength, toughness, thermal stability, etc. Polymers are long chain molecules with properties dominated by their chain behavior and the nature of their chemical make-up or constitution. Polymers are widely used in advanced materials. To date, the importance of polymers has been much more highlighted because of their applications in different dominions of sciences, technologies and industry.

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