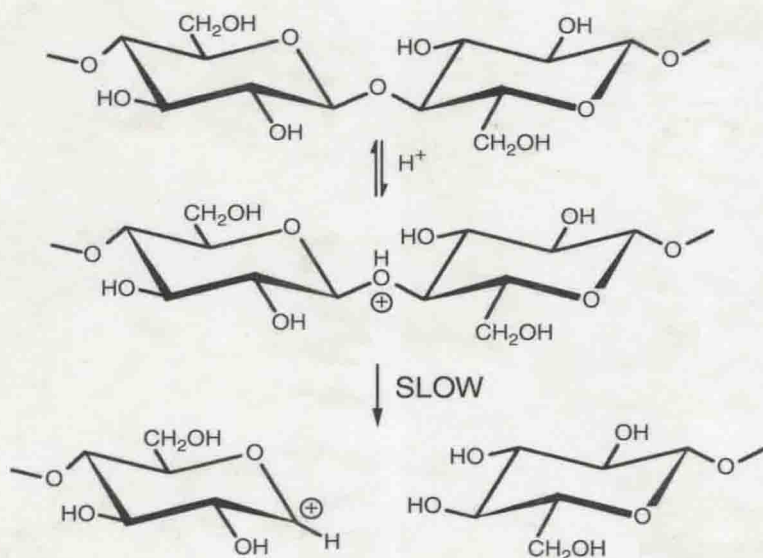


# POLYMER MODIFICATION

Principles, Techniques,  
and Applications



Acid Hydrolysis  
of Cellulose

edited by

**JOHN J. MEISTER**

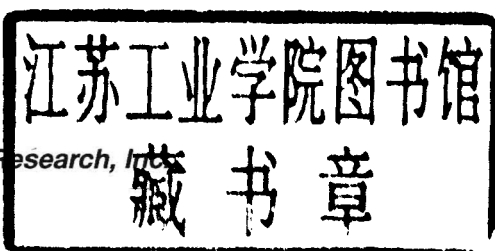
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*Center for Forest Products Research, Inc.  
Albuquerque, New Mexico*



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*To my wife, Mary Jean,  
and to R. Vincent Smith, retired manager at the Phillips Petroleum  
Company*



# Preface

This book was designed as both an advanced text for a course in polymer modification and a reference work for professionals in polymer science and engineering. In support of its use as a textbook, the work contains problems at the end of each chapter to allow students to verify their knowledge of the material in the chapter. At the end of the Introduction a series of questions are given that will allow students just starting the course to measure the expertise they possess against that which is needed to effectively utilize the materials of this book. Anyone who cannot correctly answer 80% of the questions at the end of the Introduction should read Appendix II before reading further chapters in the text. Anyone who cannot correctly answer 50% of the questions at the end of the Introduction should read Appendix II several times before reading further chapters in the text and may wish to take a good course in polymer science and engineering before utilizing this text.

The use of this book as a reference work is supported by its topical organization, the extensive references, the breadth of coverage of the chapters, and the copious index. The polymers discussed here cover the vast use of polymers today and virtually all current modification techniques.

My wife's help and support are gratefully acknowledged. I owe a great deal of my capacity to write technical material to Vince Smith and I hope that this text reflects well on his pedagogy.

*John J. Meister*

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# 1

## Introduction to Polymer Modification

**John J. Meister**

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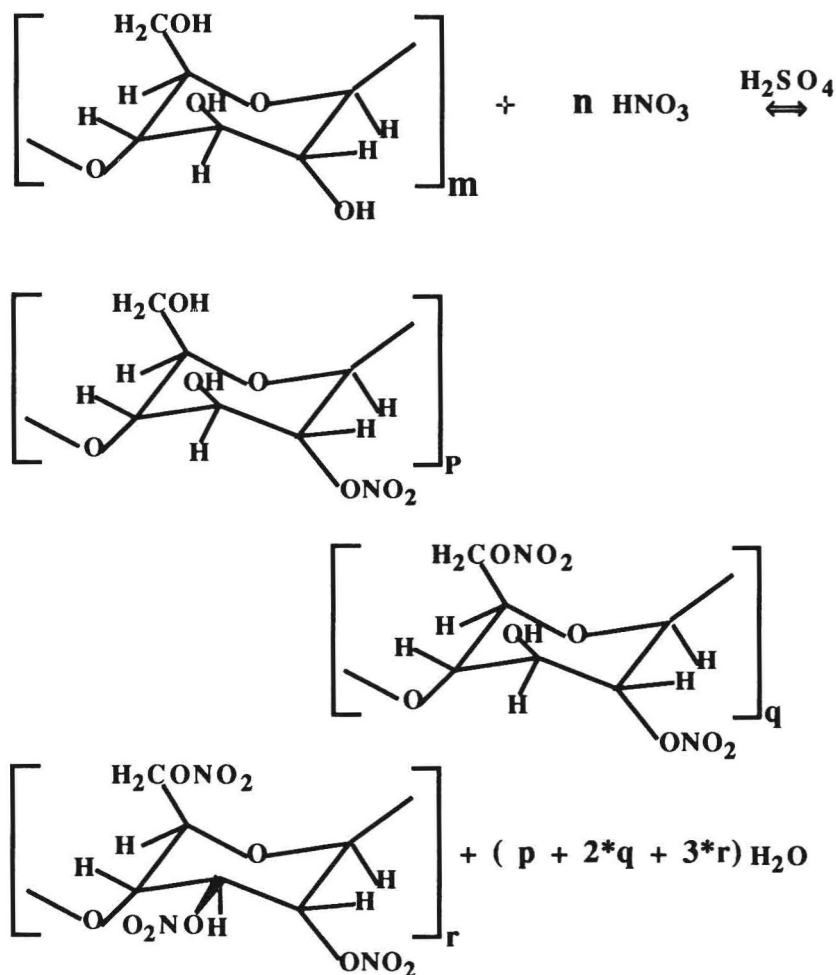
## INTRODUCTION

Polymer modification has become a major route to better polymer properties and wider polymer applicability in the 1990's. The high cost of developing a completely new polymer and the many long-term performance objectives a new polymer must meet have pushed firms to innovate by modification and blending rather than synthesis of a new monomer and polymer.

This dependence on modification is not new. Indeed, while the use of stone and clay pottery is a use of polymeric silicates, cooked meat is denatured polymeric protein, and wool or cotton fabric are woven polymers, the first commercial polymer that was not just gathered and processed from nature was a modified cellulose, gun cotton.

Gun cotton was a serendipitous discovery in about 1846 of Christian Schonbein (1), a Swiss professor of chemistry. He mopped up a spill of nitric and sulfuric acids with his wife's apron and set the washed apron to dry in front of the stove. You might say that Schonbein's discovery occurred in a flash because the apron ignited as it dried. Dr. Schonbein had created cellulose nitrate, a modified form of cellulose. This polymer was first made by Braconnot (2) in 1832 but Schonbein's synthesis method (1) could be commercialized. It is shown in Figure 1. The European political environment in which Schonbein made his discovery was one of incessant military conflict and so was highly receptive to a new explosive. Schonbein patented his discovery and allowed it to be commercialized in Austria and England. Unfortunately, cellulose nitrate was so unstable that the last plant making Schonbein's product blew itself up in 1862.





**Figure 1.** Sulfuric acid catalyzed synthesis of cellulose nitrate. The product will contain a mixture of mono ( $p$  subscript), di ( $q$  subscript), and tri ( $r$  subscript) substituted repeat units that will appear in the polymer backbone in random order.  $p + q + r \leq m$ .