$\Delta T_f = i \cdot K_f \cdot m \qquad \Delta T_f = L_{iso} \cdot c$

PHARMACEUTICAL CALCULATIONS

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8536-2

Production Credits
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Composition: diacriTech
Cover Design: Michael O'Donnell
Rights and Photo Research Coordinator: Ashley Dos Santos
Cover Image: © David Sutherland/Photographer's Choice/Getty Images
Printing and Binding: Edwards Brothers Malloy
Cover Printing: Edwards Brothers Malloy

Library of Congress Cataloging-in-Publication Data
Agarwal, Payal, 1979- , author.
Pharmaceutical calculations / Payal Agarwal.
p. ; cm.
Includes bibliographical references and index.
ISBN 978-1-284-03566-7
I. Title.
[DNLM: 1. Drug Dosage Calculations—Problems and Exercises. 2. Dosage Forms—Problems and Exercises. 3. Pharmaceutical Preparations—administration & dosage—Problems and Exercises. QV 18.2]
RS57
615.1'4076–dc23

2014023058

6048

Printed in the United States of America
18 17 16 15 14 10 9 8 7 6 5 4 3 2 1

This textbook is dedicated to:

My beloved mom, Mrs. Neelam Agarwal, and dad, Shri. Rajendra Prasad Agarwal, for making me what I am today. You have been my pillar, my stone of strength. Your love, care, and blessings for me are simply pure and divine. There is nothing more I could have asked from God; I am truly blessed to have you as my parents.

My husband, my life, my soulmate, my mentor, my love—Dr. Ritesh Jain. You mean the whole world to me!

My wonderful sister, Monalisa Agarwal, for filling my life with countless happy moments that I can cherish forever. Your trust, love, and care for me will always remain precious!

My son, Shubh, for coming into my life as a wonderful blessing of God. You have filled our lives with joy, happiness, and laughter!

Brief Contents

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Foreword

"Alle Ding sind Gift und nichts ohn' Gift; allein die Dosis macht, das ein Ding kein Gift ist."

"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison. . . . "

—Paracelsus (1493–1541)

This famous quote by the provocative Renaissance physician Philippus Aureolus Theophrastus Bombastus von Hohenheim—better known as Paracelsus—not only serves as the basis for modern dose–response theory and the field of toxicology, but also stands as a reminder of the importance of specialized practitioners with the knowledge and skill sets to accurately compound, dose, and dispense medications. The need for these types of practitioners harkens back to the time of the ancient Egyptians, when the quantitative drug formula was first used. Despite the enormous benefits in the development of the quantitative drug formula, it would be many millennia before physicians and scientists began to recognize the relationship between drug dose and response and the subsequent need for careful and precise mathematical manipulation of drug compounds.

According to the 2006 Institute of Medicine report *Preventing Medication Errors*, which is in the *Quality Chasm* series, approximately 1.5 million preventable adverse drug events (ADEs) occur each year in the United States. Many causes for these ADEs have been identified, with mistakes in the mathematical components of compounding, preparation, dosing, and dispensing of medications accounting for a significant number of them. As an important member of the healthcare team, pharmacists are uniquely positioned to ensure the safety of their patients by accurately preparing and dispensing medications, making appropriate therapeutic recommendations, and serving as the last line of defense to identify and correct potential medication-related errors before patients are negatively impacted. It is clear that knowledge and skill in pharmaceutical calculations can empower pharmacists to make these interventions and can be the difference between a positive therapeutic outcome and one that is potentially life threatening. As such, it is imperative that student pharmacists are provided with a strong foundation in the theoretical and practical components of pharmaceutical calculations.

Developed by clinical and scientific pharmacy educators, *Pharmaceutical Calculations* is an important educational tool for training the next generation of pharmacy practitioners. The text is written in a style readily accessible to students of all ability levels. The first three chapters provide students with grounding in the fundamental math skills essential for solving pharmaceutical calculation problems and an overview of the necessary skills and knowledge required for accurate weighing and measurement of pharmaceutical ingredients. Chapters 4 through 7 detail the principles involved in formulating and dispensing specific calculations for individual dosage forms while also providing application

to clinical or community pharmacy. The final three chapters discuss clinical calculations for specific patient populations, biologics, and radiopharmaceuticals.

Each chapter is structured to maximize student learning. Learning objectives written at different levels of Bloom's taxonomy set clear educational goals for readers. A list of key terms at the beginning of each chapter alerts students to important terminology and allows for the opportunity to become familiar with those terms prior to reading the chapter. A thorough review of relevant theoretical concepts and "real-world" clinical examples of therapeutic agents and dosage forms help students successfully bridge basic pharmaceutical concepts with their practical, practice-based application. A wide range of prescription-based problems accompanied by clear step-by-step solutions provide students with a valuable framework for problem solving. Numerous online and text-based resources further augment student learning by offering ample practice questions and opportunities for self-assessment. In addition, instructors will find the test banks helpful when developing assessments to gauge student mastery of the material.

With this text, Dr. Payal Agarwal and her colleagues make a significant contribution to the education of future pharmacy practitioners, pharmaceutical scientists, and pharmacy educators in the critical area of pharmaceutical calculations. It is apparent that their expertise as scientists, clinicians, and educators makes this text a relevant and useful tool for pharmacy educators and student pharmacists alike.

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Preface

Accurately performing pharmaceutical calculations to deliver the correct dose of medication to the patient population is a critical component in providing optimum patient care in any pharmacy setting. Consequently, developing a student pharmacist's calculation skills plays a significant role in building a competent healthcare professional.

Pharmaceutical Calculations is an introductory text that provides a valuable platform to pharmacy students for understanding and performing calculations that are relevant to both compounding and clinical pharmacy. This text is targeted for PharmD students as well as professional pharmacy technicians, but it can also be referenced by students pursuing their master's or PhD in pharmaceutics.

THE PURPOSE OF THIS BOOK

A number of pharmaceutical calculations textbooks written by clinical practitioners and experts in the field of pharmaceutics are currently available in the market; however, these textbooks focus too much on either theoretical concepts or mathematical calculations. In creating this textbook, the goal was to provide a good balance of both pharmaceutical concepts and calculations.

Having personally witnessed students struggling with connecting factual information to real-life pharmacy settings, our vision was to present the calculations in the form of actual prescriptions. We anticipate that this will help readers quickly grasp the concepts and make it easier to apply the information in practice. In constructing this book, we kept the following key aspects in mind:

- Present the information in a simple and easy-to-understand manner.
- Offer a large collection of both solved and test problems.
- Incorporate current and up-to-date information dealing specifically with clinical calculations.
- Provide ample prescription-based questions that demonstrate the application of these math concepts in understanding, interpreting, compounding, and dispensing actual prescriptions.

ORGANIZATION

This book divides the content typically taught in a pharmaceutical calculations course into 10 chapters. The first three chapters begin with basic math fundamentals that are the essential building blocks for any pharmaceutical calculation. These chapters also provide the necessary tools for the accurate weighing and measurement of pharmaceutical ingredients. This is then followed by four chapters in which calculations specific to the formulation and dispensing of individual dosage forms are discussed. The last three chapters deal with clinical calculations on specific patient populations, biologics, and radiopharmaceuticals.

Chapter 1, "Review of Basic Math Fundamentals," provides a quick recap of the basic yet critical math fundamentals that students learned in their undergraduate years. This chapter highlights Arabic and Roman numerals, fractions and decimals, and ratios and proportions, as well as significant figures. Keeping in mind that this chapter will serve as the student's first exposure to pharmaceutical calculations, an attempt is made at the end of the chapter to present the application of the basics in pharmaceutical settings so that students can see how the fundamentals are tied to pharmacy.

Chapter 2, "Prescriptions and Medication Orders," provides the knowledge required for understanding and interpreting the essential components of prescription and medication orders. Abbreviations and symbols commonly used (as well as restricted) in prescription writing are provided along with labeling instructions. This chapter gives the reader important tools to verify a DEA number in prescription writing and also presents a mathematical approach for calculating patient adherence to a prescribed regimen.

In any given calculation, the importance of measurement systems cannot be overstated. When dealing specifically with pharmaceutical calculations, having a thorough understanding of precision and accuracy in both solid and liquid measurements becomes critical. With this in mind, Chapter 3, "Basics of Pharmaceutical Measurement," begins with different systems of measurement that are commonly seen in pharmacy-related calculations. Although the metric system has been adopted as the official system of measurement worldwide, this chapter also provides explanations of the apothecary, avoirdupois, and household systems along with interconversions to the metric system. Although the contemporary pharmacist normally utilizes sensitive electronic scales to weigh pharmaceutical ingredients, they may need to use a manual double pan prescription balance; consequently, basic guidelines for proper use and handling are provided, along with descriptions of the official tests required for calibrating a prescription balance. The principles involved in accurately weighing solids and measuring liquids are discussed with multiple examples and an examination of the aliquot method.

Chapter 4, "Calculations for Nonsterile Pharmaceutical Liquids," covers a wide range of calculations related to the preparation and dispensing of pharmaceutical liquids that are not sterile. It includes topics such as density, specific gravity, specific volume, and their interconversion. Calculations related to different ways of expressing the concentration of a pharmaceutical liquid are emphasized, including ratio strength, percentage strength, molarity, molality, normality, parts per million, parts per billion, milliequivalent, and milliosmole. The chapter also covers concepts of dilution and alligation as well as pH, buffer, and solubility of pharmaceutical solutions.

Certain specific formulation and labeling requirements are demanded when working with solutions intended for administration through the eye, nose, or ears or that are to be injected directly into the blood or body tissue. Chapter 5, "Calculations for Sterile Pharmaceutical Liquids," deals with calculations that can be used to prepare an isotonic solution. Milliequivalent and milliosmole calculations specific to injectables are presented. Calculations for the flow rate of intravenous fluids and for understanding the necessity of reconstitution of dry powders for injectables are discussed. Dose calculations based on a patient's body weight, age, body surface area, and body mass index are provided. This chapter also exposes the students to various clinical calculations that are related to a patient's caloric and fluid needs.

Chapter 6, "Calculations for Pharmaceutical Solid Dosage Forms," focuses on various concepts related to pharmaceutical calculations for tablets, capsules, powders, and suppositories. Calculations such as geometric dilution of powders and the use of tablets and capsules in divided powders are laid out. Also, the application of the aliquot method for solids, introduced in the previous chapter, is applied for the compounding and dispensing of powders. Dosage strength calculation for tablets, extemporaneous filling and compounding of capsules, and calculations for scored and molded tablets are also provided. Calculating the displacement value of an active ingredient needed to calculate the amount of suppository base to prepare medicated suppositories and its application is illustrated at the end of this chapter.

Chapter 7, "Calculations for Semisolid Dosage Forms," features calculations necessary for the bulk preparation of ointments, creams, and pastes. This chapter also explains alligation alternate and alligation medial methods, both of which are used extensively in compounding semisolid dosage forms.

Changes in age, body weight, body surface area, or organ function necessitate dose adjustment. Consequently, Chapter 8, "Calculations Involving Special Populations," elucidates the dose calculations necessary for pediatrics, geriatrics, and patients with renal dysfunction or cancer. Chapters 9, "Biologics," and 10, "Radiopharmaceuticals," cover calculations for nontraditional pharmaceuticals such as biologicals and radiopharmaceuticals. Calculations for biological preparations such as penicillin and insulin are discussed. In addition, understanding and interpreting specific medication orders using standardized protocols for heparin dosing are presented in Chapter 9. This chapter also emphasizes calculations related to various measurement units specific to vaccines and toxoids. Calculations involving units of radioactivity and their interconversion are laid out in Chapter 10. This includes calculating half-life, mean life, radioactive decay, percentage activity remaining, and specific activity of a radiopharmaceutical.

FEATURES AND BENEFITS

Each chapter of *Pharmaceutical Calculations* features the following elements:

- **Learning Objectives** present the chapter's desired outcomes to the reader.
- **Key Terms** help the reader quickly identify critical new terms.
- **Solved Examples** provide the reader with problems as well as the steps involved in solving them.
- **Test Yourself** sections allow readers to solve problems and then check their answers at the end of the chapter.
- **Rules to Remember** provide readers with important items they need to remember for their calculations.

A workbook has been included at the back of this book that can be utilized in the classroom. The pages of the workbook have been perforated so that students can easily turn in their solutions to the instructor.

INSTRUCTOR RESOURCES

Qualified instructors can receive the full suite of instructor resources, including the following:

- Lecture outlines in PowerPoint format featuring more than 200 slides
- Test Bank containing more than 300 questions
- Instructor's Manual including a Sample Syllabus and an Answer Key for the workbook problems

To gain access to these valuable teaching materials, contact your Health Professions Account Specialist at **go.jblearning.com/findarep**.

About the Editor

Dr. Payal Agarwal has been an Assistant Professor of Pharmaceutics in the School of Pharmacy at Notre Dame of Maryland University since 2009. Dr. Agarwal received her PhD in pharmaceutical sciences from St. John's University in New York, where she specialized in industrial pharmacy. She also holds a BS in pharmacy and MS in pharmaceutics from Dr. H. S. Gour University in Sagar, India.

Dr. Agarwal currently teaches pharmaceutics, pharmaceutical calculations, and biopharmaceutics and clinical pharmacokinetics classes to first-year and second-year PharmD students. Her current research interests are oral delivery of protein- and peptide-based drugs through formulation of novel drug delivery systems.

Thus far in her career she has received prestigious awards such as the Graduate Symposium Award from the American Association of Pharmaceutical Scientists (AAPS) and the Student Scholar Award from the American Association of Indian Pharmaceutical Scientists (AAiPS). She has also won the Innovation in Biotechnology Award, sponsored by Genentech and given by AAPS at the National Biotech Conference (NBC). She has presented her research at several scientific conferences and has been a reviewer for many scientific manuscripts and book chapters.

Dr. Agarwal is a member of Rho Chi Honor Society, AAPS, NBC, AAiPS (since 2005), and the American Diabetes Association (since 2009).

Acknowledgments

The inspiration to write a pharmaceutical calculations textbook came from my first-year PharmD students in the School of Pharmacy at Notre Dame of Maryland University. Observing the struggles and challenges students experienced in their first-year pharmaceutical calculations course motivated me to create a textbook that would cater not only to the needs of students at Notre Dame, but also to the needs of pharmacy students and faculty everywhere.

As it is rightly said, "No one flower can make a garland," and this textbook is a compilation of work that has been contributed by many people. First, I would like to offer my warmest acknowledgement to my contributors—Dr. Jane F. Bowen, Dr. Morgan Culver, and Dr. Paramjeet Kaur—for providing their expertise and enriching the content of this textbook by contributing five chapters. I offer my sincere thanks to them for all their valuable ideas and input, as well as for their extremely hard work and patience that helped me fulfill my vision for this book.

I would like to show special gratitude to the reviewers for providing their constant valuable insights, thoughtful suggestions, constructive comments, and appreciation that undoubtedly strengthened this book.

I would also like to thank Dr. Himanshu Bhai Patel, RPh, for providing me with prescription examples for this book.

I offer my warmest acknowledgment to Dr. James Culhane, Chair of the Department of Pharmaceutical Sciences, and Dr. Anne Lin, Dean of the School of Pharmacy at Notre Dame of Maryland University, for their constant support, enthusiasm, and understanding on this journey, without which it would have been difficult to successfully complete the project. I would like to extend a special word of appreciation to all my esteemed faculty colleagues and staff members for providing me with their continuous help during these years at Notre Dame.

I owe my sincere thanks to all the staff members at Jones & Bartlett Learning for their exceptional work in creating this book. I am very grateful to former Acquisitions Editor Katey Birtcher as well as Teresa Reilly for giving me this wonderful opportunity to fulfill my dream of writing a pharmaceutical calculations textbook. I am very appreciative of them for having faith in me and for providing me with their constant encouragement for this project. I am grateful to Sean Fabery for his continuous support and understanding to help bring this project to reality. I offer my thanks to Rhonda Dearborn for her editorial insights in the overall process. I thank Jones & Bartlett Learning for providing me with this great learning experience.

I would like to express my sincere gratitude to all my teachers from whom I have learned so much. I thank them for inspiring and motivating me over these years.

I would like to thank all my friends and family members for their constant love and support throughout this journey. Last but not the least, I thank God, for all the blessings, and turning this humble effort into reality.

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