Finally, Eq. (15) becomes

$$t = \frac{\pi D^2 h^{3/2}}{6 c C_o A_o \sqrt{2g}} \qquad (16)$$

as the expression for the efflux time in the special case of a circular (a = b = D/2) paraboloid.

NOMENCLATURE

- A cross-sectional area of the liquid level in a tank at any time, $\mathbf{L^2}$
- A_o cross-sectional area of the drain hole or orifice, $\mathbf{L^2}$
- a length of a rectangle, edge of a regular tetrahedron, or major axis of an ellipse, **L**
- b width of a rectangle or minor axis of an ellipse, **L**
- C_o orifice discharge coefficient
- c height of a pyramid or paraboloid, **L**
- D diameter of a circle, **L**
- **F** force unit
- g acceleration due to gravity, $\mathbf{L/T^2}$
- g_c conversion factor, $\mathbf{ML/FT^2}$
- h initial height of liquid in a tank, **L**
- h_ℓ fluid head loss due to friction, **L**
- **L** length unit
- **M** mass unit
- P pressure, $\mathbf{F/L^2}$
- q liquid volumetric flow rate out of a tank, $\mathbf{L^3/T}$
- **T** time unit
- t time, **T**
- v liquid velocity, **L/T**
- x length coordinate in the horizontal plane, **L**
- y width or depth coordinate in the horizontal plane, **L**
- Z vertical elevation, **L**
- z variable elevation of the liquid level in a tank, **L**

Greek Letters

- π number pi (3.14159...)
- ρ liquid density, $\mathbf{M/L^3}$

Subscripts

- 1 liquid surface in the tank at any time
- 2 bottom of tank (at drain hole)

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ChE ***book review***

CHEMICAL KINETICS AND DYNAMICS

by Jeffrey I. Steinfeld, Joseph S. Francisco, and William L. Hase

Prentice Hall, New York; 548 pages, $48.75 (1989)

Reviewed by
Robert W. Carr
University of Minnesota

This book is a text intended for use in courses on chemical kinetics at the advanced undergraduate and graduate level. It covers a broad range of subjects in empirical (macroscopic) chemical kinetics, the kinetics of elementary reactions, the quantum state (microscopic) approach known as chemical dynamics, and the connections between them. Some background in thermodynamics, quantum and statistical mechanics, and kinetics at the level of an introductory course in physical chemistry is assumed, making it a suitable text for chemical engineering students.

The book consists of fifteen chapters and three appendices. After each chapter there is a list of references, a bibliography, and a number of problems. The references and bibliography will be useful for those seeking entry into the literature of various topics in chemical kinetics.

The book is unusually broad in its coverage, dealing with a number of subjects that are usually included only in more specialized texts, but which have now become commonplace in kinetics practice. Chapter 1 is conventional in its treatment of elementary concepts and definitions, but Chapter 2, dealing with complex reactions, goes beyond the usual presentation of analytical solutions to coupled sets of ordinary differential equations to discuss applications of Laplace transforms, matrix methods, numerical methods (Euler, Runge-Kutta, predictor-corrector) and stochastic methods. Computer programs for Runge-Kutta integration and Monte Carlo simulation are included. Chapter 3, on kinetic measurements, emphasizes modern instrumental methods for direct detection of reactive intermediates and the treatment of kinetic data. Sensitivity analysis, another subject not normally covered in introductory texts but which is of enormous help in understanding a mechanism, is introduced in this chapter.

Chapter 4 deals with reactions in solution and

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type problem, we were supplied with a minimal amount of information. Assumptions, answers , and suggestions for rather vague situations had to be made. The time to test our knowledge in a real world situation was suddenly upon us.

As the semester progressed, many hours of sleep were lost, many times tempers became short, and often the most docile student exhibited impatient behavior. The effort put forward was not wasted though; the increase in knowledge greatly outweighed the amount of time put forth towards the projects.

It is for the above reasons that I am pleased to present this final in a series of three design projects. The knowledge which has accumulated over the past two semesters will be of great importance in the years to come.

An expanded version of this paper and copies of the original problems are available from the authors.

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The authors would like to acknowledge that the concept of these individual projects or "majors" has been in existence at WVU for almost twenty years and that many faculty have contributed to its success. Most recently, we would like to recognize the contributions of A.F. Galli and W.B. Whiting.

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Chapter 5 with catalysis. The former is conventional in its coverage, while the latter introduces autocatalysis and oscillating reactions (a subject of much current interest in chemical engineering) in addition to homogeneous catalysis, heterogeneous catalysis, and enzyme reactions. These first five chapters, two hundred pages in length, comprise nearly half the book.

Chapter 6, a brief discussion of the transition from the macroscopic to the microscopic level, sets the stage for the remainder of the text. It introduces the description of reactive collisions in terms of collision cross sections and relates the cross section to the rate coefficient. Also introduced at this point are the quantum state description of reactions (state-to-state kinetics), microscopic reversibility and detailed balance, and a short discussion of the relationship between macroscopic and microscopic kinetics.

Chapter 7 discusses the role of the potential energy surface in governing the outcome of reactive events. Succeeding chapters take the microscopic approach to kinetics, covering the kinetics of elementary reactions, and chemical dynamics. A treatment of bimolecular collision dynamics and molecular beam scattering is followed by another chapter on experimental methods, this time for state-to-state kinetics. Chapters on transition-state theory (including variational transition-state theory) and unimolecular reactions are followed by one on dynamics in solution and at interfaces. Chapters 13 and 14 cover the advanced topics of the information-theoretic approach to dynamics, including surprisal analysis and the master equation. The book concludes with a chapter on applications: atmospheric chemistry, and hydrogen and methane combustion.

This book has been used for the past two years in a one-quarter course given to chemical engineering graduate students at the University of Minnesota. In the ten weeks of lectures it has not been possible to cover the entire book. The chapters on reactions in solution and dynamics in solution, catalysis (which is covered in another course), information theory, and the master equation have been omitted, and supplementary material on bimolecular collision dynamics, chain reactions, and the kinetics of combustion reactions has been incorporated. It has proved to be a satisfactory text, treating the subject at a level suitable for graduate students and giving more comprehensive coverage (particularly of modern developments) than many other texts.

For undergraduates, portions of the book could be employed as the basis for a series of lectures on kinetics that would introduce students to material of interest to engineers in a more modern vein than most chemical engineering kinetics texts. For example, at Minnesota juniors are given approximately six weeks of lectures on kinetics during the spring quarter. The first five chapters of this book, plus some selected material on rate theory from the chapters on collision dynamics, transition state theory, and unimolecular reactions (and perhaps atmospheric chemistry and combustion reactions), would provide good reading material to accompany the lectures. Students mastering this material would have an excellent foundation for future work in kinetics and reaction engineering.

Chemical kinetics in an enormously broad area. It is difficult to find a text that gives good treatment of the fundamentals of the subject, as well as coverage of subjects of interest to chemical engineers. This book is one that succeeds and can be recommended. ❐