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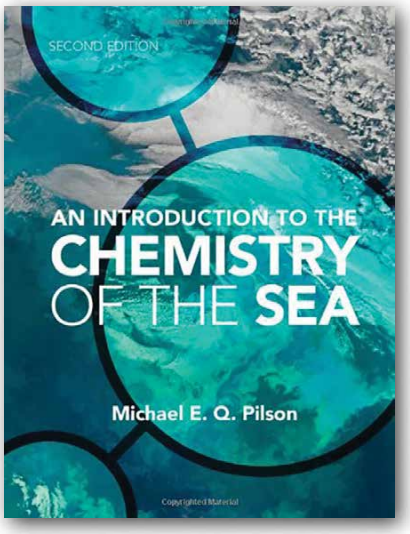
An Introduction to the Chemistry of the Sea



By Michael E.Q. Pilson, 2nd edition, 2013, Cambridge University Press, 524 pages, ISBN 978-521-88707-6, Hardcover $80.00 US

REVIEWED BY ANA AGUILAR-ISLAS

The second edition of Michael Pilson's classic textbook *An Introduction to the Chemistry of the Sea* is a welcome addition to introductory oceanography texts. This new edition, recently published by Cambridge University Press, updates advances in ocean biogeochemistry understanding and analytical techniques of the past 15 years, while keeping the beginner in mind and retaining the range of general topics presented in the first edition. It is an excellent textbook choice for introductory chemical oceanography courses, and it also provides a good resource for anyone else interested in the field. Pilson uses a direct conversational tone and integrates historical and personal notes throughout the text. The result is an informal and engaging narrative. This is one of the strengths of the textbook—making the information accessible while providing a sense of the history behind developments and practices in the chemical oceanography field.

The black and white figures are clear and well chosen to illustrate and support the material presented in the text (the figures are also available in .ppt and .jpg formats at the book's website, http://www.cambridge.org/us/academic/subjects/earth-and-environmental-science/oceanography-and-marine-science/introduction-chemistry-sea-2nd-edition). Additionally, figure captions and table notes regularly provide extensive useful information, such as experimental condition caveats, or aspects to be noted for better understanding. For quantitative discussions and practice, step-by-step calculations are often presented in boxed text, and a section with questions is included in the back of the book (solutions for instructors are available through the book's website). The text is well referenced, and 11 appendices provide information for calculations of chemical parameters and processes. Also, notes on the specific merits of suggested further reading at the end of each chapter provide a useful selection guide.

The textbook was developed from Pilson's class notes and extensive experience teaching introductory chemical oceanography. His approach is to present the complex nature of seawater while providing a foundation for understanding interactions between oceanographic processes and the chemical behavior of various constituents. It is not until the end of the book that he gives an integrated view of the flux of constituents at the boundaries. As with the first edition, the book is divided into 15 chapters that are generally short (20 pages on average), with the exception of those covering "Carbon Dioxide," "Nutrients," and "Organic Matter." The enhanced coverage of these topics results in part when the subject is "deeply intertwined with most areas of marine science," as Pilson indicates in the preface.

After providing background on chemical oceanography, its history, and a general outline of ocean circulation in Chapter 1, the following three chapters focus on fundamental seawater properties. Chapter 2 discusses water's molecular structure and resulting physical properties, isotopic composition, and fractionation, and includes a new section on clathrate compounds. Chapter 3 presents an in-depth look at the various definitions and measurements of salts in seawater and provides current standards used for calculating the density and thermodynamic properties of seawater (TEOS-10), but it does not discuss satellite surface salinity sensing. Chapter 4 introduces the concept of residence time along with the major constituents of seawater and their conservative behavior.

Chapter 5 covers Henry's law, explains the foundation for understanding the exchange of simple gases between ocean and atmosphere, exchange by diffusion, and the importance of wind speed and air injection to these processes. A short section on in situ sources and sinks is also included, as is a discussion of the complications of measuring fluxes in the real world.

Chapter 6 discusses the effect of salts on various seawater properties. Explanations of saturation state of seawater for a mineral (Ω), activity coefficients, and ionic strength are easy to

follow, and there is interesting coverage of osmotic pressure, sound absorption, electrostriction, and uncertainties in pH measurements.

Chapter 7 addresses the marine chemistry of inorganic carbon as well as issues related to anthropogenic input of CO_2. The chapter starts with a brief introduction to carbon reservoirs, continues with extensive sections on the chemistry of CO_2 and $CaCO_3$ in seawater, and ends by discussing anthropogenic perturbations to the system in context with the natural carbon cycle. Pilson does a great job in providing easy-to-follow explanations for calculating constants and inorganic carbon species, as well as in explaining related concepts such as alkalinity or the Revelle factor.

Chapter 8 covers nutrient elements. Phosphate, nitrogen, and silicon are treated separately in terms of their chemical species and cycles, while nutrient relationships are integrated into the last two sections of the chapter where concepts such as the Redfield ratio, apparent oxygen utilization (AOU), and preformed nutrients are presented. A section on "other nutrients" discusses the role of trace metals, in particular, that of iron. The chapter would have benefited from the inclusion of maps of global nutrient distributions, discussion of N*, and better integration of the role of oceanic circulation and observed distribution of nutrients.

Chapter 9 describes the distribution and chemical species of trace metals and other minor elements. The chapter begins with a short section describing sampling and analytical difficulties. Here was a missed opportunity for updating the sampling and analytical advances developed over the past decade. In the following section, brief descriptions of a suite of trace elements provide examples of various distribution types, sources, sinks, and internal cycling. Mercury and iron are presented in greater detail as special cases, while copper is examined within the speciation section. Trace elements in sediment are only briefly outlined in the last section.

Chapter 10 presents the background for tackling calculations involving nuclear transformations and for understanding the use of radionuclides as tracers. The behavior of three radionuclides from the ^{238}U series (^{234}Th, ^{222}Rd, and ^{210}Pb) is used to illustrate the quantification of oceanographic processes. A description of the use of ^{14}C for dating and the corrections necessary in the calculations are explained in the last section of the chapter. The explanations and calculations are easy to follow, and although the chapter is short, it gives an appreciation for the use of radionuclides in oceanography.

Chapter 11 introduces concepts and measurements related to the cycling of organic matter. Primary production (gross, net, new, regenerated, and export) and external sources of organic matter (riverine and atmospheric) are discussed at the beginning of the chapter. This is followed by discussions on the downward flux of particles, and on the distribution and age of dissolved organic matter. The chapter concludes by presenting characteristics of various organic compounds and some of the insights gained from their distribution.

Chapter 12 briefly presents rates of oxygen utilization, the oxidation of organic matter by electron acceptors other than oxygen, and suboxic regions. Connections to previously discussed water column denitrification and AOU (Chapter 8) might have been explicitly stated here. In the last section of the chapter, Pilson does a nice job of describing the processes that lead to anoxia in the Black Sea, the resulting profiles of redox-active elements such as manganese, and the development of varves in the sediment of this basin.

Boundary exchange is the subject of Chapter 13. Riverine input and air-sea exchange are briefly covered, while water-sediment exchange and exchanges at divergent and convergent boundaries are covered more extensively. This chapter presents calculations of water flow during hydrothermal exchange, processes that contribute to the chemistry of hydrothermal fluid, calculations of sedimentary fluxes, and diagenetic processes. The chapter concludes by discussing residence time calculations and caveats.

The last two chapters present interesting information on the extraction of chemicals from the sea and on the geochemical history of the ocean. The book is light on sedimentary processes, and a chapter dedicated to accumulation, composition, and distribution of sediments would have been a good addition.

As with the first edition, the new one offers a comprehensive and accessible foundation for studying the chemistry of the sea, and it likely will become a standard textbook for introductory chemical oceanography courses, as well as a valuable resource for anyone interested in the topic. Pilson has succeeded in his hope to provide an "overview of the whole field of marine chemistry" that "will be helpful to all who care to know something of the marine world."

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