BOOK REVIEW


Absolute age determinations based on the detection and measurement of the time-integrated accumulation of radiogenic isotopes, with varying lifetimes and abundances in natural systems, is called radiometric dating. Considering the tremendous expansion of literature due to the fundamental relevance of isotope methods to place temporal constraints in the Earth and Planetary Sciences, a timely addition to the books being used at present (Faure, Dickin, Allegre, Faure and Mensing, White), is the concise book for both nonspecialist students and researchers by Prof. K. Gopalan. A background of high school-level physics, chemistry and mathematics is the only prerequisite to follow and appreciate the subject matter which can be read also in conjunction with the existing textbooks. The choice of references in each chapter is such that the reader is introduced to the basic and original work as textbooks or research papers.

The self-contained material in the chapters of the book can be divided broadly into four sections, with Chapters 1, 2 and 3 on basics, nuclear transformations and nucleosynthesis, respectively, setting out the fundamentals of nuclear physics. Chapters 4 and 5, deal with isotopes and radioactivity and radiometric dating, whereas Chapters 6 and 7 introduce the reader to methods of mass spectrometry and isotope geochemistry and a very important brief summary on error analysis. In the last section, which can be termed as the applications part of the book, Chapters 8 and 9 are devoted to meteorites and outline clearly their link between cosmo- and geochemistry and their chronology whereas Chapter 10 summarizes the fundamental high-temperature processes that led to the chemical evolution of the earth and Chapter 11 is a succinct geological summary of the chronology of major earth events and utilizes fundamental applications of isotope systematics of Hf-W, Sm-Nd and Sr-Pb-Hf to a range of processes starting from core formation to seawater evolution.

The introductory chapters cover the basics of nuclear and atomic physics, composition of nuclides and their terrestrial and solar abundances, transformation of composition of nuclides due to natural radioactivity (feeble radioactivity), the statistical nature of radioactivity (a very important concept that students should grasp and which is simply explained), process of formation of the stable and unstable nuclides (generally termed as elements) inherited by the solar system and concludes with emphasizing that chronology actually depends on the duration of unstable nuclides produced both in stellar and terrestrial nuclear reactions, to reach a stable nuclear composition.

The most important aspects of radiometric dating are developed in a simple and novel manner, in chapters 4 and 5, that explain what isotopes and mixtures of isotopically different components mean and thereafter to the most important treatment of how radioactive isotopes and their daughter products can be used to date natural events and processes, which strictly speaking is the radioactive decay time interval being measured. Chapter 5 gives one of the most insightful explanations, in simple mathematical generalizations, of the creative transpositions and the ensuing interpretations of the fundamental equation of radiometric dating especially explaining the multistage evolution of isotope systems and model ages, parts of which were published earlier (Gopalan, K., 2015, Journal of Applied Geochemistry 17(3), 266-289).

Basic mass spectrometry is clearly explained using the configurations of modern mass spectrometer (its three components being the ion source, mass analyzer and ion detector) and analytical methods introduced that include a simple treatment on isotope dilution and mass fractionation. The chapter on error analysis starts with a well-known quote by K. Ludwig that “the uncertainty of a date is as important as the date itself” which should alert the user of geochronological data and results that an understanding of errors is critical to place limits on interpretation. Basic concepts of errors and statistics have been introduced before explaining the propagation of measurement uncertainties followed by importance of sample size and the central limits theorem and finally by a simple explanation of regression analysis and goodness-of-fit.

The final applications section is different from those given in standard texts in that each isotope system has not been examined separately, which can of course be found in the existing textbooks, but the four chapters treat the earth from a planetary perspective linking its evolution to meteorites (from the least evolved chondrites to one of the most evolved earth) and, therefore, outline the major evolutionary events and processes.

The cosmo- and geochemistry link, as deciphered from meteorites, is very well introduced that explains concepts of extinct nuclides and the formation interval and the process of nebular condensation and planetary accretion. This is taken further exploring the fullest utilization of isotope systems in chronology of meteorites, from stages 1 to 7, starting with formation interval as measured from extinct isotopes, through the formation age of meteorites, the meaning of younger meteorite ages, their parent body cooling and heating histories, their duration in space and terrestrial residence time, using Rb-Sr, Sm-Nd and U-Pb isotope systems and gas retention ages.

Chapter 10 outlines the fundamental geochemical and magmatic processes involved in the chemical evolution of the earth and this sets out the various geochemical processes from the formation of the earth to its present-day evolution as a large geochemical system. The final chapter 11 starts from where the geochemical system was understood to its isotopic evolution as a consequence of chemical processes. Here examples of the utility of different isotope systems are presented for important terrestrial events which include the core formation and its timing from the $^{182}$Hf-$^{182}$W isotope system, timing of the primitive atmosphere from the isotopes of He, $^{3}$He-$^{129}$Xe and the noble gasses, the earliest differentiation in the mantle using the $^{146}$Sm-$^{142}$Nd and $^{182}$Sm-$^{141}$Nd systems, along with $^{87}$Sr-$^{207}$Pb-$^{206}$Pb-$^{176}$Hf and $^{187}$Os isotopic evolution of the earth’s mantle. Finally isotopes of Sr and Nd are used to decipher magma sources in the mantle and constrain the evolution of seawater over time.

Of course the book has tried to balance a tremendous amount of conceptual and isotopic data on planetary and terrestrial material but that a certain amount of treatment on crustal evolution appears to be missing, which in all probability could have been deliberate, as these are well developed and espoused in existing textbooks. In my personal opinion, the simplicity and originality of the presentation in each chapter is such that the reader is introduced to the school-level physics, chemistry and mathematics is the only prerequisite.
opinion, there might have been space, in the applications section, given to the evolving fields of high-precision geochronology in orogenic belts where there is a deluge of dates given to and being used by the nonspecialist, and herein the basic concepts of understanding errors associated with dated events and, therefore, discriminating dates from ages would have served the community.

The book comes across as a reference text for all scientists and students who, although not being geochronologists, routinely use geochronological data in most of their research and fills in the need to critically understand and evaluate their data for correct and complete interpretation. The whole writing of the text has a distinct scientific flavour with the use of basic quotes at the beginning of each chapter that really set the stage to understand the contents of the following chapter, and probably could have been done only by Prof. Gopalan from his vast experience as an outstanding scientist, who initiated modern isotope studies in India, with some small personal nuggets of wisdom slipped in (what Prof Wetherhill told him that ‘an effect need not be spectacular to be significant’). The language used by Prof. Gopalan is very precise, with all conceptual treatment being mathematically supported with simple derivations where possible, and in itself is a very good example of the correct English language usage in scientific writing. There are no factual errors but only a few typographic errors in the text (e.g. on page eight mass of 2p should read 2.014652; in Table 5.2 on row three, $^{234}$Pa should replace $^{234}$Th and on row 12, $^{210}$Pb should replace $^{210}$Th) which would probably be corrected in subsequent prints. The print quality is good and simple with the figures and tables neatly depicted, as can be expected in an edition from the Cambridge University Press.

Overall an invaluable, affordable, handy text for the student and researcher and a welcome addition to the existing literature and more so which can be readily used as basic teaching material at the graduate-level by teachers at universities teaching diverse subjects like planetary science, petrology, geochemistry and paleoclimate, to name a few, who could also develop it creatively for use as an advanced text for their individualistically-styled teaching needs.

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