

Chapter 2

Goals

Richard Feynman (Feynman et al. 1963) began his famous “Lectures on Physics” with the question: *“If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words?”* His answer was: *“I believe it is the atomic hypothesis that all things are made up of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.”*

We know today that everything in the universe, the stars, the planets and ourselves are made up of only about 90 different atoms (the elements) which themselves consist of just three particles: protons, neutrons, and electrons. A 100 years ago, only physicists and chemists studied and made use of atoms, and this was regarded then as “fundamental science”. The word physics, however, is derived from the Greek word physis (ΦΥΣΙΣ) and means “nature”, or the science of matter in space and time. All the natural sciences (and applications thereof) ultimately deal with the interaction and the motion of atoms and frequently the best (and sometimes the only) way to study these interactions is to trace the individual atoms themselves.

Today there is hardly a scientific profession that does not use atomic or nuclear techniques on a day to day basis – in lasers, in specialized semiconductors, in studying the growth of plants, in magnetic resonance tomography, and so on. This book deals with yet another application: the ability to use isotopes, and in particular the radioisotopes, to permit the study of a great number of environmental processes.

Until recently, the precise measurement of small quantities of atoms was an extremely difficult task, and this impeded the development of the applications that have blossomed over the past two decades. Stable isotopes are traditionally measured by mass spectrometers and both mass resolution and precision have steadily improved, together with a reduction in sample size. Radioisotopes had been measured by radioactive decay counting; however, this is very inefficient for radionuclides with long half-lives. The invention of the accelerator mass spectrometry technique (AMS) in the late 1970s revolutionized the field, enabling the measurement of isotopic ratios as low as 10^{-14} and increasing sensitivity by

5–6 orders of magnitude. The importance of such an increase may be illustrated by an analogy from astronomy. Imagine a Greek astronomer who was observing the stars with the 5 mm wide iris of his naked eye. Switching to AMS was equivalent to giving our ancient astronomer access to the 5 m telescope at Mount Palomar.

The cosmogenic radionuclides have been generated here on Earth, in quite miniscule amounts, from time immemorial. They were created by the cosmic radiation that bombards the Earth, and they provide a record of astronomical, solar, and Earth bound events that extend far into the past. Until recently, we did not have the means to read or decipher these records. However, as a result of the analytical advances outlined above, the number of applications of cosmogenic radionuclides to understand the past and investigate the present is growing rapidly and spreading over many scientific disciplines. The number of students and scientists working with cosmogenic radionuclides is steadily increasing, and with it the need for a comprehensive overview of what cosmogenic radionuclides are, and a discussion of their potential and their (present-day) limitations.

To date, some specialised review articles, conference proceedings, and a few books have appeared dealing with cosmogenic radionuclides as tracers and as dating tools, the primary focus being on specific fields of applications with only passing discussions of the basic underlying concepts and mechanisms. The main goal of this book is to provide the reader with a comprehensive discussion of the basic principles lying behind the applications of the cosmogenic (and other) radionuclides.

Part I (Chaps. 1–3) provides an introduction to the book and outlines the goals.

Part II (Chaps. 4–8) provides the background knowledge of the properties of the cosmic radiation that will allow the reader to understand the concepts, terminology, and formulae that are used later in the book.

Part III (Chaps. 9–15) of the book is dedicated to the cosmogenic radionuclides and discusses in some detail their production by the cosmic radiation, their transport and distribution in the atmosphere and the hydrosphere, their storage in natural archives, and how they are measured. A good understanding of these basics is a prerequisite for optimal use of cosmogenic radionuclides as environmental tracers and dating tools.

Part IV (Chaps. 16–23) deals with applications of cosmogenic radionuclides. It presents a number of examples selected to illustrate typical tracer and dating applications in a number of different spheres (atmosphere, hydrosphere, geosphere, biosphere, solar physics and astronomy). The goal of this part is not to give a comprehensive overview of all the many different applications developed so far. Its aim is to give the reader an understanding of what is possible, and possibly to provide the insight and motivation to develop new applications. At the same time, we have outlined the limitations of the use of cosmogenic radionuclides, to prevent unfortunate experiences in the future.

We are aware that we are addressing a wide audience, ranging from archaeology, biophysics, and geophysics, to atmospheric physics, hydrology, astrophysics and space science. We have therefore tried to explain everything at the level of a graduate student without specialist skills in physics or mathematics. To provide

the reader with more technical details, or the derivation of a few interesting equations, we use boxes which are separated from the main text and are not mandatory in order to understand the basic ideas. We would rather bore the specialists in their own field with “trivial” matter, than to keep others from understanding important concepts they are not familiar with. For the same reason, and to make reading individual chapters easier, we provide extensive internal referencing, and occasionally some basic information is repeated briefly in the introductions to chapters on specific applications.

Finally we express our hope that this book will help the reader to achieve a greater understanding of the use of the cosmogenic radionuclides, and also to enjoy the thrill of using this marvellous technology to uncover the mysteries of the past, and the world around us as we authors do.

Reference

Feynman RP, Leighton RB, Sands M (1963) The Feynman lectures on physics. Addison-Wesley, Menlo Park, CA

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