

Preface

...energy is applied to the sample in the form of short, intense pulses, and nuclear signals are observed after the pulses are removed. The effects which result can be compared to the free vibration or “ringing” of a bell...

Eric Hahn, 1953, *Physics Today* 6, 4–9

The essence of NMR is quite simple. You place a sample in a magnetic field, apply another field, and then collect the electromagnetic wave generated by the sample. No need to ionize, crystallize, burn, or even heat up the sample. A plain-vanilla solution of a compound in water is all you need to identify the substance and characterize many of its key biophysical properties.

Unfortunately, the elegance and beauty of NMR is often lost when students open a textbook. Even the simplest introductions on NMR immediately immerse students in mathematics and theories laced with constants and concepts that lack tangible, macroscopic manifestations. For example, many textbooks begin by defining the energy of a nucleus in a magnetic field, $E = -\gamma\hbar mB_0$, a simple equation that is clear and understandable to all. However, take a closer look at this equality. Hidden inside the constants and variables are sophisticated concepts that are tough for many of us to relate to. Take “ γ ” for instance. Wikipedia defines “ γ ” (i.e., the gyromagnetic ratio) as the ratio of the nucleus’s magnetic dipole moment to its angular momentum. Riding the swings at a carnival definitely helps us to relate to angular momentum. But what exactly is a magnetic dipole moment, and why would

taking the ratio of the magnetic dipole moment and the angular moment be proportional energy? Very quickly, the theory and mathematics behind NMR plunges into ideas and phenomenon that aren't present in our macroscopic world, making them difficult to grasp, remember, and use.

In contrast to the labyrinth of equations in NMR textbooks, performing actual NMR experiments is remarkably easy. You place the sample in the magnet, set a couple of parameters, and hit "go." After a few commands at the keyboard, your spectrum appears on the screen with a peak for each hydrogen in the compound. Can't get much easier than that! So why can't the theory of NMR be that simple too?

That, indeed, is the purpose of this book—to bring the common sense and practicality of experimental NMR to the theory of NMR. To accomplish this task, we set three major goals:

1. *Preserve the simplicity of NMR:* Instead of using equations and complex formulism to explain *why* nuclei behave as they do in a magnetic field, we simply describe *how* nuclei act during NMR experiments. We minimize jargon and keep the descriptions short, pithy, and easy to understand. Students with minimal experience in chemistry and biology should easily follow the entire book. The only equations used in the main text are the sine and exponential functions.
2. *Add a hefty dose of intuition to NMR:* In place of mathematics and formulism, we use concrete analogies to which readers can relate, making concepts easy to assimilate and use. In this regard, we have created a new framework for explaining NMR experiments. Instead of trying to define "spin," we simply state that nuclei "ring" in magnetic fields like tiny bells. This bell analogy, which is employed throughout the book, has never been used to explain NMR and makes it surprisingly easy to learn advanced NMR concepts, such as dipole–dipole coupling and relaxation theory.
3. *Flatten the learning curve:* The "bell" analogy also provides a new language for discussing NMR experiments. Because this language is based on an intuitive model of NMR, students quickly master

it. In other words, this new approach flattens the steep learning curve of NMR and makes NMR accessible to students at all levels, even those with little experience in spectroscopy, quantum mechanics, or physics. Furthermore, the intuitive perspective presented in this book will help advanced students remember and integrate more mathematical explanations of NMR into their experimental designs and analyses.

The small size and fast pace of the book makes it well suited as a companion to traditional biophysics or biochemistry textbooks at the undergraduate or graduate levels. However, we hope that the book will also be useful for professional researchers in the biological sciences who are interested in collaborating with NMR spectroscopists or in garnering a better understanding of research articles that present NMR data.

Finally, one note about the style and tone of the book. The book is written to be read. Therefore, we use a light, fun style that will hopefully hold your attention from the initial descriptions of one-dimensional experiments to the final pages covering CPMG sequences. We hope that you enjoy it!

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