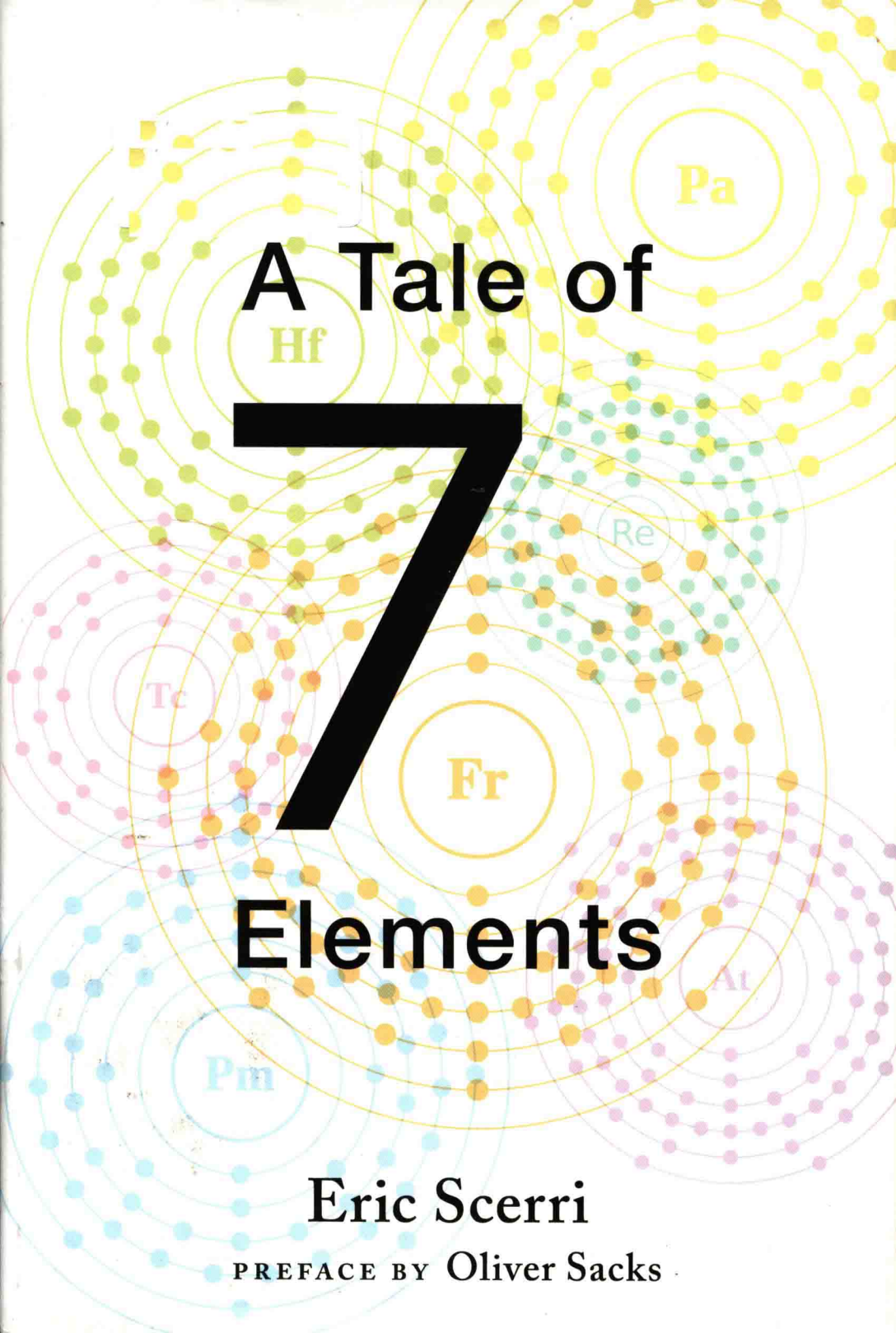

A Tale of 7 Elements

Eric Scerri

PREFACE BY Oliver Sacks

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A TALE OF SEVEN ELEMENTS

Dedicated to my mother, Ines Scerri,
on the occasion of her 90th birthday
and to my wife Elisa

Also dedicated to the centenary of
Henry Mosley's landmark 1913
article on an x-ray method for
ordering the elements

PREFACE

The first thing to be said about *A Tale of Seven Elements* is that it is wonderfully rich and full, imparting a huge range of knowledge not only on the properties of each of these elements but on the nature of science, the meaning of discovery, and how these are deeply entwined in their social and political context.

In his earlier book *The Periodic Table*, Eric Scerri concentrated on the history and philosophy of periodic systems and the many forms these have taken since Mendeleev's original table. It was evident to Mendeleev that there were gaps or holes in the Periodic Table, and he boldly predicted the discovery of several as-yet-undiscovered elements to fill these gaps. But it was only in 1913, with Moseley's demonstration that the elements had integral atomic numbers that one could confidently say that, of the 92 elements up to uranium, just seven were missing: those with the atomic numbers of 43, 61, 72, 75, 85, 87, and 91.

Scerri expands here on the stories of these elements, which were painstakingly isolated between the First and Second World Wars. These seven elements—technetium, promethium, hafnium, rhenium, astatine, francium and protactinium—are nearly all tantalizingly elusive and difficult to isolate. Four of them are intensely radioactive and exist in only trace amounts, if at all, in the Earth's

crust. Their discoveries involved intricate stories of epic labors, inspired detective work, scientific passions, collaborations, competitions, and hopes repeatedly raised and dashed.

Scerri is particularly interested in the bitter and protracted disputes over priority that often arose with these seven elusive elements, and how partisanship and national pride, intensified by the demands of war, inflamed these disputes. What constitutes "discovery"? How do we define "priority"? With so many researchers looking for the same few elements, much is left to chance, to the lucky hunch, to national rivalries, to personal ambition.

Scerri's vivid storytelling, and the letters and journals he quotes, allow us to see chemistry, and science generally, as an essentially historical enterprise—a human adventure that shows the best, and sometimes the worst, of human nature. As a boy I read Mary Elvira Weeks' classic *Discovery of the Elements* with great delight. Now, seventy years later, I get the same sort of delight from *A Tale of Seven Elements*, and I think that it, too, will become a classic.

Oliver Sacks, March, 2013.

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INTRODUCTION

Over just the past four or five years, the periodic table has become far more than simply a scientific icon. It is fair to say that it has captured the public imagination like never before, in addition to becoming an icon of style and an icon of design used to market all kinds of products. Part of this explosion of interest has been spawned by the growth of the Internet. For example, there are now hundreds of YouTube videos featuring attempts to explain the history of the periodic table or Tom Lehrer's song of the elements sung by anything from two-year-old children to established movie actors. There have been several popular books on the subject as well as iPhone and iPad applications.[1] Every day or so, it seems, sees the invention of a new periodic table of some particular domain. Two of my own particular favorites are the periodic table of guitarists and of jazz music.[2] Even fine artists and advertisers have embraced the periodic table, sometimes transforming it in ways that are almost unrecognizable. In addition, there are websites dedicated to the variety of scientific periodic tables that are continually being devised by professionals and amateurs alike. We should also not forget what my friend and fellow periodic table author, John Emsley, has written about the table:

> As long as chemistry is studied there will be a periodic table. And even if someday we communicate with another part of the universe, we can be sure that one thing that both cultures will have in common is an ordered system of the elements that will be instantly recognizable by both intelligent life forms.[3]

The present book is aimed at readers who are interested in digging a little deeper into the science of the elements and the periodic table. The writing of the book has been motivated by a number of factors. It came about as a result of wanting to write a follow-up book to my book on the periodic table.[4] One day while reading, I rediscovered an interesting paper by Vladimir Karpenko on what he calls "spurious elements," meaning elements that were announced but later turned out to be incorrect for a variety of reasons.[5] This article reminded me of an ongoing controversy concerning element number 43 and the fact that Professor Fathi Habashi, a metallurgist based in Quebec City, had written to me to point out that I had made an error in my book when briefly discussing the discovery of this element. Professor Habashi sent me a copy of a letter he had published in the *Journal of Chemical Education*.[6] In it he had pointed out that the work of Van Assche and Armstrong, in their attempt to rehabilitate the claim made by the Noddacks in 1925 for having isolated element 43, was in fact untenable.

Within a couple of days, it suddenly came to me. I would write a book to examine this case as one of the seven elements, which represented the missing gaps in the periodic table after Moseley had established his elegant method for "counting" the elements. Another of these seven elements is hafnium (# 72), on which I had written a couple of papers and whose isolation was also a controversial issue.

In addition, another interesting "element" emerged, if you will excuse the pun. I realized that of the seven elements in question, all of them rather exotic (technetium, promethium, hafnium, rhenium, astatine, francium, and protactinium), three or possibly four of them had been first isolated by women (Meitner, Noddack, Peyer). And if I were to begin my story a few years earlier, I would need to include the even more famous Marie Curie, who quite definitely isolated two elements, polonium and radium. Although it is something of a truism that women were and still are highly unrepresented in the sciences, the discovery of the elements has been one area where they have been rather influential, even if they have not always received

their due credit.[7] But the idea of the seven elements that are rather nicely delineated from the others, as I will explain, made me decide to go with the idea of "A tale of seven elements."

I should expand a little further what I mean by the seven missing gaps in the periodic table. I am referring to the fact that after Moseley had developed his method, which will be discussed in due course, it became clear that there were seven elements yet to be isolated among the ninety-two naturally occurring elements from hydrogen (#1) to uranium (#92).[8] Now again, this apparent simplicity is somewhat spoiled by the fact that, as it turned out, some of these seven elements were first isolated from natural sources following their being artificially created, but this raises several more issues that are best left to later sections of this book. The fact remains that five of these seven elements are radioactive, the two exceptions being hafnium and rhenium, the second and third of them to be isolated.[9]

It could be said that there were many more than seven gaps in the periodic table since a remarkable further twenty-six elements, lying beyond uranium, have been discovered and have taken their places in the periodic table.[10] Indeed, one of these elements, neptunium, was synthesized before the seven gaps within the elements 1–92 had been filled. These synthetic elements had not even been envisaged at the time when Moseley devised his method. Their discovery, or more accurately their creation, will be discussed in the last chapter of the book.

So given this somewhat arbitrary decision to begin with the above-named seven elements, I am nearly ready to begin the tale. But first I should say something about scientific stories. There is now a growing literature on the importance of stories and narrative in science as well as in science education.[11] Given my long-term interest in the history of science, and my growing interest in science stories, I knew I had arrived at an interesting topic for a book. I can only hope that you will agree.

What remained was the question of the order in which to consider these elements. Should I simply follow an alphabetic order

as done in the excellent books on the elements by Emsley and by Stwertka?[12] Should I take the more naturalistic approach of following the order of increasing atomic number, especially given the importance of atomic number in actually identifying the remaining seven elements in the periodic table? Or, given the historical dimension of this project, should I follow the chronological order of the seven elements' isolation?

After much thought, I decided to follow a historical order of the discovery of the seven elements, starting with protactinium in 1917 and ending with promethium in 1945 (fig. 0.1).

This period, therefore, roughly spans the two world wars. In some cases the state of war that existed had a very direct influence on attempts to isolate some of the seven elements. This is true of protactinium, for example, the first of them to be isolated. In 1916 its discoverer, Lise Meitner, writes of the problems she encounters in purchasing even the most basic items of laboratory equipment:

> Dear Herr Hahn!
>
> The pitchblende experiment is of course important and interesting but you must not be angry with me if I cannot do it right now...I have ordered the vessels for our actinium experiments, will get them in a few days and will begin right away... Be well and

Meitner	Hevesy	Noddacks	Segrè	Perey	Segrè	Marinsky
91	72	75	43	87	85	61
Pa	Hf	Re	Tc	Fr	At	Pm
1917	1923	1925	1937	1939	1940	1945

FIGURE 0.1 The seven elements in chronological order of their official discovery, including names of most senior discoverer and atomic numbers.

> please don't be angry about delays with the pitchblende. Believe me, it is not because of lack of will, but because of lack of time. I can't very well do as much work alone as the three of us did together. Yesterday I bought 3 meters of rubber tubing for 22M!! I got quite a shock when I saw the bill.[13]

In the case of the second war, the discovery of nuclear fission, also by Meitner and her associates, quickly led to the development of the nuclear weapons program and bringing the war to a close. Nuclear research also led to the development of particle accelerators. And it was by using a particle accelerator that some of the remaining seven elements were first identified, such as promethium in 1945, as World War II was drawing to an end. It goes without saying that scientific discoveries occur within a social and political context and the discovery of the seven elements is no exception to this trend. Moreover, the twenty-six elements that lie beyond uranium have all been

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	**Tc**	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	**Hf**	Ta	W	**Re**	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	**At**	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn		Fl		Lv		

La	Ce	Pr	Nd	**Pm**	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
Ac	Th	**Pa**	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No

FIGURE 0.2 Positions of the seven elements (shown in bold letters) on a medium-long form periodic table. The elements in this and many following tables include all the elements known today.

synthesized using accelerator technology of one form or another, as will be described.

This book is primarily about the final seven elements to be discovered among the first ninety-two elements that I propose to call the "infra-uranium elements" by contrast to those beyond uranium or the transuranium elements.[14] These elements appear in all parts of the periodic table, as can be seen from fig. 0.2.

The Nature of Science and Priority Disputes

Whereas theories and concepts that appear in textbooks are presented as being fully formed, real science is in a constant state of flux. When science is reported in the press, one seldom hears of the errors that led up to a discovery. In fact, actual science is full of mistakes and wrong turns. We don't ever reach the "truth." The best we can hope for is an approach to the truth, perhaps in an incremental fashion, meaning that current science is necessarily incorrect.

To better understand science is to face up to the historical twists and turns and the mistakes. Moreover, the practice of science often involves struggles between individuals or teams of scientists trying to establish their priority, not because scientists are egotists, although some are, but because scientific society rewards the winners and those who can boldly assert their claims. In the search to discover elements, priority disputes have frequently occurred and in some cases continue to occur to this day. One of the most bitter priority issues involved the discovery of element 72, which was eventually named hafnium as we will see.

Heated arguments and protracted debates, often with nationalistic undertones, are part of science whether we may like it or not. In fact, scientific knowledge as a whole might be said to benefit from the fierce scrutiny to which new claims are subjected, even if the individuals involved in the process may suffer in the process. Scientific knowledge, as it develops, is not in the slightest bit interested in the feelings of individual scientists. What matters is progress in