# Strike it Lucky

**The 13th Element: The Sordid Tale of Murder, Fire, and Phosphorus**. By *John Emsley*. John Wiley & Sons Ltd., New York 2000. viii + 27 pp., hardcover $ 24.95.—ISBN 0-471-39455-6

Phosphorus is a key component of all living things, being a constituent of DNA (deoxyribonucleic acid) and ATP (adenosine triphosphate). Also, every gardener is familiar with the three-numeral fertilizer formulation expressing the analytical percentage by weight of the three major plant nutrients (N: total nitrogen; P: available phosphoric acid as $P_2O_5$; and K: soluble potash as $K_2O$).

The thirteenth element to be discovered, phosphorus, was preceded by the elements known to the ancients: carbon, sulfur, copper, silver, gold, iron, tin, mercury, and lead; and the later-discovered antimony, arsenic, and bismuth. John Emsley, an award-winning freelance writer, and science writer in residence at Cambridge University, makes use of triskadekaphobia (fear of the number 13) in his title to lend a sinister aspect to his "first biography" of this eerily luminescent element.

Emsley's most recent honors include the 1995 Rhône-Poulenc Prize for best science book of the year (*The Consumer's Good Chemical Guide*; G. B. Kauffman, L. M. Kauffman, *Angew. Chem.* **1995**, *107*, 2778; *Angew. Chem. Int. Ed. Engl.* **1995**, *34*, 2659) and the Royal Society of Chemistry tertiary chemical education award "for making chemistry popular to a wider public both nationally and internationally." He is well qualified to write a book on the chemistry of phosphorus, for he received his PhD degree in that subject (1963) from the University of Manchester. While collecting material for a book (J. Emsley, D. Hall, *The Chemistry of Phosphorus*; Harper & Row: London, 1976), he found many human-interest stories unsuitable for an academic textbook but ideal for a popular-science article, which he wrote for the *New Scientist* magazine. This led to a talk with demonstrations for Britain's "Molecule Theatre." He received numerous invitations to repeat the talk. He transformed it into a script for a program, "The Shocking History of Phosphorus" (the title for the British edition of the book), broadcast on BBC Radio 4 in September, 1992, which won a Glaxo Award for popular-science broadcasting and a Sony Award for memorable radio programs. During this time he accumulated many of the anecdotes that make this book (his seventh) so entertaining, engaging, and fascinating.

Intended for the general reader, but equally suitable for the scientist, Emsley's book presents in 14 chapters the 300-year history of the element whose name is derived from the Greek words meaning "bringing light," with an emphasis on curious, bizarre, and horrific events and in the context of its multifaceted role in human history. He begins his account with Hamburg alchemist Hennig Brandt's 1669 isolation of phosphorus from urine. Hoping that the substance might be the philosopher's stone, Brandt kept his discovery secret for six years. The toxic substance was soon advertised as a panacea for all sorts of diseases, especially mental conditions, and it appeared in 18th-century pharmacopoeias before it was considered "the devil's element" that caused more curses than cures. Emsley continues his tale with a panorama of the activities of alchemists, apothecaries, scientists, entrepreneurs, charlatans, and assorted characters, most of whom are brought to life in thumbnail sketches or detailed portraits.

Emsley devotes three chapters to the phosphorus match, nicknamed the lucifer, which Victorian philosopher Herbert Spencer called "the greatest boon and blessing to come to mankind in the nineteenth century." However, in keeping with his goal to present both sides of the history of phosphorus—the good and the bad—Emsley considers in great detail the social, labor, and medical problems involved in the match industry.

The women ("match girls") and children employed to manufacture matches endured dangerous and unbearable working conditions and eventually contracted phosphorus necrosis ("phossy jaw"), a painful, corrosive, and sometimes fatal disease attacking the teeth and gums. The use of white phosphorus in match-making was finally outlawed by the Berne Convention of 1906 and signed by all countries except the United States. In Great Britain, the country to which Emsley devotes the most space in his stories, Parliament passed a law in 1908 making phosphorus matches illegal. Emsley also discusses non-phosphorus friction matches, first manufactured by the English surgeon and pharmacist John Walker in 1827, as well as safety matches.

Emsley describes the horrors that civilians faced in World War II, when attempts were made to destroy entire cities with phosphorus bombs. For example, he chronicles day by day the incendiary bombing, appropriately codenamed "Operation Gomorrah" (July 24-August, 1943), of Hamburg, Germany's second largest city and largest seaport and ironically the hometown of the element's discoverer. From one of the many "boxes" which Emsley scatters throughout his book to present data and information in an easily assimilated format we learn that the Allies' raid resulted in the death of at least 37 000

persons and the destruction of an immense amount of property. Although dropping phosphorus bombs on civilians is not likely to occur again, he concludes that "no other substance can produce the dense smoke of phosphorus pentoxide… [and] phosphorus will continue to be part of the armoury of all armed forces in the foreseeable future."

Emsley depicts the development of some of the most deadly poisons known—nerve gases including sarin, soman, tabun, and "the ultimate nerve gas" VX as well as their antidotes. He also discusses organophosphate insecticides (OPs). He also describes a number of famous cases of poisoning, and he surveys the production of phosphorus from the 18th to 20th centuries. During the second half of the last century its peaceful use in making phosphates for detergents sent its production soaring to more than a million tons per year.

After detailing several disasters involving phosphorus, Emsley considers the phosphate cycle in nature that governs all life on earth. He surveys the development of phosphate fertilizers including "superphosphate" and "triple superphosphate", emphasizing the contributions of Justus Liebig, John Lawes, and Henry Gilbert. He quotes Isaac Asimov: "We may be able to substitute nuclear power for coal, and plastics for wood, and yeast for meat, and friendliness for isolation—but for phosphorus there is neither substitute nor replacement."

In the chapter "Oh, Shit!" (Emsley favors attention-getting titles) he deals with the problems that phosphorus causes when human and animal sewage as well as phosphate food additives and detergents enter our environment. Eutrophication refers to aquatic systems oversupplied with nutrients which results in perpetual algal blooms that make them green, smelly, devoid of fish, and unfit for drinking or recreation. Although phosphates were first thought to be responsible for such environmental disasters, they were later vindicated. When used as fuel, chicken manure (hence the chapter title) with its high phosphate and high energy content can generate electricity and yields an ash containing as much as 25% phosphate.

In a final, intriguing chapter Emsley discusses alleged cases of spontaneous human combustion, which he calls "probably a myth" that he attributes to external sources of ignition and the "wick effect." After reciting all the horrors that preceded it, his succinct four-page epilogue, "the Devil's Element," which summarizes the entire book, is optimistic. He attributes the damage and misery that elemental phosphorus has caused to its flammability and toxicity, but he concludes that the damage caused by the human exploitation of phosphates and other compounds is due to an entirely different set of properties. He claims that current regulations will ensure that only completely safe compounds will be allowed, and he predicts "a golden future" for the element.

A three-page appendix summarizes important numerical data on phosphorus and discusses its allotropes. A 10-page list of sources, arranged according to chapter and ranging from 1677 to 1998, serves as a list of references and suggestions for further reading. A detailed index (11 double-column pages) facilitates location of material.

Emsley occasionally uses formulas, but he writes equations in terms of words. He possesses a felicitous, almost poetic way with words, and he makes chemistry come alive with vivid images, for example, "when we strip away [phosphorus'] protective cage of four oxygen atoms and expose the element itself, we release a tiger." A lapse in grammar, "The average person has in *their* body about 3.5 kg of calcium phosphate" (p. 257), is an exception rather the rule.

Although Emsley often considers phosphorus as "nature's nefarious element," he generally presents a balanced blend of its positive and negative aspects, and he uses it to praise the benefits of chemistry in everyday life and to dispel any exaggerated fears about its environmental impact. I heartily recommend this modestly priced volume to both scientists and nonscientists.

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**The Nitro Group in Organic Synthesis.** By *Noboru Ono*. John Wiley & Sons Ltd., New York 2001. 372 pp., hardcover £92.95.—ISBN 0-471-31611-3

This book focuses on the preparation, reactivity, and transformation of organic nitro compounds. It summarizes the recent important advances in organic synthesis using nitro compounds up to the year 2000. A large number of equations, schemes, and tabulated data are presented, and the yields of the products in almost all reactions are shown. Plenty of references at the end of each chapter allow fast access to the relevant original publications. However, as a result of the limited size of the book only a few principles and mechanisms are discussed.

After a short introduction, the preparation of nitro compounds by nitration of hydrocarbons and by oxidation of amines and oximes is outlined in Chapter 2. Chapter 3 describes the nitro-aldol (Henry) reaction. In particular, recent progress on the catalytic asymmetric Henry reaction is included. Chapter 4 is devoted to the utilization of nitroalkenes and nitroalkanes as Michael acceptors and donors, respectively. Stereoselective Michael reactions are also summarized.

Chapter 5 deals with methods for regioselective C-alkylation, acylation, arylation, and heteroatom incorporation. In particular, the carbon–carbon bond forming reactions by radical substitution and by a transition-metal-catalyzed reaction are described. In Chapter 6 the transformation of nitro compounds into carbonyl compounds and nitrogen-containing compounds such as nitrile oxides, nitriles, and amines is discussed. Chapter 7 highlights the nucleophilic substitution of nitro compounds mediated by radical and ionic processes and elimination of $NO_2$ from $R-NO_2$ giving $R-H$ or alkenes. Chapter 8 begins by outlining the methodology and stereochemistry of cycloaddition using nitro compounds, then continues with a discussion of recent applications in the total synthesis of natural products.

The penultimate chapter deals with nucleophilic aromatic substitutions on nitro-arenes where the nitro group behaves as a leaving group, and also describes the NASH reaction (nucleo-

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