From Transuranic to Superheavy Elements: A Story of Dispute and Creation, Helge Kragh, Springer Nature, Switzerland, 2018, viii + 106 pp, ISBN 978-3-319-75812-1, $69.99

Plenum enuntiatum: I, the reviewer, am an actor in the "dispute" but will confine my comments as much as possible to the published perspective.

Author Helge Kragh is a prolific and well-known Danish scholar in the history of science with advanced degrees in both philosophy and science and an academic career at Aarhus University and the Niels Bohr Institute. A timely contribution for the International Year of the Periodic Table, this Springer Brief on transuranics and superheavy elements is reasonably complete in its coverage of the international intrigue, competition, duels and eventual cooperation in extending the reach of the Periodic Table by twenty-five percent. In keeping with the philosophy behind the Springer Briefs, this is accomplished in just 80 pages of text including an unobtrusive few figures and tables. The presentation proceeds on a logical timeline with a concise recast of the discovery of radioactivity over a century ago and continuing through the official public disclosure of *oganesson*, element 118 just below *radon* on the Table.

Much of the description of the six-decade trek from transuranics *neptunium* through *oganesson* is presented in a crisp, clear manner. Initial production of *einsteinium* and *fermium* (99 and 100) as the result of an early H-bomb test (now known as a thermonuclear fission-fusion-fission bomb) is the most unusual of the production routes. Syntheses of the elements are not nearly as interesting as the disputes that arose as a consequence of human competitive spirit. Particular emphasis of the story is placed on the more remarkable element discoveries starting with *nobelium* whose discovery by a Swedish-led team was found later to be unsupported and reassigned to the Soviet Union, but with no name change.

The highpoint of the history is the extensive discussion of competing claims between Soviet and American researchers and the battle for names understandably tied to priority for those discoveries. For two decades, element 104 was known both as *rutherfordium* and *kurchatovium*, Igor Kurchatov being the "father of the Soviet atomic bomb project." A subsidiary conflict for element 105 between *hahnium* and *dubnium* was also in play. Attempts by international societies to resolve the conflicts were ineffective, arguably because the quarrel was during the peak of the Cold War. Most formal among the conciliation attempts was the formation of the "TWG," the Transfermium Working Group in 1991, a nine-member panel appointed by the International Union of Pure and Applied Physics (IUPAP) and the International Union of Pure and Applied Chemistry (IUPAC). Criticism of that group's constitution, charge, integrity, conclusions and methodology are accurately covered. The 1992 decision on priorities of discovery assignments, the entitlement to name a discovery, and the acceptability of names was brutally condemned by the nuclear science community although that point is not made clearly enough in Kragh's history. The TWG did do a great service by constructing a formal set of criteria for the discovery of new elements. Imposing these criteria allowed the transuranium element numbers through atomic number 109 to be acknowledged as "discovered" and, with the exception of 106, named. Kragh also notes the neologism "transfermium wars" (coined by this reviewer in 1994) as an expression of the battle over assigned but disputed discovery priorities for the transuraniums, but that was not exactly the case. Transfermium Wars was a phrase introduced to express the outrage felt by all competing discovery institutes and researchers with IUPAC, IUPAP and the TWG over their intrusive diktats on priority and name assignments. Furthermore, the situation was not helped by IUPAC's insistence that unproven element names should be based on a greco-latin three-letter system advocated by J. Chatt in 1979, *ununennium* (Uue) being an example of the only approved name (and symbol) for element 119. This silly system was scorned by the entire nuclear physics and chemistry communities and Kragh does a good job of recognizing its rejection (something IUPAC still does not accept).

And then we get to "*seaborgium*", named in 1994 by the Berkeley heavy element group in honor of then 82-year old Glenn Seaborg, nuclear chemistry behemoth, figuratively and literally. (Seaborg was six feet three inches tall.) Kragh tells us about the attempts of IUPAC to asphyxiate naming of a new element after a living person, a denial of discoverers' rights never before implemented as Kragh clearly describes, although, as Kragh notes, *einsteinium* was named *ante mortem* by the discovery group. This exclusion catalyzed the "war," there being no such obstructive rule in existence (1). Furthermore, IUPAC proclaimed itself the sole body empowered to name a new element in transparent defiance of well-established tradition. Part of the untold history is that this arrogant move by IUPAC was nearly their undoing as an effective international science cooperative.

A beneficial outcome of all this disruption was formation of a new oversight group, the "JWP," Joint

Working Party on the discovery of new elements. "Joint" because it was convened in collaboration between IUPAP and IUPAC. The JWP was chaired by this reviewer for its four incarnations between 1999 and 2016. Kragh did err on the composition and chairmanship of the JWPs in his presentation. Furthermore, there is little recognition of the JWP's deep reliance on the existing (1991) criteria as guidance in concluding their recommendations.

There is a hint of bias (pro-physics) in the author's testimony, but this does not detract in any significant way from the history although it is somewhat irksome to this chemistry chauvinist. In noting that chemistry Nobel laureate Edwin McMillan was not a chemist (he co-discovered the first transuranic, *neptunium*, with Philip Abelson using entirely chemical techniques), Kragh continues to buttress that perceived slight by citing other laureate "physicists" also so miscategorized: Rutherford (yet with an undergraduate degree in chemistry), Marie Curie (a chemist), Francis Aston (who did organic chemistry research), Peter Debye (chair of the Cornell University Chemistry Department), and Gerhard Ertl (surface physical chemist and winner of the Wolf Prize in Chemistry). Kragh refers to "physicist" Lew Keller of the Oak Ridge Transuranium Institute whose training was actually in biochemistry. This reminds me of the continued reference over the past two decades to solar neutrino Nobel Laureate in Physics Ray Davis Jr., as a physicist when he was, in fact, a physical chemist.

There are some curious errors in the work. For instance, "ms" is correctly used in half life values for "milliseconds," but paradoxically, "meV" is incorrectly employed multiple times for "mega (or million) electron volts" rather than the conventional "MeV." A formula on p 64 relating fission half life to Z^2/A is wrong.

The final chapter on philosophical issues is lucid and thought-provoking, discussing the meaning of "discovery," of "element," and of the controversial territorial conflict between chemistry and physics over superheavy elements. The latter should irritate the chemistry readership and hearten some physicists. The discussion, though, is an excellent way to exit the story (for now).

Among unfortunate omissions is speculation on the probable existence of superheavy elements in nature as a result of neutron star collisions and black hole collisions, a surprising oversight considering the author's background in astronomy and cosmology. The index is inadequate and the many acronyms will prove irksome to the nonexpert reader. Al Ghiorso's partially successful early attempt to synthesize element 110 is not mentioned and there is a missed opportunity to explore Amnon Marinov's unconvincing yet intriguing claims for superheavy element discoveries through $Z = 122$ in more detail.

This reviewer was disappointed in the author's reliance on secondary sources rather than original references with many citations extracted from other historical reviews. Finally, an alternative publication (270 pages, Bloomsbury Sigma Press) by Kit Chapman, *Superheavy* has also just been released and covers the same territory but with a greater emphasis on personal stories, conversations, site visits and character insight.

The History of Science and Technology series has 17 titles so far. A companion Springer Briefs series on the History of Chemistry is edited by HIST chair-elect Seth Rasmussen and has 21 titles to date. The Series are an elegant concept and this reviewer looks forward to further publications.

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Reference

1. This is the equivalent of the following seasonally appropriate fable: Knute Rockne, Notre Dame football coach and chemist, invented and deployed the forward pass. Imagine what the sport would be like today if the opposing coach had then successfully challenged the forward pass insisting it was not allowed despite there being no rule against it!