Rev. CENIC Cienc. Quím.; Vol. 53. Número Especial. 018-037 Año. 2022. e-ISSN: 2221-2442.

REVISION BIBLIOGRAFICA

Frederick Soddy (1877-1956) – The Most Outstanding British Chemist of the First Half of the XX century (To the 145 th Anniversary of His Birth)

Frederick Soddy (1877-1956) - El químico británico más destacado de la primera mitad del siglo XX (Al 145 aniversario de su nacimiento)

Aleksander Sztejnberg[a, *] (0000-0003-2443-763X)

[a] **University of Opole, Oleska.**
* a.sztejnberg@uni.opole.pl

Recibido: 14 de julio de 2021; Aceptado: 28 de enero de 2022;

ABSTRACT
Frederick Soddy (1877-1956) was the most prominent chemists of the first half of the 20th century. He is known for his numerous papers in the field of radiochemistry. He was the laureate of the Nobel Prize in Chemistry for 1921. The purpose of this paper is to familiarize readers with the important events in the life of Soddy and his research activities, in particular with selected results of his experimental studies as well as with his selected publications. In addition, his writing activity was described, in particular his books, well known in various countries, were presented.

Keywords: J. A. Chaptal, Applied chemistry, Chaptal's textbooks on chemistry, French – XVIII-XIX centuries.

RESUMEN
Frederick Soddy (1877-1956) fue el químico más destacado de la primera mitad del siglo XX. Es conocido por sus numerosos trabajos en el campo de la radioquímica. Fue galardonado con el Premio Nobel de Química en 1921. El propósito de este artículo es familiarizar a los lectores con los acontecimientos importantes en la vida de Soddy y sus actividades de investigación, en particular con los resultados seleccionados de sus estudios experimentales, así como con sus investigaciones. Publicaciones Seleccionadas. Además, se describió su actividad como escritora, en particular se presentaron sus libros, muy conocidos en varios países.

Palabras claves: Frederick Soddy, Isótopos, la ley de desplazamiento de Soddy-Fajans, Premio Nobel, Gran Bretaña - siglo XX.

INTRODUCTION

The important events in the Soddy's life

Frederick Soddy (Figure 1), was born at Eastbourne, on Sptember 2, 1877, and he was the youngest son of Benjamin Soddy, a corn merchant (Fleck, 1957, p. 203; Krivomazov, 1978, p. 16), and his wife Hannach Soddy ("The University of", n.d.a). She died when he was 18 months old (Kauffman, 2013, p. 30).

He was educated first at private schools and then in 1892, at he age of 15, he entered Eastbourne College. Two years later, he enrolled at the University College of Wales in Aberystwyth. In 1895, he reeived a science scholarship at Merton College, Oxford. He studied chemistry there until 1898 and graduated with first-class honors B.A. (Davies, 1992, p. 353). In 1898-1900, he conducted independent chemical research at Oxford.

In 1900, he moved to Canada and worked as a Demonstrator in Chemistry Department, McGill University in Montreal. He met there the British physicist Ernest Rutherford (1871-1937). Three years later, in 1903, he began working at University College, London with the British chemist William Ramsay (1852-1916). In 1904, he became Lecturer in Physical Chemistry and Radioactivity at Glasgow University (Scotland). He worked there for ten years until 1914.

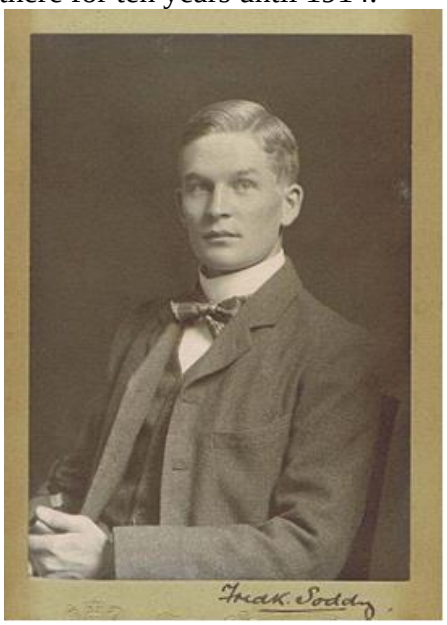

Fig. 1. *Portrait of Frederick Soddy (1877-1956) probably from about 1900 to 1903. With permission of Royal Geographical Society*

In 1908, he married Winifred Moller (née Beilby) (1885-1936), the daughter of the British industrial chemist Sir George Beilby (1850-1924) and his wife Emma Bielby. In 1914-1919, he became Professor of Chemistry at the Aberdeen University (Scotland). The spouses had no children.

In 1919, at the age of forty-two, he moved to Oxford University as Dr. Lee's Professor of Chemistry (Kent, 1963, p.328). He worked there for seventeen years, until 1936 (Bleaney, 2002; Cruickshank, 1979; "Paper and correspondence", n.d.). After his wife's death, he resigned from the work at the University. "Her sudden death in 1936 from a thrombosis was a great shock to him" (Fleck, 1957, p. 212).

Soddy was a great adventurer. On one of his journeys, Fleck (1957) wrote as

follow:

“ ... after his wife's death he decided to further the interest he had in thorium minerals, such as monazite sands, by an extended journey to India, Malaya and Ceylon. This journey extended from November 1937 to April 1938 ... ” (p. 212).

On June 23-27, 1952 he participated in dedicated to chemistry, 2nd Nobel Laureate Meeting in Lindau (Germany). He was one of 10 invited Nobel Prize Laureates. The meeting was also attended by 43 young scientists (“2nd Lindau Nobel”, n.d.). Figure 2 is a photography made during this meeting.

Fig. 2. *Frederick Soddy (1877-1956) at the 2nd Nobel Laureates Meeting in Lindau. With permission of Royal Geographical Society*

Soddy is second from the left. On his right is the Swedish nobleman Count Lennart Bernadotte (1909-2004), co-founder of the Lindau Meetings, and on his left are the Finnish chemist Artturi Ilmari Virtanen (1895-1973), who won Nobel Prize in Chemistry in 1945, the Hungarian radiochemist Georg von Hevesy (1885-1966), 1943 Nobel Laureate in Chemistry, and the German chemist Otto Hahn (1879-1968), winner of the Nobel Prize in Chemistry in 1944 (“About Frederic Soddy”, n.d.).

He lectured in Lindau and “gave [in German] a long and intricate talk on the history of isotopes” (“Comment. Anders Bárány”, n.d.). There is a video of his lecture on the website of the Lindau Nobel Laureate Meetings (“Frederick Soddy (1952)”, n.d.).

He also attended in subsequent Nobel Laureates Meetings in Lindau, including the 6th Meeting, which took place on July 25-29, 1956. He died two months later, on September 22, 1956. in Brighton (England), at the age of 79.

Vincenzo Cioci (2009) wrote about him:

“Soddy was a shining example of a man of science who didn't limit himself to a single field of knowledge, but, driven by profound ethical reasons, he faced the most important issues in an interdisciplinary, or rather transdisciplinary, way, to account for the complexity of reality, … “ (p. 328).

In 1957, under the conditions specified in his will, the Frederick Soddy Trust was estabilished. In 2018 the Trust became the charity of the RGS-IBG (Royal Geographical Society-The Institute of British Geography). This organization created the Frederick Soddy Fund, which continues the work of the Trust through the Frederick Soddy Awards (“Frederic Soddy Awards”, n.d.).

Soddy's works

An almost complete list of Soddy's most important works (prepared by himself) includes over 80 of his main scientific papers, book, lectures, addresses and obituaries that appeared in print for fifty-nine years from 1894 to 1953 (Fleck, 1957, pp. 213-216).

In 1894, at the age of 17, he published his first paper, *The Action of Dried Ammonia On Dried Carbon Dioxide Gas*, as co-author with R. E. Hughes. The experimental study was conducted in a chemical laboratory at the Eastbourne College (Hughes & Soddy, 1894).

From 1901, he conducted his research in the field of radiochemistry. The majority of his papers presenting the results of his experimental works, published in *Journal of the Chemical Society*, *Transactions* as well as in other British journals. His numerous experimental studies were carried out in laboratories in Montreal, Glasgow, Aberdeen and Oxford.

He collaborated with Rutherford for 18 months, from mid-October 1901 to mid-April 1903. It resulting in a jointly papers (Rutherford & Soddy, 1902a; Rutherford & Soddy, 1902b; Rutherford & Soddy, 1902c; Rutherford & Soddy, 1903a; Rutherford & Soddy, 1903b; Rutherford & Soddy, 1903c; Trenn, 1977). They discovered the thorium-X and proposed the Transformation Theory (Rutherford & Soddy, 1902d). In April 1903, they developed their disintegration theory of radioactive transformations. This explained that radioactivity was the result of spontaneous disintegration of radioactive elements into new elements (Rutherford & Soddy, 1903d).

The British chemist Alexander Fleck (1889-1968) about their collaboration wrote:

"The collaboration between Rutherford and Soddy was a happy one. Rutherford was essentially an experimental physicist with a knowledge of chemistry that would not be regarded as fundamental. Soddy was a chemist and always had a good grasp of atomic conceptions. Although the two men were both outstandingly strong personalities and thus might easily have found it difficult to get on with one another, the fact that their approach to their own experimental work was from different directions made for ready and complementary discussion. Certainly their period of collaboration left Soddy with an appreciation of Rutherford as a great experimental physicist. The partnership in Montreal was a happy one, both from the point of view of the participants and of science" (pp. 204-205).

Working with Ramsay at University College London, he continued his research on radium emanation. They demonstrated "spectroscopically the production of helium from radium". It was "the first claear experimantal proof of the natural transmutation of elements" (Kauffman, 1986, p. xv; Ramsay & Soddy, 1903; Ramsay & Soddy, 1904a; Ramsay & Soddy, 1904b).

In 1909, he extended the disintegration theory to branched series (Soddy, 1909a) and in 1913, he introduced the term "isotope" (Soddy, 1913a). At that time, he worked at the Physical Chemistry Laboratory at Glasgow University. In a letter sent to *Nature*, he wrote:

"So far as I personally am concerned, this has resulted in a great clarification of my ideas, and it may be helpful to others, though no doubt there is little originality in it. The same algebraic sum of the positive and negative charges in the nucleus, when the arithmetic sum is different, gives what I call " isotopes" or "isotopic elements," because the occupy the same place in the periodic table. They are chemically identical, and save only as regards the relatively few physical properties which depend upon atomic mass directly, physically identical also. Unit changes of this nuclear charge, so reckoned algebraically, give the succesive places in the periodic table. For any one "place,"or any one nuclear charge,

more than one number electrons in the outer-ring system may exist, and in such a case of the element exibits variable valency. But such changes of number , or of valency, concern only the ring and its external environment. There is no in- and out-going of electrons between ring and nucleus" (p. 400).

The above quote was also placed on a plaque awarded to Glasgow University in 2013 ("Division of the", 2013) as a 2013 Chemical Breakthrough Award by Division of the History of Chemistry of the American Chemical Society (Giunta, 2017).

In the year of the 50th anniversary of isotopes, a reprint of the article in *Nature* dated December 4, 1913 was published in the *Proceedings of the Chemical Society* (Soddy, 1963).

In his published Nobel Lecture (2021) *The origins of the conceptions of isotopes*, given on December 12, 1922, Soddy wrote:

"Chemical analysis classifies according to the external systems of electrons which surround a small massive internal nucleus, whereas radioactive changes, which are of the character of veritable transmutations, concern the internal constitution of this inner nucleus. They showed that the same exterior may conceal very different interiors in the atomic structure. These elements which are identical in their whole chemical character and are not separable by any method of chemical analysis are now called isotopes. ... Thus the chemically identical elements - or isotopes, as I called them for the first time in this letter to *Nature*, because they occupy *the same place* in the Periodic Table - are elements with the same algebraic or nett nuclear charge, but with different numbers of + and - charges in the nucleus" (pp. 371-372, 393).

A. Fleck (1957) about the place where the word "isotope" was first used, wrote as follows:

"Up to 1913 we used the phrase 'radio elements chemically non-separable' and at that time the word isotope was suggested in a drawing-room discussion with Dr Margaret Todd in the home of Soddy's father-in-law, Sir George Beilby. Dr Todd was an Edinburgh trained medical doctor and was a writer of some distinction under the name of Graham Travers. The readiness and etymological accuracy with which she produced 'isotopes' is a standing testimony to her practical knowledge of the Greek tongue" (p. 208).

Soddy together with Henry Hyman determined atomic weight of lead from Ceylon thorite in 1914. In the course of their research, they found that common lead is a mixture of isotopes (Soddy & Hyman, 1914).

In 1913, Soddy and the American chemist Kasimir Fajans (1887-1975), independently of each other, formulated a law called *Soddy-Fajans Displacement Law*. This is a rule that governs the transmutation of elements during radioactive decay (Fajans, 1913a; Fajans, 1913b; Soddy, 1913b Soddy, 1913c; Soddy, 2013; Paneth, 1957, p. 1085). Soddy in his published Nobel Lecture (2021) wrote about this rule as follows:

"A fortnight after Fajans, … , I published exactly the same scheme as that of Fajans, whose paper only reached England after mine was written. In the correct generalization of Fajans … and myself …, each α-ray expelled causes a shift of two places in the direction of diminishing mass and diminishing valency, as I had pointed out two years before, and each β-ray expelled causes a shift of one place in the opposite direction, consistently throughout the whole series, … including the very complicated branchings … " (pp. 387-388).

Soddy's other works in chemistry

In 1904, the first edition of his book under the title *Radio-Activity*. *An Elementary Treatise, from the Standpoint of the Disintegration Theory* was published in London (Soddy, 1904a). In the same year, this book was translated into German. The translators were G. Siebert and L. F. Guttmann (Soddy, 1904b). A Russian edition was published one year later (Soddi, 1905).

In 1908, he gave six free popular experimental lectures on radium at the University of Glasgow. A year later, in March 1909, these lectures were published in his book in London (Soddy, 1909b). The second edition of this book appeared in November 1909. Three years later, in October 1912, the third edition of the book, revised and enlarged, was published in New York (Soddy, 1912a). The fourth edition, revised and enlarged, appeared in August 1920 in London (Soddy, 1920a) and in New York (Soddy, 1920b). In May 1922, a reprint of the fourth edition was published in New York by G. P. Putnam's Sons (Soddy, 1922). The German edition of this book appeared in 1909 under the title *Die Natur des Radiums. Nachs sechs an der Universität zu Glasgow im Jahre 1908 gehaltenen freien populären Experimentalvorlesungen* in Lepzig. The translator was G. Siebert (Soddy, 1909c). The first Russian edition of this book was published in 1910 in Odessa. The translator was D. D. Khmyrov, laboratory assistant of the Imperial Novorossiysk University (Soddi, 1910a). The next two editions appeared in 1915 and 1923 (Soddi, 1915; Soddi, 1923). In 1910, the Moscow edition of this book in the N. A. Shilow translation was also published (Soddi, 1910b). The Hungarian edition of this book appeared in 1912. The translator was Salamon Gábor (Soddy, 1912c).

In 1908, his book entitled *The Chemistry of the Radio-Elements* was published in London (Soddy, 1908). The second edition appeared in 1914 (Soddy, 1914a; Soddy, 1914b) and 1917 (Soddy, 1917). The second Russian edition of this book was published in 1913 in St. Petersburg (Soddi, 1913a). In the preface to a new edition (October, 1914a) of this book, Soddy wrote:

“ THE Chemistry of the Radio-Elements was first published as a single volume in 1911. Early in 1913 the important generalisation was made which connects the chemical nature of the radio-elements with the sequence of changes in which they result, and which has given rise to the theory of isotopic elements, and thrown a fresh light on the Periodic Law. These discoveries formed the subject of a new volume, published at the end of 1913, as Part II of the Chemistry of the Radio-Elements, the original volume thus becoming Part I. In 1914, a new edition of Part I being called for, the present volume was written. The whole subject can now be presented much more clearly and completely than in 1911, and in consequence Part I has had to be largely rewritten from the new point of view. But whilst the general mode of presentation has been much modified, the ground already covered in detail in Part II has been, as far as possible, avoided in the present volume, which concerns itself rather with the practical consequences than with the theoretical significance of the new generalisations” (pp. v-vi).

In 1949, his *The Story of Atomic Energy* was published in London (Soddy, 1949). The Italian edition of this book appeared two year later (Soddy, 1951), and a Russian edition appeared in 1979, thirty years later (Soddi, 1979).

Other Soddy's books

In 1912-1934, he wrote several books setting forth his political and economic views. In 1912, his book under the title *Matter and Energy* was published in London (Soddy, 1912c). A one year later, the Russian edition of this book appeared in Moscow. The translators were S. A. Zaymovskiy and N. A. Morozov (Soddi, 1913b).

One of his book entitled *Science and Life*. *Aberdeen Addresses* enjoyed great popularity among readers. The first edition appeared in January 1920, and a further two reprints were published in March and August 1920, respectively. The book was published in London by John Murray (Soddy, 1920c) and in New York by E.P. Duton and Company (Soddy, 1920d). Soddy dedicated the book to his students at the University of Aberdeen. In the preface, he wrote:

"I HAVE collected together this series of addresses and articles, written, for the most part, during my five years at the University of Aberdeen, in the hope that, in volume form, they may prove acceptable to the students of the university and those for whom, in the first place, they were written. But I am not without hope that, in these days of stress and change, they may be useful to a wider circle, anxious to explore to the foundations the causes of modern unrest, and to rectify for the future the causes which have led to failure in the past. I have, from the standpoint of an original investigator in physical science, attempted to show how fundamentally and beyond the possibility of escape our knowledge and control of the inanimate world underlies and determines the development of all the potentialities of life" (p. vii).

In 1926, the first edition of his book entitled *Wealth, Virtual Wealth and Debt. The Solution of the Economic Paradox* appeared in London (Soddy, 1926). A second edition of this book was published in 1933 in London (Soddy, 1933a) as well as in the same year, a reprint of a second edition containing new material and foreword to the American nation, appeared in New York (1933b).

In 1931, his book entitled *Money versus Man. A Statement of the World Problem From the Standpoint of the New Economics* was published in London (Soddy, 1931). The first American edition of this book was published two years later (Soddy, 1933c). His book under the title *The Role of Money. What It Shoud Be, Contrasted with What it has Become* was published in 1934 in London (Soddy, 1934).

CONCLUSION

Frederick Soddy was one of the most famous British chemists of the first half of the twentieth century. He was especially famous for his research in the field of radioactivity.

He was a Foreign member of the Swedish (1919) and Italian (1928) Academies of Science (Fleck, 1957, p. 213). He became a corresponding member of the *Rossiyskoy akademii nauk* (Russian Academy of Sciences) on December 6, 1924 ("Rossiyskaya akademiya nauk", 2007). *The Royal Society of London* elected him a Fellow on May 5, 1910 ("List of Fellows", 2020, p. 132). He received the Cannizzaro Prize in 1913 and in 1934 – the honorary title of Doctor of Laws (LL.D.) awarded by the University of Glasgow (Fleck, 1957, p. 213). In 1981, he was honored on a postage stamp issued by Sweden (Shampo, Kyle, & Steensma, 2011, p. e39). The Nobel Prize in Chemistry 1921 was awarded to him "for his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes." In fact, he received his Nobel Prize one year later, in 1922 ("The Nobel Prize", 2021). Jeff Hughes (2009) Hughes about his trip to Stockholm wrote as follows: "In early December 1922, after weeks of worry about travel arrangements and top-hats, the Oxford chemist Frederick Soddy and the Cambridge

physicist Francis Aston [(1877-1945)] sailed from Newcastle for Bergen, Christiania [now, Oslo] and Stockholm. Accompanied by Soddy's wife and Aston's two sisters, they were en route to the glittering annual Nobel Prize ceremony to receive the 1921 and 1922 Nobel Chemistry Prizes respectively. On an icy 10 December, they sat stiffly on the platform in Stockholm's Musical Academy. Following a performance of Sibelius' Elégie, they duly received their awards from King Gustav [(1858-1950)] " (p. 132). Soddy's wonderfull books have been published in Great Britain, Germany, Russia, U.S.A., Italy and in Hungary. Some authors also wrote about his life and work. For instance, in 1958, Muriel Howorth written the book entitled *Pioneer Research on the Atom. Rutherford and Soddy in a glorius chapter of science. The Life Story of Frederick Soddy, M.A., LL.D, F.R.S., Nobel Laureate* (Howorth, 1958). In 1978, a book by Aleksandr Nikolayevich Krivomazov under the title *Frederik Soddi* (Frederick Soddy) was published in Moscow (Krivomazov, 1978). Thaddeus J. Trenn is the author of a Soddy's biographical sketch with a detailed review of his bibliography up to 1986 (Trenn, 1986, pp. xix-xxviii). A biographical book about Soddy, written by Linda Merrics, was published at Oxford in 1996 (Merrics, 1996).

After Soddy, not only his papers, books, lectures, and obituaries survived. Moreover, several of his photos and commemorative plaques were created. His photo from 1952 can be found on the Royal Geographical Society website ("Frederic Soddy Awards", n.d.). Two his photographs are from the Edgar Fahs Smith Chemistry Collection ("Soddy, Frederick (1877", 1919; "Soddy, Frederick (1877", 1920). His photo can be found in a Fleck's article (Fleck, 1957, p. 203).

The First Solvay Chemistry Conference was held on April 21-27, 1922 in Brussels (Belgium). There, Soddy gave a lecture on isotopes and radioactivity (van Tiggelen, 1999, p. 3016). In the photo of conference participants, Soddy sits first from the right. The Swedish chemist Svante Arrhenius (1859-1927), who won the Nobel Prize in Chemistry in 1903, sits next to him. The Belgian industrial chemist Ernest Solvay (1838-1922), who founded this conference, sits fourth from the right. He died one month after conference ended ("First Solvay conference", 1922).

Images of plaques made in Soddy's honor can also be found in the literature. The first one, funded by the Institute of Physics, shows a commemorative plaque at Eastbourne College with the following inscription: "FREDERICK SODDY / 1877 – 1956 / EDUCATED AT EASTBOURNE COLLEGE / NOBEL LAUREATE 1921 / FOR HIS FUNDAMENTAL CONTRIBUTIONS TO THE UNDERSTANDING OF RADIOACTIVITY"/ ("About Frederic Soddy", n.d.).

The second image shows a plaque from Frederick Soddy's birthplace in Eastbourne. The inscription reads: Here was " HERE WAS BORN/FREDERICK SODDY / NOBEL LAUREATE IN CHEMISTRY / FOREMOST RADIOCHEMIST OF HIS TIME / HE DISCOVERED / THE TRANSMUTATION OF MATTER / AND / THE CONCEPT OF ISOTOPES /HIS LIFE WAS DEDICATED TO HUMAN WELFARE / THROUGH THE BENEFITS OF SCIENCE / 1877 – 1956" / ("About Frederic Soddy", n.d.). Frederick Soddy's commemorative plaque is in the James Black Building at Glasgow University. It has the following inscription: "1877 1956 / FREDERICK SODDY / F.R.S. NOBEL LAUREATE / LECTURER IN PHYSICAL CHEMISTRY (INCLUDING RADIOACTIVITY) GLASGOW UNIVERSITY. 1904-1914 / WITH RUTHERFORD HE SHARED THE DISCOVERY OF ATOMIC DISINTEGRATION, WITH RAMSAY THE PROOF OF HELIUM PRODUCTION FROM α – PARTICLES. IN THIS DEPARTMENT HE FORMULATED HIS CONCEPTION OF ISOTOPES" /. ("The University of", n.d.b).

Another Frederick Soddy memorial plaque is on the wall of one of the houses in

Glasgow. It has the following inscription: "At a dinner party held in this / house in 1913 / **Frederick Soddy** / (1877-1956) / introduced the concept of "ISOTOPES" / He was awarded the Nobel Prize in / 1921 for his work on radioactivity." ("Plaque to Frederick", n.d.).

Soddy's collection of papers and correspondence is held by several institutions. At Oxford University are stored in the Bodleian Library. His lecture notes and papers from 1914-1917 are in the Museum of the History of Science, University of Oxford, and his 25 letters to Royal Institution are stored in the Royal Institution of Grat Britain. Most of the Soddy-Rutherford corrspondence (96 letters from the years 1902 to 1937) is stored in the Cambridge University Library ("The National Archives", n.d.). His correspondence and other archival sources are kept at Soddy's Record held at the Royal Society. The original certificate of a Candidate for election to the Royal Society of December 28, 1908 is kept there as well as his Nobel Prize Medal. There are also copies of his letters, for instance from Francis Alexander Towle (1874-1932), Assistant Secretary of the Royal Society, and copies of his letters to James Mackenzie Davidson (1856-1919), President of the British Institute of Radiology (1917-1919) ("The Royal Society", n.d.).

The name of this remarkable British chemist is loudly heard not only in the United Kingdom and Ireland, but also in the various countries of the world. "The Frederick Soddy Awards provide funding for studies of the social, economic and cultural life of a region - anywhere in the world - to schools, undergraduate teams, and PhD students". There are three awards associated with his name. *The Frederick Soddy Schools Award* "offers of £ 200 to £ 600 for school fieldwork groups". *The Frederick Soddy Postgraduate Award* "gives two annual awards of up to £ 6,000 for PhD students carrying out research "on the study of the social, economic and cultural life of a region" anywhere in the world". *The Frederick Soddy Awards support team fieldwork and expeditions* "are awarded between £500 and £2,000 for "groups undertaking primarily human geography research"" ("Frederic Soddy Awards", n.d.).

BIBLIOGRAPHIC REFERENCES

2nd Lindau Nobel Laureate Meeting. 1952. Chemistry. (n.d.). Retrieved from Lindau Nobel Laureate Meetings website: https://www.mediatheque.lindau-nobel.org/meetings/1952

About Frederic Soddy. (n.d.). Retrieved from Royal Geographical Society website: https://www.rgs.org/getattachment/In-the-field/In-the-field-grants/Expedition-grants/Frederick-Soddy-Awards/About-Frederick-Soddy.pdf?lang=en-GB

Bleaney, B. (2002). Two Oxford Science Professors, F. Soddy and J. S. E. Townsend. *Notes and Records of the Royal Society of London, 56*(1), 83-88. https://doi.org/10.1098/rsnr.2002.0168

Cioci, V. (2009). Frederick Soddy, un chimico alle frontiere della conoscenza, fra Fisica, Economia, Matematica ed Ecologia. *Memorie di Scienze Fisiche e Naturali, vol. 127, «Rendiconti della Accademia Nazionale delle Scienze detta dei XL», serie V, vol. XXXIII, parte II, tomo II*. 319-330. Retrieved from https://media.accademiaxl.it/memorie/S5-VXXXIII-P2-2009/Cioci319-330.pdf

Comment. Anders Bárány. (n.d.). Retrieved from Lindau Nobel Laureate Meetings website: https://www.mediatheque.lindau-nobel.org/videos/31532/isotopes-1952/meeting-1952

Cruickshank, A. D. (1979). Soddy at Oxford. *The British Journal for the History of Science*, *12* (3), 277-288. https://doi.org/10.1017/S0007087400017337

Davies, M. (1992). Frederick Soddy: The Ascientist as Prophet. *Annals of Science, 49*,

351-367.
https://doi.org/10.1080/00033799200200301

Fajans, K. (1913). Die radioaktiven Umwandlungen und das periodische System der Elemente. *Berichte der deutschen chemischen Gesellschaft, 46*(1), 422-439. *https://doi.org/10.1002/cber.19130460162*

Fajans, K. (1913). Die Stellung der Radioelemente im periodischen System. *Physikalische Zeitschrift, 14*, 136-142. Retrieved from the Staats- und Universitätsbibliothek Hamburg (State and niversity Library Hamburg) website: https://digitalisate.sub.uni-hamburg.de/de/nc/detail.html?id=1901&tx_dlf%5Bid%5D=36828&tx_dlf%5Bpage%5D=172

First Solvay conference on Chemistry. (1922). Public Domain. Retrieved from https://commons.wikimedia.org/wiki/File:Solvay_conference,_1922.jpg

Fleck, A. (1957). Frederick Soddy. Born Eastbourne 2 September 1877 Died Brighton 26 September 1956. *Biographical Memoirs of Fellows of the Royal Society, 3*, 203-216. https://doi.org/10.1098/rsbm.1957.0014

Frederic Soddy Awards. (n.d.). Retrieved from Royal Geographical Society webdsite:
https://www.rgs.org/in-the-field/in-the-field-grants/expedition-grants/frederick-soddy-awards/

Frederick Soddy (1952). Isotopes. (n.d.). Retrieved from Lindau Nobel Laureate Meetings website: https://www.mediatheque.lindau-nobel.org/videos/31532/isotopes-1952/meeting-1952

Frederick Soddy Nobel Lecture. December 12, 1922. The Origins of the Conception of Isotopes.(2021). Retrieved form https://www.nobelprize.org/prizes/chemistry/1921/soddy/lecture/

Giunta, C. J. (2017). Isotopes: Identifying the Breakthrough Publication (1). *Bulletin for the History of Chemistry*, *42*(2), 103-111. Retrieved from http://acshist.scs.illinois.edu/bulletin_open_access/v42-2/v42-2%20p103-111.pdf

Howorth, M. (1958). *Pioneer Research on the Atom. Rutherford and Soddy in a glorius chapter of science. The Life Story of Frederick Soddy, M.A., LL.D, F.R.S., Nobel Laureate*. London: New World Publications.

Hughes, J. (2009). Making isotopes matter: Francis Aston and the mass-spectrograph. *Dynamis*, *29*, 131-165. https://doi.org/10.4321/S0211-95362009000100007

Hughes, R. E., & Soddy, F. (1894). The Action of Dried Ammonia on Dried Carbon Dioxide Gas. *The Chemical News and Journal of Physical Science*, *69*(1791), 138-139. Retrieved from https://babel.hathitrust.org/cgi/pt?id=njp.32101075379204&view=1up&seq=144

Kauffman, G. B. (2013). Celebrating the Isotope. *Chemical & Engineering News*. *91*(48), 30-31. http://doi.org/10.1021/cen-09148-scitech1

Kauffman, G. B. (Ed.) (1986). *Frederick Soddy (1877–1956). Early Pioneer in Radiochemistry*. Dordrecht: Springer. http://doi.org/10.1007/978-94-009-5297-3

Kent, A. (1963). Frederick Soddy (1877-1956). *Proceedings of the Chemical Society (November 1963)*, 327-330. https://doi.org/10.1039/PS9630000325

Krivomazov, A. N. (1978). *Frederik Soddi. 1877-1956*, Nauka: Moskva (in Russian). Retrieved from http://publ.lib.ru/ARCHIVES/N/"Nauchno-populyarnaya_literatura"_(ser.AN)/"NPLAN_NBL"._Krivomazov_A.N._Frederik_Soddi.(1978).[djv-fax].zip

List of Fellows of the Royal Society 1660–2019. (2020). Retrieved from http://royalsociety.org/uploadedFiles/Royal_Society_Content/about-

us/fellowship/Fellows1660-2019.pdf

Merrics, L. (1996). *The World Made New: Frederick Soddy, Science, Politics, and Environment*. Oxford, New York: Oxford University Press.

Papers and correspondence of Frederick Soddy, 1877-1956. Archive Collection. (n.d.). Retrieved from https://archiveshub.jisc.ac.uk/search/archives/4418ac0b-ccde-3b5b-b621-8b3878a55d5f

Paneth, F. A. (1957). A Tribute to Frederick Soddy. *Nature, 180*(4595), 1085-1087. https://doi.org/10.1038/1801085a0

Plaque to Frederick Soddy. (n.d.). Retrieved from https://www.geograph.org.uk/photo/5196345

Ramsay, W., & Soddy, F. (1904a). Experiments in Radioactivity, and the Production of Helium from Radium. *Proceedings of the Royal Society of London, 72*(477-486), 204-207. https://doi.org/10.1098/rspl.1903.0040

Ramsay, W., & Soddy, F. (1904b). Further Experiments on the Production of Helium from Radium. *Proceedings of the Royal Society of London, 73*(488-496), 346-358. https://doi.org/10.1098/rspl.1904.0050

Ramsay, W., & Soddy, F. (1903). Experiments in Radio-Activity, and the Production of Helium From Radium. *Nature, 68*, 354-355. https://doi.org/10.1038/068354a0

Rossiyskaya akademiya nauk. (2007). Содди Фредерик [Soddi Frederik]. Retrieved from

http://www.ras.ru/win/db/show_per.asp?P=.id-52171.ln-ru.dl-.pr-inf.uk-12

Rutherford, E., & Soddy, F. (1903a). XLIII. The Radioactivity of Uranium. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 5*(28), 441-445. http://doi.org/10.1080/14786440309462942

Rutherford, E., & Soddy, F. (1903b). XLIV. A Comparative Study of the Radioactivity of Radium and Thorium. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 5*(28), 445-457. http://doi.org/10.1080/14786440309462943

Rutherford, E., & Soddy, F. (1903c). LIX. Condensation of the Radioactive Emanations. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 5*(29), 561-576. http://doi.org/10.1080/14786440309462959

Rutherford, E., & Soddy, F. (1903d). LX. Radioactive Change. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 5*(29), 576-591. https://doi.org/10.1080/14786440309462960

Rutherford, E., & Soddy, F. (1902a). XXXIII.—The Radioactivity of Thorium Compounds. I. An Investigation of the Radioactive Emanation. *Journal of the Chemical Society Transactions, 81*, 321-350. http://doi.org/10.1039/ct9028100321

Rutherford, E., & Soddy, F. (1902b). XLI. The Cause and Nature of Radioactivity .—Part I. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 4*(21), 370-396. http://doi.org/10.1080/14786440209462856

Rutherford, E., & Soddy, F. (1902c). LXIV. The Cause and Nature of Radioactivity.—Part II. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6, 4*(23), 569-585. http://doi.org/10.1080/14786440209462881

Rutherford, E., & Soddy, F. (1902d). LXXXIV.—The Radioactivity of Thorium Compounds. II. The Cause and Nature of Radioactivity. *Journal of the Chemical Society Transactions, 81*, 837-860. http://doi.org/10.1039/ct9028100837

Shampo, M. A., Kyle, R. A., Steensma, D. P. (2011). Frederick Soddy—Pioneer in Radioactivity, *Mayo Clinic Proceedings, 86(*6), e39.

https://doi.org/10.4065/mcp.2011.0300

Soddi, F. (1979). *Istoriya Atomnoy Energii* (M. Yu. Bogdanov, M. V. Kolokol'nikova, A. Yu. Pentin, A. N. Krivomazov, & D. N. Trifonov, Trans.). Moskva: Atomizdat (in Russian). (Oryginal work published 1949). Retrieved from http://www.eduspb.com/public/books/classiki/soddi_f_istoriya_atomnoy_energii.pdf

Soddi, F. (1923). *Radiy i stroyeniye atoma* (Radium and the Structure of the Atom) (3rd ed.) (D. D. Khmyrov, Trans.). Odessa: Mathesis (in Russian). (Oryginal work published 1909). Retrieved from https://www.mathesis.ru/book/soddy/

Soddi, F. (1915). *Radiy i yego razgadka* (Radium and Its Solution) (2 nd ed.). (D. D. Khmyrov, Trans.). Odessa: Mathesis (in Russian). (Oryginal work published 1909). Retrieved from https://www.mathesis.ru/book/soddy/

Soddi, F. (1913a). *Khimiya Radioelementov* (2nd ed.). (Ya. R. Shmidt & V. A. Borodovskiy, Trans.). S.-Peterburg: Izdatel'stvo "Obrazovaniye (in Russian). (Oryginal work published 1908)

Soddi, F. (1913b). *Materiya i Energiya* (S. A. Zaymovskiy & N. A. Morozov, Trans.). Moskva: Izdatel'stvo Priroda. (Oryginal work published 1912)

Soddi, F. (1910a). *Radiy i yego razgadka* (Radium and Its Solution) (D. D. Khmyrov, Trans.). Odessa: Mathesis (in Russian). (Oryginal work published 1909). Retrieved from https://www.mathesis.ru/book/soddy/

Soddi, F. (1910b). *Radiy. Obshchedostupnyye Lektsii o Prirode Radiya, Chitannyye v Universitete v Glazgo v 1908 g* (N. A. Shilov, Trans.). Moskva: Tipo-litografiya T-va I. N. Kushnerev i Ko (in Russian). (Oryginal work published 1909)

Soddi, F. (1905). *Radioaktivnost'. Elementarnoye Izlozheniye S Tochki Zreniya Teorii Raspada Atomov* (F. N. Indrikson, Trans.). S.-Peterburg: Tipografiya M. M. Stasyulevicha (in Russian).(Oryginal work published 1904)

Soddy, F. (2013). The Radio-Elements and the Periodic Law. In H. M. Leicester (Ed.), *Source Book in Chemistry, 1900-1950* (pp.75-77). Cambridge, Massachusetts: Harvard University Press. https://doi.org/10.4159/harvard.9780674366701.c35

Soddy, F. (1963). Intra-atomic Charge. *Proceedings of the Chemical Society (November 1963)*, 325-326. https://doi.org/10.1039/PS9630000325

Soddy, F. (1951). *La Storia Dell'Energia Atomica* (M. Montagnana, Trans.). Torino: Edizioni scientifiche Einaudi. Retrieved from https://www.worldcat.org/title/storia-dellenergia-atomica/oclc/946580619?referer=di&ht=edition

Soddy, F. (1949). *The Story of Atomic Energy*. London: Nova Atlantis. Retrieved from https://www.worldcat.org/title/story-of-atomic-energy/oclc/488705436?referer=di&ht=edition

Soddy, F. (1934). *The Role of Money. What It Shoud Be, Contrasted with What it has Become*. London: George Routledge and Sons, Ltd. Retrieved from https://archive.org/details/soddy-f.-the-role-of-money-1934/page/n1/mode/2up

Soddy, F. (1933a). *Wealth, Virtual Wealth and Debt. The Solution of the Economic Paradox*. London: Allen & Unwin. Retrieved from https://www.worldcat.org/title/wealth-virtual-wealth-and-debt-the-solution-of-the-economic-paradox/oclc/1192866569?referer=di&ht=edition

Soddy, F. (1933b). *Wealth, Virtual Wealth and Debt. The Solution of the Economic Paradox* (2nd ed.). New York: E. P. Dutton. Retrieved from https://www.fadedpage.com/showbook.php?pid=20140873

Soddy, F. (1933c). *Money versus Man. A Statement of the World Problem From the Standpoint of the New Economics*. New York: E.P. Dutton & Co., Inc. Retrieved from https://www.worldcat.org/title/money-versus-man-a-statement-of-the-world-problem-

from-the-standpoint-of-the-new-economics/oclc/4048972

Soddy, F. (1931). *Money versus Man. A Statement of the World Problem From the Standpoint of the New Economics*. London: Elkin Mathews & Marrot. Retrieved from https://dspace.gipe.ac.in/xmlui/handle/10973/22230

Soddy, F. (1926). *Wealth, Virtual Wealth and Debt. The Solution of the Economic Paradox*. London: Allen & Unwin. Retrieved from https://www.worldcat.org/title/wealth-virtual-wealth-and-debt-the-solution-of-the-economic-paradox/oclc/901125773?referer=di&ht=edition

Soddy, F. (1922). *The Interpretation of Radium and the Structure of Atom* (4th ed.). New York: G. P. Putnam's Sons. Retrieved from https://archive.org/details/interpretationof00sodd/page/n9/mode/2up

Soddy, F. (1920a). *The Interpretation of Radium and the Structure of Atom* (4th ed.). London: John Murray. Retrieved from https://archive.org/details/interpretationof00sodduoft/page/n5/mode/2up

Soddy, F. (1920b). *The Interpretation of Radium and the Structure of Atom* (4th ed.). New York: G. P. Putnam's Sons. Retrieved from https://archive.org/details/interpretationr00soddgoog/page/n7/mode/2up

Soddy, F. (1920c). *Science and Life*. *Aberdeen Addresses*. London: John Murray. Retrieved from https://archive.org/details/sciencelifeaberd00sodduoft/page/n5/mode/2up

Soddy, F. (1920d). *Science and Life*. *Aberdeen Addresses*. New York: E.P. Duton and Company. Retrieved from https://archive.org/details/sciencelifeaberd00soddrich/page/n7/mode/2up

Soddy, F. (1917). *The Chemistry of the Radio-Elements* (2nd ed.). London: Longmans, Green and Co. Retrieved from https://archive.org/details/chemistryofradio00sodduoft/page/n5/mode/2up

Soddy, F. (1914a). *The Chemistry of the Radio-Elements* (2nd ed.). London: Longmans, Green and Co. Retrieved from https://archive.org/details/chemistryradioe05soddgoog/page/n4/mode/2up

Soddy, F. (1914b). *The Chemistry of the Radio-Elements. Part II. The Radio-Elements and The Periodic Table*. London: Longmans, Green and Co. Retrieved from https://archive.org/details/chemistradio02soddrich/page/n9/mode/2up

Soddy, F. (1913a). Intra-Atomic Charge. *Nature*, *92(*2301), 399-400. https://doi.org/10.1038/092399c0

Soddy, F. (1913b). The Radio-Elements and the Periodic Law. *Chemical News*, *107*, 97-99. Retrieved from https://web.lemoyne.edu/~giunta/soddycn.html

Soddy, F. (1913c). Die Radioelemente und das periodische Gesetz. *Jahrbuch der Radioaktivität und Elektronik*, *10*, 188-197. Retrieved from https://archive.org/details/jahrbuch-der-radioaktivitat-und-elektronik-10.1913/page/188/mode/2up

Soddy, F. (1912a). *The Interpretation of Radium Being the Substance of Six Free Popular Experimental Lectures Delivered at the University of Glasgow, 1908* (3rd ed.). New York: G.P. Putnam's Sons. Retrieved from https://archive.org/details/interpretationrad00soddrich/page/n9/mode/2up

Soddy, F. (1912b). *A Rádium* (S. Gábor, Trans.). Budapest: Nyomtatta „Pátria" (in Hungarian).

Soddy, F. (1912c). *Matter and Energy*. New York: H. Holt and Company, London: Williams and Norgate. Retrieved from https://archive.org/details/matterenergy00soddiala/page/n5/mode/2up

Soddy, F. (1911). *The Chemistry of the Radio-Elements*. London: Longmans, Green and

Co. Retrieved from https://archive.org/details/in.ernet.dli.2015.168675/page/n9/mode/2up

Soddy, F. (1909a). LXXVI. Multiple Atomic Disintegration. A Suggestion in Radioactive Theory. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science Series 6*, *18*(107), 739-744. http://doi.org/10.1080/14786441108636745

Soddy, F. (1909b). *The Interpretation of Radium Being the Substance of Six Free Popular Experimental Lectures Delivered at the University of Glasgow, 1908*. London: John Murray. Retrieved from https://archive.org/details/interpretationof00soddrich/page/n7/mode/2up

Soddy, F. (1909). *Die Natur des Radiums. Nachs sechs an der Universität zu Glasgow im Jahre 1908 gehaltenen freien populären Experimentalvorlesungen* (G. Siebert, Trans.). Leipzig: J.A. Barth. Rterieved from https://catalog.hathitrust.org/Record/006558131

Soddy, F. (1904a). *Radio-Activity. An Elementary Treatise, from the Standpoint of the Disintegration Theory*. London: "The Electrician" Printing & Publishing Company, Ltd. Retrieved from https://archive.org/details/radioactivityele00sodd/page/n7/mode/2up

Soddy, F. (1904b). *Die Radioaktivität: Vom Standpunkt der Desaggregationstheorie Elementar Dargestellt* (G. Siebert & L.F. Guttmann, Trans.). Leipzig: Verlag von Johann Ambrosius Barth. (Oryginal work published 1904). Retrieved from https://archive.org/details/dieradioaktivit00siebgoog/page/n9/mode/2up

Soddy, Frederick (1877-1956). smith_pso130_1_s. (1920). Retrieved from https://www.jstor.org/stable/community.21321210

Soddy, Frederick (1877-1956). smith_pso130_2_s. (1919). Retrieved from https://www.jstor.org/stable/community.21320809

Soddy, F., & Hyman, H. (1914). CXXXII.—The Atomic Weight of Lead from Ceylon Thorite. *Journal of the Chemical Society, Transaction*, *105*, 1402-1408. https://doi.org/10.1039/CT9140501402

The National Archives. Soddy, Frederick, (1877 - 1956). (n.d.). Retrieved from http://discovery.nationalarchives.gov.uk/details/c/F35495

The Nobel Prize in Chemistry 1921. (2021). Retrieved from the Nobel Prize website: https://www.nobelprize.org/prizes/chemistry/1921/summary/

The Royal Society. Record. Soddy, Frederick (1877-1956). (n.d.). Retrieved from https://catalogues.royalsociety.org/CalmView/Record.aspx?src=CalmView.Persons&id=NA8018&pos=1

The University of Glasgow Story. *Frederick Soddy*. (n.d.a). Retrieved from https://universitystory.gla.ac.uk/biography/?id=WH0182&type=P

The University of Glasgow Story. Frederick Soddy Plaque. (n.d.b). Retrieved from https://universitystory.gla.ac.uk/image/?id=UGSP00117

Trenn, T. J. (1986). Frederick Soddy. In G. B. Kauffman (Ed.), *Frederick Soddy (1877-1956). Early Pioneer in Radiochemistry* (pp. xix-xxviii). Dordrecht: D. Reidel Publishing Company.

Trenn, T. J. (1977). *The Self-Splitting Atom. The History of the Rutherford-Soddy Collaboration*. London: Taylor & Francis Ltd. van Tiggelen, B. (1999). Les premiers Conseils de chimie Solvay (1922-1928). Entre ingérence et collaboration, les nouvelles relations de la physique et de la chimie. *Chimie Nouvelle*, *17*(68), 3015-3018.

This article has no conflict of interest