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Sztejnberg, Aleksander

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) - the Important French chemist of the Second Half of the XIX Century and the First Decade of the XX Century

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Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) – the Important French chemist of the Second Half of the XIX Century and the First Decade of the XX Century

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) – el importante químico francésde la segunda mitad del siglo XIX y la primera década del siglo XX

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

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

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ABSTRACT

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) was an important French chemist in the second half of the XIX century and the first decade of the XX century. He was one of the founders of spectroscopy. He discovered gallium (1875), samarium (1879), and dysprosium (1886) and improved methods for the separation of rare earths elements. The purpose of this paper is to familiarize readers with the important events in the life of Lecoq de Boisbaudran and his great discoveries. In addition, literature on his selected papers and books, as well as literature on his chapters in books is presented.

Keywords: P.-É. Lecoq de Boisbaudran, Gallium, Samarium, Dysprosium and Gadolinium, Spectrochemistry, Spectral analysis, France – XIX –XX centuries.

RESUMEN

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) fue un importante químico francés de la segunda mitad del siglo XIX y la primera década del siglo XX. Fue uno de los fundadores de la espectroscopia. Descubrió el galio (1875), el samario (1879) y el disprosio (1886) y mejoró los métodos para la separación de elementos de tierras raras. El propósito de este artículo es familiarizar a los lectores con los acontecimientos importantes de la vida de Lecoq de Boisbaudran y sus grandes descubrimientos. Además, se presenta literatura sobre sus artículos y libros seleccionados, así como literatura sobre sus capítulos en los libros.

Palabras claves: P.-É. Lecoq de Boisbaudran, Galio, Samario, Disprosio y Gadolinio, Espectroquímica, Análisis espectral, Francia - Siglos XIX-XX.

INTRODUCTION

The important events in the Lecoq de Boisbaudran's life

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) (Figure 1), known simply as Lecoq de Boisbaudran was called "one of the most brilliant and energetic of French investigators" (Gardiner, 1912, p. 255) and "a brilliant spectral analyst" (Trifonov & Trifonov, 1985, p. 257). "His most famous work dealt with spectroscopy, resulting in the discovery of several elements" (Marshall & Marshall, 2002, p. 78).

One hundred and ten years have passed since his death, but during this time only a few articles about this accomplished experimenter were published. Little is known about his life, and the information available in the literature is usually of a general nature. His name is most often associated with the discovery of gallium and little is said about his other achievements. The American chemist Henry Monmouth Smith (1868-1950) wrote about him and his achievements in his book published in 1949:

Held no academic position and most of his work was done in his own small laboratory. Although he worked in Agricultural and Physical Chemistry his work with the spectroscope is his outstanding contribution to Science. He discovered a relation existing between the lines emited by members of the same family of metals and their atomic weights and developed the use of the spark spectra in place of the flame. ... Other investigations of Boisbaudran were with the rare earths, resulting in the identification of Samaria (1875), Dysprosia (1886) and Gadolinia (1889) (p. 35).

Paul-Émile (François) Lecoq de Boisbaudran was born in Cognac (France) on April 18, 1838 and he was the son of Paul Lecoq de Boisbaudran (1801-1870) and his wife Anne-Louise-Alexandrine, née Joubert (1814-1891) (Fontani, Costa, & Orna, 2015, p. 211; Marshall & Marshall, 2002, p. 78).

His father, together with his brother Scœvola (1802-1878), a former student of the *École Polytechnique*, started working in a wine business at Cognac. Over time, the venture prospered better and better, and from his youth, Paul-Émile also entered the business under the leadership of his father and uncle (De Gramont, 1923, p. XI).

He was educated by his mother. She tought him "the classics, history, and foreign languages" (Ramsay, 1913, p. 742), while every evening his uncle Scœvola, after having finished commercial accounting, returned to the teachings previously received at the *École Polytechnique*. His father, a cultivated mind and above all an artist, gave him also his lessons (De Gramont, 1923, p. XI).

He learned to speak English fluently, so in the late 1860s he went to England and Scotland, where he met various famous scientists (Marshall & Marshall, 2002, p. 78). He also dealt with matters related to the wine business there (Ramsay, 1913, p. 742). He became interested in chemistry, and his uncle supported him after his father died, and even funded a laboratory for him in the home in Cognac.

After 1875 he moved to Paris, where he worked in a little home laboratory. He "did not attend a formal university, but he followed the syllabi of classes tought at École Politechnique" (Marshall & Marshall, 2002, p. 78). He succeeded in acquiring, a very general scientific education (De Gramont, 1923, p. XI).

After 1895 his research activity seemed to slow down. This was mainly due to his deteriorating health and family duties (De Gramont, 1923, p. XLI). On December 27, 1897, at the age of of fifty-nine, he married a forty-five-year-old widow Jeannette Nadault-Valette (1852-1926) (Fontani, Costa, & Orna, 2015, p. 213) and his marriage brought him a lot of happiness. The spouses had no children.

Fig. 1. *P.-É. Lecoq de Boisbaudran (1838-1912) ("Paul Emile (François)", n.d.)*

"His sufferings from anchylosis of the joints, which were very severe, were borne with stoical resignation" (Ramsay, 1913, p. 746). He died in his Parisian home on May 28, 1912, at the age of seventy-four. His body, according to his will, was brought back to Cognac. He rests in the family vault of the cemetery of Breuil ("Patrimoine de Cognac", n.d.).

Lecoq de Boisbaudran's greatest discoveries

On August 27, 1875, he discovered a new chemical element which he named gallium. He wrote about this important event (Lecoq de Boisbaudran, 1875a) as follows:

The day before yesterday, on Friday, August 27, 1875, between 3 and 4 o'clock in the evening, I found clues of the probable existence of a new simple body, in the products of the chemical examination of a blende from the mine of Pierrefitte, Argelès valley (Pyrenees). Here is the data I have been able to collect so far. … The oxide … is precipitated in the long run by the metallic zinc, in a solution containing chlorides and sulphates. … The chloride is precipitated by a small amount of ammonia. (p. 493).

In November 1875, two months after the announcement of his discovery, he received by electrolysis small amounts of pure gallium. He also described (Lecoq de Boisbaudran, 1875b; Lecoq de Boisbaudran, 1876a) the course of this process:

The ammoniacal solution of sulphate of gallium is decomposed by the voltaic current. Metallic gallium is deposited on the platinum plate which serves as negative electrode. The positive electrode becomes covered at the same time with a whitish coating,

consisting of a pellicle which is easily detached from the platinum and is insoluble in a large excess of NH_3 (specimen 5). In a first operation 1.6 milligram was deposited in 4 hours 30 minutes on a platinum plate of about 185 square millims, superficies. The surface of the positive electrode was 877 square millims. The pile was composed of five bichromate couples (zincs 17 x 10 centims.) coupled in tension (1875b, p. 1103; 1876a, p. 175).

He also donated a sample of metallic gallium to the *Académie des Sciences* in Paris. He wrote (Lecoq de Boisbaudran, 1875b; Lecoq de Boisbaudran, 1876a) about it as follows as:

The sample which I have the honour to offer to the Academy (No. 1) weighs 3.4 milligrams: it was deposited in 5 hours 40 minutes, on a surface of 123 or 124 square millims.; the positive electrode had a surface of 877 square millims.; the current was supplied by ten bichromate elements (zincs 17 x 10 centims.) coupled in tension (1875b, p. 1103; 1876a, p. 175).

In 1878, Lecoq de Boisbaudran together with E. Jungfleisch (1878a; 1878b) began produced gallium in gram quantities. He wrote about how hard work it was:

At the Javel works all the gallium of the 4300 kilograms of [Bensberg] blende [that ore being the richest known] was thus concentrated into a mass weighing (still wet) about 100 kilograms. ... At this point, indeed, the treatment ceased to be on the large scale, and could be pursued in a laboratory. …The gallium is isolated by electrolysis of the potassic solution of the subsalt. The deposition of the metal is effected adwntageously only under special conditions. The intensity of the electric current, for example, should vary according to the state of the liquor; but the surface of the negative electrode must always be relatively small compared with that of the positive electrode. In one of our operations, which produced 8 grams of gallium in twenty-four hours, 40 Bunsen elements (18 centims. in height) arranged in eight parallel series, each comprising 5 elements in tension, put in action a negative electrode the double surface of which did not exceed 15 square centimetres, while the positive electrode presented an expanse of about 450 centimetres square. …

By operating in the manner above described, we collected 62 grams of crude gallium. If account be taken of the inevitable losses, and of some grams of gallium which still remain in our various products, the content of the Bensberg blende may be estimated at 1/60000, or nearly 16 milligrams per kilogram. This minute proportion of material capable of extraction accounts for the operations requiring so long a time (1878a, pp. 476-478; 1878b, pp. 318-320).

Boisbaudran's discovery of gallium and Mendeleev's prognose relating the discovery of this element

In 1869, the outstanding Russian chemist Dmitri Ivanovich Mendeleev (1834-1907) elaborated classification of the chemical elements for the first time. All 63 known elements he arranged in a table according to increasing atomic weight. He also left empty places, claiming that they should be fulfilled by undiscovered elements. In 1870, he made a few corrections in his table. His final ideas he presented in the publication entitled *Yestestvennaya sistema elementov i primeneniye yeye k ukazaniyu svoystv neotkrytykh elementov* (*The Natural System of Elements and Its Application to Indicating the Properties of Undiscovered Elements*) which was published in the *Zhurnal Russkogo khimicheskogo obshchestva* (Journal of the Russian Chemical Society) in 1871 (Mendeleyev, 1871, cited by Mendeleyev, 1958, pp. 69-101). He, first of all, defined new

locations of indium, cerium, thorium, and uranium. Special attention he paid to aluminium analogue – an element of the third group. According to Mendeleev, zinc should be followed by another element, named by him *ekaalumini* – El. Mendeleev predicted its atomic weight, atomic volume, density, and other spectral characteristics.

In 1875, he wrote an article entitled *Remarques à propos de la découverte du gallium* (Notes on the Discovery of Gallium) which was published in the *Comptes Rendus Hebdomadaires des Séances de L'Academie des Sciences* (Mendeleeff, 1875). He wrote in it about the properties of ekaaluminium as follows:

The properties of ekaaluminium [El], according to the periodic law, must be as follows. Its atomic weight will be El=68; its oxide will have the formula El^2O^3; its salts will have the formula ElX^3. So, for example, the (unique?) ekaaluminum chloride will be $ElCl^3$; it will give 39 percent of the metal and 61 percent of the chlorine on analysis and will be more volatile than $ZnCl^2$. The sulfide El^2S^3, or oxysulfide $El^2(S,O)^3$, must be precipitated by hydrogen sulfide and will be insoluble in ammonium sulfide. The metal will be obtained easily by reduction; its density will be 5.9; … Mr. Lecoq de Boisbaudran, by applying his new method of spectral analysis, has just announced (*Comptes rendus*, p. 493) the presence, in Pierrefitte (Pyrenees) blende, of a new metal which he called gallium. The way in which it was discovered, the separation process (precipitation by H^2S before Zn) and some properties described (precipitation by $BaCO^3$, solubility of the hydrate in ammonia, degree of volatility, etc.) lead to the presumption that this new metal is just the ekaaliminium. If further research confirms the identity of the properties I have just indicated for ekaaluminium with those of gallium, this will be an instructive example of the utility of the periodic law (pp. 970-971).

In 1876, Boisbaudran had enough milligrams of metallic gallium to determine, among other things, the density of this element. He wrote (Lecoq de Boisbaudran, 1877a, Lecoq de Boisbaudran, 1877b) about it as follows:

In May, 1876, I tried to determine approximatively the density of the new metal on a sample weighing 64 milligrams. I obtained 4.7 at +15°C with reference to water at the same temperature. The mean specific gravity of aluminium and indium being about 4.8 … , that found provisionally for gallium seemed to agree tolerably well with a theory which would place the new metal between indium and aluminium. However, the calculations established by M[r]. Mendeleef for a hypothetical body which seems to correspond to gallium, at least in its general properties, point to the number 5.9.

As soon as I had prepared a fresh supply of pure gallium I continued my researches as to its density, and I found that gallium crystallised under water, decrepitates sometimes when heated, which leads me to think that in my first experiment the metal perhaps contained interstices filled with air or water.

I am ignorant wheter this cause of error combined with others to falsify my first determination. Howewer this may be, I avoided it afterwards by subjecting the metal to a strong heat, and solidyfying it in a dry atmosphere. By these means I obtined higher densities, varing form 5.5 to 6.2 although the samples experimented with did not weigh more than a few centigrams.

I then operated on a single ingot of pure gallium weighting about 58 centigrams, formed by the union of the six samples mentioned above. The density of this ingot I found to be at +23° (and referred to water at +23°):

1st experiment	5.90[0]
2nd experiment	5.97[0]

Mean 5.935

M[r]. Mendeleef's previsionis thus complety verified (1877a, p. 114; 1877b, p. 157).

It should be emphasized at this point that Mendeleev was able to predicted in 1871 the properties of three chemical elements, not only Lecoq de Boisbaudran's gallium, as well as the scandium and germanium. Mendeleev's prognosis concerning an existence of boron analogue, which he named *ekabor* – Eb, became the truth (Mendeleyev, 1958, pp. 90-91). This element was discovered by the Swedish chemist Lars Frederic Nilson (1840-1899) in 1879 and named scandium (Nilson, 1879, pp. 645-648). Discovery of germanium by the German chemist Clemens Alexander Winkler on the 6th February, 1886, decisively confirmed correctness of the periodic table of the elements defined by Mendeleev (Winkler, 1886, pp. 210-211). Mendeleev predicted its existence. He named it *ekasilici* – Es, and described some of its properties (Mendeleyev, 1958, p. 95).

Lecoq de Boisbaudran's articles on gallium in foreign scientific journals

In the years 1875-1883, many of his articles about gallium and its properties and separation were published in Great Britain, Germany and USA. His article entitled *On the Chemical and Spectroscopic Characters of a New Metal (Gallium)* was published in 1875 in *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* (Lecoq de Boisbaudran, 1875c). In 1876, three of his articles appeared in the same journal on: the physical properties of gallium (Lecoq de Boisbaudran, 1876b), a new process for it separation (Lecoq de Boisbaudran, 1876c) and it spectrum (Lecoq de Boisbaudran, 1876d).

In 1877, his article entitled *Sur Un Nouveau Métal, Le Gallium* was published in *Annales de Chimie et de Physique* (Lecoq de Boisbaudran, 1877a). In the same year, the English version of this article appeared in *The Chemical News* (Lecoq de Boisbaudran, 1877b).

In 1876, his article on the physical properties of gallium was published in *Annalen der Physik* (Lecoq de Boisbaudran, 1876e). One year later, his paper entitled *Ueber das Gallium. Mit dem Namen Gallium und dem Symbol Ga bezeichnet* (About the gallium. Denoted by the name Gallium and the symbol Ga) appeared in the *Fresenius, Zeitschrift für analytische Chemie* (Lecoq de Boisbaudran, 1877c). His article under the title *Separations of Gallium* was published in 1883 in the *Scientific American* (Lecoq de Boisbaudran, 1883).

Discovery of samarium and dysprosium by Lecoq de Boisbaudran

In 1879, Lecoq de Boisbaudran showed that didymium from cerite differed from that coming from samarskite (Lecoq de Boisbaudran, 1879a). This discrepancy made it possible to discover of samarium. In the didymium of the samarskite, he recognized the presence of a new earth with a higher atomic weight, to which he gave the name *terre de la samarskite* (earth of the samarskite) (Lecoq de Boisbaudran, 1879b). In the next article (Lecoq de Boisbaudran, 1879c) entitled *Recherches sur le samarium, radical d'une terre*

nouvelle, extraite de la samarskite (Research on the Samarium, Radical of a New Earth, Extracted from the Samarskite), he wrote:

The fear of having to deal with a mixture of new bodies and elements already known or announced had hitherto prevented me from giving a radical name, which was, however, already sufficiently distinguished by the two white bands; this reason no longer seems to me to exist now. However, I think I should remind you here that knowledge of the new metal is the result of research carried out independently by several people. To each will subsequently be attributed his fair share in the deconverte. These reservations made, I propose the name of *samarium* (symbol = Sm) derived from the root which has already been used to form the word *samarskite* (p. 214).

D. N. Trifonov & V. D. Trifonov (1985) wrote about the history of the discovery of *samarium* as follows:

Mendeleev put the symbol Di into his periodic table and described "didymium" as a separate chemical element although, in general, the great Russian scientist was suspicious about the REEs [Rare Earths] (for instance, he did not recognize the existence of terbium). The death sentence to "didymium" was signed by the study of samarskite. At the end of 1878 the French spectroscopist M. Delafontaine [(1837-1911)] began to study didymium extracted from this mineral and found two new lines in its spectrum. Since at that time the accepted approach was "a new line in the spectrum means a new element", Delafontaine thought just that. In his opinion, a new previously unknown element contained in "didymium" was responsible for the appearance of the new lines in the spectrum. He named it "decipium" from the Latin "to deceive, to stupefy" and the name proved to be ironical: "decipium" turned out to be a mixture of several REEs both known and unknown ones. Decipium was debunked in 1879 by L. de Boisbaudran of France who played a prominent role in the discovery of new REEs. … Boisbaudran extracted "didymium" from samarskite and thoroughly studied the sample by spectroscopy. Boisbaudran was a much more skillful experimenter than Delafontaine and he succeeded in separating the impurity from "didymium". He named the new element "samarium" after samarskite, being unaware that "samarium" was also a mixture of elements. Boisbaudran's discovery was immediately confirmed by [the Swiss chemist Jean-Charles de] Marignac [(1817-1894)] who, after multiple recrystallizations of "samarium", separated two fractions which he marked Yα and Yβ … The spectrum of the second fraction was identical to the spectrum of "samarium" (p. 132).

In 1886, Lecoq de Boisbaudran discovered *dysprosium*. He wrote about the discovery of this element (Lecoq de Boisbaudran, 1886b; Lecoq de Boisbaudran, 1886c) as follows:

The oxide hitherto called *holmia* is therefore not homogeneous, and contains *at least* two radicles. As the bands 640.4 and 536.3 are those especially which served [the Swiss chemist] M[r]. [Jacques-Louis] Soret [(1827-1890)] and [the Swedish chemist] M[r]. [Per Teodor] Cleve [(1840-1905)] for recognising the presence of a new element in the old erbium, the author proposes to retain the name *holmium* for the element which produces these bands, and to call the metal giving the bands 753 and 451.5 *dysprosium* (symbol Dy) (1886b, p. 1004; 1886c, p. 265).

D. N. Trifonov & V. D. Trifonov in their book (1985) on the discovery of *dysprosium*, they wrote the following:

It is unquestionable that dysprosium was discovered (1886) by de Boisbaudran alone. Having prepared sufficiently pure "holmium", the scientist thoroughly studied its spectrum and discovered two new lines which pointed to the presence of an unknown element. After multiple recrystallizations he separated the impurity; thus, dysprosium was discovered, as

well as holmium. Its name originates from the Greek for “difficult to obtain”. The name is symbolic since it is characteristic of the REEs history (p. 134).

Lecoq de Boisbaudran and Gadolinium

The element 64 in the Periodic Table was named after the Finnish chemist Johan Gadolin (1760-1852) (Adunka, 2018, p. 23; Childs, 1998, p. 42; McLennan, 2018, p. 525; Sztejnberg, 2020; Weeks, 1960, p. 875). Jean-Charles de Marignac in a letter sent in 1886 to the Lecoq de Boisbaudran proposed the name *gadolinium* for the element Yα, which he identified spectroscopically in the mineral gadolinite in 1880. Marigniac also separated his oxide and is credited with its discovery. This metal was isolated by Lecoq de Boisbaudran in 1886 (“Gadolinium”, n.d.).

Lecoq de Boisbaudran (1886d) in a short note published in *Comptes Rendus de l'Académie des Sciences* under the title *Le Yα de M. de Marignac est définitivement nomme gadolinium* (Mr. de Marignac's Yα Is Definitely Named Gadolinium), wrote:
During a correspondence which I recently had the honor of maintaining with M[r]. de Marignac, I took the liberty to draw the attention of the illustrious chemist to the advantage which there would be, for those who deal with rare earths, to see the Yα receivings interesting, has long been too well studied and its spectrum offers characteristics too clear for any doubt to exist as to its individuality. ... Mr. de Marignac kindly asked me to announce to the Academy that he had chosen the name of gadolinium (symbol Gd) for the metal of Yα (p. 902).

Articles, books and chapters in books written by Lecoq de Boisbaudran

The list of Lecoq de Boisbaudran’s works includes two hundred and forty six papers that appeared in print for a period of fifty-five years from 1866 to 1911 (“Bibliographie Des Travaux”, 1923, pp. XLV-LIV). These are articles on various topics published in French, Germany, Great Britain, and USA. Most of his articles have been published in the *Comptes Rendus Hebdomadaires Des Séances De L'Académie Des Sciences*. His work also appeared in *Bulletin De La Sociéte Chimique De Paris, Annales De Chimie Et De Physique, Bulletin De La Sociéte Française De Minéralogie, Fresenius, Zeitschrift für analytische Chemie, The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science, The Chemical News,* and the *Scientific American*.

His early works were devoted to physical chemistry, in which he was one of the precursors. His first article entitled *Sur les solutions sursaturées* (On Supersaturated Solutions) appeared in 1866 in the *Comptes Rendus Hebdomadaires Des Séances De L'Académie Des Sciences* (Lecoq de Boisbaudran, 1866).

In 1869, he pointed out the similarities in the structure of the spectra of potassium, rubidium, and caesium (Lecoq de Boisbaudran, 1869).

His article entitled *Séparation du cérium et du Thorium* (Separation of cerium and thorium) was published in 1884 in the *Comptes Rendus Hebdomadaires Des Séances De L'Académie Des Sciences* (Lecoq de Boisbaudran, 1884a). Two years later, he proved that Lawrence Smith's *mosandrium* (Smith, 1878a; Smith, 1878b; Smith, 1878c) is a mixture of didymium and samarium (Lecoq de Boisbaudran, 1886a).

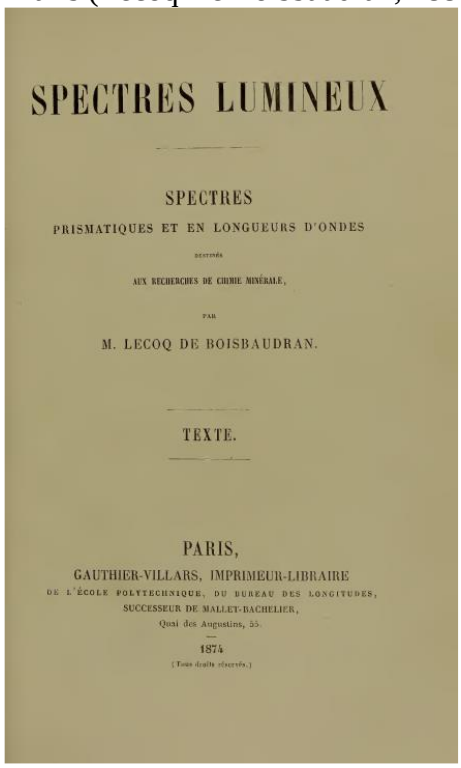
His last two papers were published in the *Comptes Rendus Hebdomadaires Des Séances De L'Académie Des Sciences* in 1911. The first article was entitled *Sur la déshydratation des sels (*On the Dehydration of Salts) (Lecoq de Boisbaudran, 1911). The second paper under the title *Sur le spectre du glucinium et sur ses bandes, dans diverses*

sources lumineuses (On the Spectrum of Glucinium and on its Bands, in Various Light Sources), he wrote together with the French physicist and mineralogist Arnaud de Gramont (1861-1923) (Lecoq de Boisbaudran & De Gramont, 1911).

He was the author of several books written in French. *His Sur La Constitution Des Spectres Lumineux. Extrait* (On the Constitution of Light Specters. Extract) was published in 1870 in La Rochelle (Lecoq de Boisbaudran, 1870).

In 1871, he wrote a book (Figure 2) entitled *Spectres Lumineux. Spectres Prismatiques Et En Longueurs D'Ondes Destinés Aux Recherches De Chimie Minérale* (Light Specters. Prismatic and Wavelength Spectra for Mineral Chemistry Research) (Lecoq de Boisbaudran, 1874a). His *Atlas* with spectra of various chemical compounds was published the same year (Lecoq de Boisbaudran, 1874b).

In 1877, his *Sur Un Nouveau Métal, Le Gallium* was published by Gauthier-Villars in Paris (Lecoq De Boisbaudran, 1877d). Seven years later in 1884, his book under the title *Séparation Du Gallium D'Avec Les Autres Éléments* (Separation of Gallium from other Elements) appeared in Paris (Lecoq De Boisbaudran, 1884b).


SPECTRES LUMINEUX

SPECTRES

PRISMATIQUES ET EN LONGUEURS D'ONDES

AUX RECHERCHES DE CHIMIE MINÉRALE,

PAR

M. LECOQ DE BOISBAUDRAN.

TEXTE.

PARIS,

GAUTHIER-VILLARS, IMPRIMEUR-LIBRAIRE

DE L'ÉCOLE POLYTECHNIQUE, DU BUREAU DES LONGITUDES,

SUCCESSEUR DE MALLET-BACHELIER,

Quai des Augustins, 55.

1874

Fig 2. *Title page of Lecoq de Boisbaudran's Spectres Luminex (Paris: Gauthier-Villars, Imprimeur-Libraire, 1874).*

He was the author of one chapter and one part in books written in French. In 1884, his chapter on *Gallium* was published in the third volume of the *Encyclopédie Chimique* under the direction of Edmond Frémy (1814-1894) (Lecoq de Boisbaudran, 1884c).

Twelve years after the death of Lecoq de Boisbaudran, a book entitled *Analyse Spectrale Appliquée Aux Recherches De Chimie Minérale* (Spectral Analysis Applied To Mineral Chemistry Research) was published in Paris. Lecoq de Boisbaudran's name can be seen on the title page as the author of the first part of this book, entitled *Dessins Et Leurs Descriptions* (Drawings and Their Descriptions) (Lecoq de Boisbaudran, 1923). The author of the second part was Arnaud de Gramont. This book also includes a bibliography

of the works of Lecoq de Boisbaudran (Lecoq de Boisbaudran & de Gramont, 1923, pp. XLV-LIV).

CONCLUSION

Paul-Émile (François) Lecoq de Boisbaudran (1838-1912) was an important French chemist of the second half of the XIX century and the first decade of the XX century. He was one of the founders of spectroscopy. He discovered gallium, samarium, and dysprosium and improved methods for the separation of rare earths elements.

He was a man who never sought honors. He received the *croix de la Légion d'honneur* (Cross of the Legion of Honor) in 1876 for his discovery of gallium. "But, as he never took any steps for himself, he never received the officer's rosette" (Urbain, 1912, p. 664).

He received the Bordin Prize in 1872. In 1878, he became a corresponding member of the chemical section of the *Académie des sciences* ("Lecoq de Boisbaudran", 2014; Urbain, 1912, p. 664). On February 2, 1888, he was elected a foreign member of the *Chemical Society of London* ("The Jubilee of", 1896).

In 1879, he was awarded the Davy Medal by *the Royal Society of London* for his discovery of gallium ("The Royal Society", 2020; Urbain, 1912, p. 664). In the same year, the *Académie des sciences* awarded him the L. Lacaze Prize. The rationale (Figuier, 1881) was written as follows:

After discovering gallium, characterized by two lines placed in the violet, with wavelengths of 417.0 and 403.1, Mr. Lecoq de Boisbaudran studied with the greatest care the chemical properties of gallium, which he succeeded in extracting, by a work of several months, of a few hundred kilograms of blende. This study showed that there exists a close relationship between gallium and a metal predicted by the Russian chemist Mr. Mendeleev in his remarkable classification of the elements, … The new course following the discovery of this simple body assigns to the work of Mr. Lecoq de Boisbaudran all the characteristics of a true event in the history of chemistry. It is to consecrate the memory of this discovery that the Academy awards Mr. Lecoq de Boisbaudran the Lacaze Prize for 1879 (p. 507).

His books were written in French, and his papers were written not only in French, but also in English and German. Some authors also wrote about his life and works. For instance, J. H. Gardiner wrote briefly about him and his research activities in *Nature* (Gardiner, 1912). The French chemist George Urbain (1872-1938) wrote article about his works (Urbain, 1912). In 1913, his obituary notice was written by the British chemist Sir William Ramsay (1852-1916) (Ramsay, 1913). Arnaud de Gramont wrote about his life and works in 1923 (De Gramont, 1923). In 2002, James L. Marshall and Virginia R. Marshall wrote an article about him and the discovery of gallium (Marshall & Marshall, 2002). Marco Fontani, Mariagrazia Costa and Mary Virginia Orna briefly wrote about him in their book published in 2015 (Fontani, Costa, & Orna, 2015, pp. 211-213).

George Urbain (1912) wrote about one of his meetings with Lecoq de Boisbaudran as follows:

One day, face to face with him, I lamented the fact that his work was so little known and I reproached him for not having done enough to make it better known; he replies with a peaceful smile that science certainly was not lacking in impartial historians. I cannot recall this without being moved. … I then realized that I had before me not just a great scientist, but also a great person (p. 664).

Lecoq de Boisbaudran, as one of the great masters of the spectrochemistry, went

down in the history of chemistry, and his name was written in it forewer. This was made possible thanks to his wonderful studies in which he discovered gallium (1875), samarium (1879) and dysprosium (1886), his works in physical chemistry, analitycal chemistry, rare earth chemistry and spectrochemistry as well as his books and his chapters in books on chemistry and spectrochemistry.

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