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Name game: the naming history of the chemical elements—part 1—from antiquity till the end of 18th century

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Abstract
The aim of the series of the three articles entitled "Name game…" is to present the historical information about nomenclature history of every known chemical element. The process of naming each chemical element is analyzed, with particular emphasis on the first publication with a given name. It turned out that in many cases this information is not obvious and unambiguous, and the published data are even contradictory. In a few cases, the names of the elements were changed even several times. Moreover, even when the author of a given element name is known, it is sometimes not entirely clear in which publication he/she first used it. Therefore, the series of three articles are an attempt to sort out the issue of first publishing of the names of all 118 chemical elements known so far, based on original source texts, available thanks to the digitization of a number of collections of scientific literature. The articles are divided according to the time of discoveries: (1) research till the end of the 18th century, (2) discoveries in the 19th century, (3) discoveries and syntheses of elements in the 20th and 21st centuries. This particular article presents the history of naming of the first 37 elements: known from antiquity, discovered in nature and named in 17th and 18th century.

Keywords Chemical elements · Naming history · History of chemistry

Introduction

Browsing through publications on chemical discoveries, it is usually easy to find information about discoverer, as well as to identify the time of the event. A more detailed analysis can also answer the question about the motivations, causes and effects of a particular discovery. Surprisingly, when analyzing the discoveries of chemical elements, it turns out that while the information mentioned above is relatively easy to find, the facts about the first publication about a given element, along with a proposal for its name, happen to be a challenge in many cases. It appears that one often cannot put an equal

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sign between the element discoverer, the name giver and name publisher, the time of the discovery and the time of the naming, as well as between what was in fact discovered and how it was named. Detailed publications in the field of the history of chemical elements, starting with the classic book of Mary Elvira Weeks, do not devote much space to this aspect (Emsley 2003; Weeks and Leicester 1968). Moreover, in several cases it turns out that the duplicated data are inaccurate or even incorrect. In general, the information on this subject is scattered and should be gathered and systematized in a comprehensive and compact form.

The series of articles is an attempt of such systematics and information collection about the official birth of the current names of chemical elements in a consistent and unambiguous manner. To the author's best knowledge it is probably the first article of its kind, which focuses on such a specific aspect in the history of the elements discovery.

Due to the large number of elements the description of the research has to be divided in three parts. Moreover, the historical thread is shortened to the very minimum in order to fulfill the objectives on one hand, and on the other hand to put all the necessary information into the article. Thus, the laconic nature of the message is imposed by the number of elements.

The development of the concept of an element is widely presented in many publications and books (Ball 2014; Connelly et al. 2005; Emsley 2003; Hunter 2000; Iskander 2001; Weeks and Leicester 1968) therefore it is not going to be discussed here. However, in order to systematize the historical background, necessary to present the history of the elements' nomenclature one has to point out the most crucial stages and milestones in the history of discovery of chemical elements:

- Antiquity—simple substances existing in the consciousness of alchemists and others since the dawn of time (gold, silver, copper, tin, lead, iron, mercury, carbon, sulphur).
- The medieval works on isolation of metals of Arab and European scholars (Jabir ibn Hayan, Albertus Magnus). Attempts of the arsenic and antimony isolation.
- The 16th century works of Vannocio Biringuccio, Georgius Agricola and Paracelsus. Isolation of antimony, bismuth, zinc.The beginnings of European modern metallurgy.
- The idea of the chemical element, that already bore the hallmarks of today's understanding of this word, stated by Robert Boyle in his work *Sceptycal Chymist* (1661). The twilight of alchemy.
- 1669 phosphorus as the first element discovered, previously unknown. Subsequent elements were discovered by methods of increasingly sophisticated chemical analysis.
- 1787 the first modern list of chemical elements was given in Antoine Lavoisier's, Louis Guyton the Morveau and coauthors of *Méthode de nomenclature chimique*, which contained thirty-three elements (Morveau et al. 1787).The beginning of the fall of the phlogiston theory.
- 1800 description of a galvanic cell by Alessandro Volta. Application of electrochemical methods in the isolation of new chemical elements.
- 1814 the invention of spectroscope by Joseph von Frauenhofer, and the application of spectroscopic method in analysis of the elements from the mid-nineteenth century.
- 1869 Dimitri Mendeleev proposed his periodic table of elements.
- 1896 the discovery of the phenomenon of radioactivity by Henri Becquerel. The beginning of the discovery of radioactive elements.
- 1932 commissioning the first cyclotron. The beginning of synthesis of artificial elements.

Research methodology

Due to the multitude of the backgrounds of discoveries, certain methodological assumptions had to be made to fulfill the objectives of the work and maintain the consistency of the message. The assumptions are as follows:

- The large number of elements to present imposed the reduction of the historical background and information about the discovery to the necessary minimum. Only the essential facts for understanding the naming mechanism remain, including some simplifications. The turbulent history of discovering new elements is widely described in many specialized books and articles, starting with the work of Mary Elvira Weeks *Discovery of the Elements* (Weeks and Leicester 1968).
- The term "first publication" means an article, book, treatise, press release, available to the world of science of the particular time, the author of which can be indicated and/or the publisher's position itself guarantees the quality of the information provided. The above assumption excludes scientists' laboratory notes and private correspondence, despite the fact that they were often made public in subsequent years.
- The proposed name refers to the element itself or its compound, but by an implication the authors of the publication suggest the existence of the element in a pure state.
- In the case of the seven metals known in antiquity, as well as carbon and sulfur, their names have been known since ancient times, therefore it is naturally impossible to provide both the date of discovery and the first publication. In these cases, certain assumptions, concerning their perception as independent beings, were made and are described in particular paragraphs. Similar assumptions apply to elements isolated in Europe before the 17th century.
- On the other hand, in the case of the transuranium elements syntheses and the parallel dynamic development of the media since the Second World War, at least three paths of publishing information should be distinguished. The first is the most official—when information about the synthesis of a new chemical element appears in scientific journals or conference reports. The second, usually faster, when the same information is published in the news sections of scientific journals, in articles in popular science journals, and (in modern times) on the websites of interested research institutes. And finally, the third—by far the fastest—when the name of the new element is quoted on the radio, TV, Internet or in the daily press. This article attempts to systematize only the order of events on the first two paths of information transfer, leaving the research on the third one to media scholars.
- In case of every element (with the exceptions of the elements of antiquity) the full title and author of the particular article/chapter/ treatise/note is presented, as well as the year of publication and the place of issue (book title, journal name). In case of books, the book chapters and treatises the exact page number with the new name is given. In case of scientific articles, the page ranges can be found in the reference section.
- The information about other books/articles, which are important for the understanding of the problem of the discovery and nomenclature of a given element, are cited as well. However, due to the extensive reference section, the number of these additional articles had to be limited.
- Each of the presented element-naming publication was, according to the author's best knowledge, the first to officially publish the name of the element in the form used presently in English (or in a slightly different form, but with a currently sounding core).

Additional nomenclature information in non-English languages has only been added for nitrogen, tungsten, sodium and potassium, as their alternatives to English are commonly used in other languages.
– The chronology of discovery and naming of elements is generally preserved. However, some elements have been grouped in order to show the problem of naming more clearly. That is why in some cases the chronology of events is slightly disrupted.

From carbon to chromium – nomenclature history till the end of 18th century

The following paragraphs discuss 37 chemical elements discovered and named by the end of the 18th century. The discussed elements are distinguished in the periodic table of elements in Fig. 1.

Elements of antiquity

Carbon

Carbon in the forms of charcoal and soot was known to the earliest humans. In 1730 Sir Isaac Newton, in his book *Opticks,* proposed that diamonds must be combustible. In 1772 Antoine Lavoisier demonstrated that charcoal, graphite, and diamond contain the same substance (Lavoisier 1772a, b). Finally, Morveu, Foucroy and Lavoisier, in the book *Méthode de nomenclature chimique,* called the element "carbone", to distinguish it from the French term "charbon" for charcoal (the explanation one can find at the page 44 of the treatise) (Morveau 1787).

Sulfur

Sulfur/sulphur was regarded by the alchemists to be the principle of combustibility. Antoine Lavoisier recognized it as an element already in 1777 in the work entitled *Memoire sur la Combustion en General,* published in *Histoire de l'Academie Royale des Sciences* (Lavoisier 1777). John Dalton stated in *A new System of chemical Philosophy* that: "sulphur appears to be an elementary substance" (Dalton 1808).However, by some other chemists it was still considered to be a compound of hydrogen and oxygen. Its elemental nature was confirmed by series of experiments of Joseph Gay-Lussac and Louis Thenardand, published in papers in 1810 (Gay-Lussac and Thenard 1810; Thenard and Gay-Lussac 1810).

The seven planetary metals: gold, silver, iron, mercury, tin, copper, lead

Each of the seven metals known since antiquity had a symbolic connection with the respective planet and deity. The solar disk of Sol symbolized gold, silver symbolized Luna—the goddess of the moon, the shield with the spear of Mars – iron, the stylized Mercury's caduceus meant mercury, the Jupiter's thunderbolt– tin, the mirror of Venus—copper, the sickle of Saturn—lead, (Table 1).It is naturally difficult to speak of the first official introduction

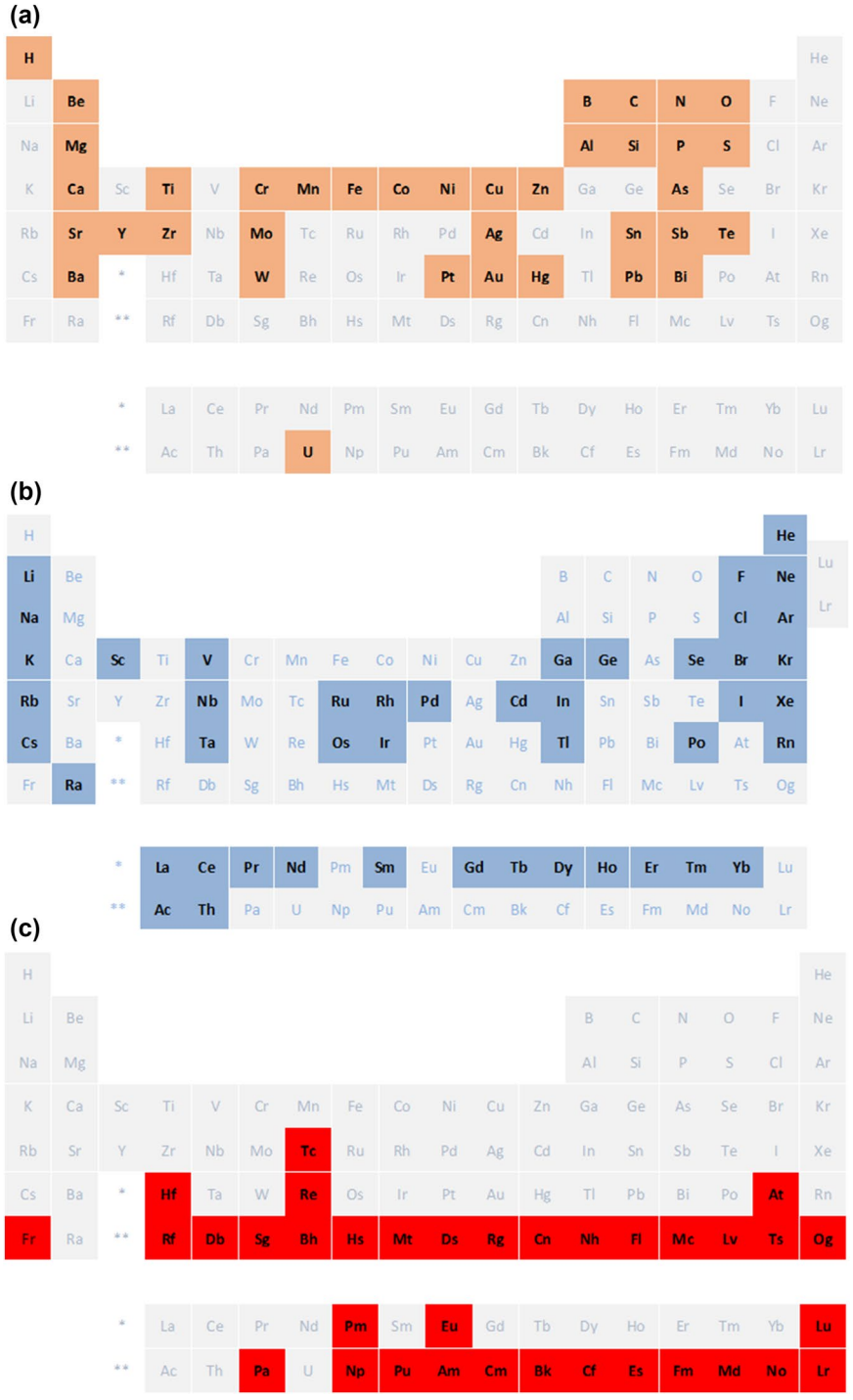

Fig.1 Elements discovered and named till the end of eighteenth century (**a**), elements discovered and named in nineteenth century (**b**), elements discovered, synthesized and named in twentieth and twenty first century (**c**)

Table 1 The ancient symbols of metals and their symbolic connection with planets and deities

Metal	Symbol	Planet	Deity Roman/Greek
Gold	☉	Sun	Sol/Helios
Silver	☾	Moon	Luna/Selene
Iron	♂	Mars	Mars/Ares
Mercury	☿	Mercury	Mercury/Hermes
Tin	♃	Jupiter	Jupiter/Zeus
Copper	♀	Venus	Venus/Aphrodite
Lead	♄	Saturn	Saturn/Cronus

and use of the metals name. The change in their perception over the centuries is inherently related to the change in the perception of the structure of the world, described in a number of studies (Emsley 2003; Weeks and Leicester 1968). At this point, the works of Antoine Lavoisier should again be cited. In 1787, he, together with Guyton de Morveu, Antoine Fourcroy and Claude Bertholet, codified and systematized in already cited *Méthode de nomenclature chimique* the above mentioned elements as "substances non decomposes"(substances not decompounded), that is the chemical elements according to today's definition (Morveau et al. 1787).

The medieval elements: arsenic, antimony, bismuth, zinc

The history of the discoveries and nomenclature of the following four elements: arsenic, antimony, bismuth and zinc, is also not entirely clear. It is documented that they were known to prehistoric people either as free simple substances or in the form of minerals but the knowledge about them was often erroneous, because it was empirical. It was only with the advent of alchemy, when many chemical procedures were developed, that the information about them was somewhat structured and expanded. The nature of these moieties was still unclear, although many useful substances were obtained, such as their acids, bases and salts. On the other hand, analytical chemistry had not existed yet, so it is difficult, in the understanding of modern science, to accept the descriptions of that time (Emsley 2003).

Arsenic

The first written information about the isolation of arsenic can be found in the 42nd treatise of The 112 Books of Jabir ibn Hayyan, called Kitāb al-Khalis al-mubarak (The Book of the Blessed Pure), composed probably in the 9th century in Baghdad. In this treatise, according to bibliographers of medieval works, a reference to the way of arsenic production can be found (Iskander 2001). In Europe the German Dominican scholar and alchemist, Albertus Magnus, is supposed the be the first one to provide documented evidence of the arsenic recovery by heating orpiment with soap, in his book *De mineralibus et rebus metallicis libri quinque*. This experiment was described in the second traitise *Liber secundus qvi est de lapidibus pretiosis;tractatus secundus* and chapter sixth*: de labipidibus nominate & eorum virtutibus; capitulo 6: De incipientibus a littera F*, in the paragraph entitled *Falcones* (Magnus 1250). Other sources question Magnus's work and claim, that it was Vannocio Biringuccio who, in his work from 1540 *De la pirotechnia,* distinguished orphiment

from crystalline arsenic. The cited description can be found in the chapter seven of the second book *(libro secondo, capitolo settimo,* p.33*),* entitled *Del arsenico orpimento etri sagallo* (Biringuccio 1540). Finally, one needs to mention Johann Schröder, who, in 1641 in his *Pharmacopeia,* clearly and undoubtedly reported the preparation of metallic arsenic by reducing white arsenic with charcoal. The description is presented in the part 3 (liber III) *De Macrocosmologia seu mineralogia,* in the chapter 27 *(caput XXVII) De Arsenico* (Schröder 1641). However, it has to be noted, that arsenic has been considered most likely a kind of complex substance for ages. It wasn't until Lavoisier established a new definition for elements in 1787, in which arsenic was listed as a simple substance.

Antimony

The so called "Father of Chemistry"- Jabir ibn Hayyan, first recognized antimony in the 8th century(Iskander 2001). The first widely recognized European work on the isolation of metallic antimony (with the assigned name) was the already mentioned *De la pirotechnia* of 1540 by Vannoccio Biringuccio (*libro secondo, capitolo terzo Del antimonio et sua miniera,* p.27) (Biringuccio 1540), predating the more famous 1556 book by Georgius Agricola *De re metallica* (book X) (Agricola 1556). The native antimony was first discovered by Anton von Swab around 1748 in the sample from the Sala Silver Mine in Sweden (von Swab 1748). Antimony, like other metals, was probably not considered elementary until it was proposed by Antoine Lavoisier in 1787.

Bismuth

Due to the similarity in appearance to tin and lead, bismuth was most likely not identified till the 15th century. The first clear and confirmed description of this metal as a separate entity came from Georgius Agricola, who in his two works: *Bermannus Sive De Re Metallica Dialogus* (p.75), from 1530, and *De Natura Fossilium, Lib X* (p.439) from 1546, asserts that bismuth was considered to be an element distinct from other metals of that time (Agricola 1530, 1546).

Zinc

Centuries before zinc was recognized as a distinct element, zinc ores were used for making brass (Habashi 2006). The technology of zinc smelting was mastered in China and India around 1300. In Europe, the term "zinc" for metal from the Far East was probably introduced into the literature by Paracelsus in one of his treatises called for short *"De Mineralibus",* published posthumously in 1570 in the set of treatises entitled *Etliche Tractatus Des Hocherfarnen vnnd berümbtesten Philipii Theophrasti Paracelsi, der waren Philosophi und Artzney Doctoris: I. Von natürlichen Dingen. II. Beschreibung etlicher kreütter. III. Von Metallen. IIII. Von Mineralen. V. Von Edlen Gesteinen,* in which the author devotes a one-page chapter (p. 450) to zinc as a new metal with the properties distinct from other known metals (Paracelsus 1570). There is no evidence that the metal was isolated in Europe before 1668, when Flemish metallurgist and alchemist Moras de Respour

reported that he had extracted metallic zinc from zinc oxide (de Respour 1668). However, it is Andreas Sigismund Marggraf who is usually credited for the first detailed documentation of the method of extracting zinc from its ore in 1746 (Marggraf 1746).

The elements whose discovery, as well as their naming, is already well documented

From the mid-seventeenth century, starting with phosphorus, both the documentation of the discovery and the naming of the elements is more widely accessible and it is systematized below.

Phosphorus – the first documented discovery and the swan song of alchemists

The first well-documented and widely recognized discovery of a chemical element was the 1669 discovery of phosphorus by the amateur alchemist Henning Brand (Ashley et al. 2011; Partington 1936). However, the first publication in which the term *"posfesfor"* appeared for the glowing element was the work of Georg Kaspar Kirchmayer published in 1676, entitled: *Noctiluca, constans &per vices fulgurans, diutissimè quoesita, nunc reperta; Dissertatione brevi proevia de Luce, Igne ac Perennibus Lucernis, Publicata à Georgio Gaspare Kirchmajerus*. The phosphorus is mentioned in the chapter III (Caput III), entitled *Nocticula aliqua Constanti & per vices fulgurante, nunc reperta (§2)* (Kirchmayer 1676). Antoine Lavoisier recognized phosphorus as an element a century after Brandt's discovery.

Cobalt

The next discovered element was cobalt. Although its name itself had appeared in ancient Greece and spread in medieval Germany, it had referred to contaminated silver ores. The name strictly related to the isolated metal – *regulum cobalt* appeared for the first time in 1735 in the work of Georg Brandt, entitled *„Dissertatio de Semi – Metalis*, published in *Acta Literaria et Scientiarium Sveciae*. (Brandt 1735). Thus, cobalt has become the first metal to be discovered since ancient times.

Nickel

The name *Kupfernickel*, similarly as in the case of cobalt, was originally used in relation to the mineral – nickel arsenide (Baldwin 1931; Nature 1965). The discovery of metallic nickel was published in 1751 by Axel Fredrik Cronstedt. In his article Cronstedt did describe a new *"half-metal"*, however, he did not use the name "nickel" (Cronstedt 1751). It appeared in 1754, in the next Cronstedt's publication *Fortsättning af rön och försök, Gjorde Med en Malm-art från Los Kobolt Grufvor*, published in *Kongliga Svenska vetenskapsakademiens handlingar* (Cronstedt 1754).

Platinum

The history of platinum starts in the New World and is connected with conquistadors. The name of this metal, discovered c.a 1735 in present-day Ecuador, is a Spanish diminutive of the word silver – plata. The name „platina" was used to emphasize the low usefulness of the newly discovered metal. This scornful name was described for the first time in Europe in 1748 by the Spaniards Antonio de Ulloa and Jorge Juan y Santacilia, in the adventure story reflecting over a ten-year-long journey to the New World. The full title of the book is *Relacion historica del viage a la America Meridional: hecho de orden de S. Mag. para medir algunos grados de meridiano terrestre, y venir por ellos en conocimiento de la verdadera figura, y magnitud de la tierra, con otras varias observaciones astronomicas, y phisicas*. Platinum is described in the first part of the work, the second volume, book VI entitled: *Descripción cíe la Provincia de Quito en lo que se estiende la Jurisdicción de su Audiencia con varias noticias Geográphícas y de historia, tanto Política como Natural, de aquel País y de sus Habitadores*. The name of the metal appears for the first time in the chapter X (CAPITULO X) entitled *Dase una breve noticia de los Minerales de Plata, y Oro, de que abunda la Provincia de Quito,y del methdo de extraer el Metal en algunos de Oro*, at page 606 (de Ulloa and Santacilia 1748).

The problem of "earths" and minerals of elements

The history of naming of the following several elements has many common features. The difficulty of unequivocally establishing the moment of naming lies in the fact that the sources of the present names functioned earlier than the discovery of a particular entity occurred. Moreover, in the years after Antoine Lavoisier had questioned the phlogiston theory and developed the new chemistry based on the concept of the so called "earths", that could be reduced to their elements, the discovery and description of a "new earth" was regarded as equivalent to discovering the element within. In view of the above complexity of the subject, for most of the 12 elements discussed below (manganese to beryllium), more than one publication may claim to be the first one to describe the element's name and thus it has to be presented.

Manganese

With the name of stone of Magnesia (Μαγνητιςλιθος) were described both the ores containing pyrolusite (MnO_2) *magnesia nigra* and magnesium hydroxycarbonate ($Mg_5(OH)_2(CO_3)_4 \cdot xH_2O$, x = 3,4,5 depending on the type of mineral), that is *magnesia alba*. Manganese was isolated for the first time probably in 1770 by Ignaz Gottfried Kaim from braunstein ore, which had been regarded before as an impure ore of iron (Kaim 1770). The first fully confirmed manganese isolation was made in 1774 by Swedish metallurgist Johan Gottlieb Gahn, who obtained it from manganese(IV) oxide. However, Gahn hardly published anything of his work, so there is no publication by him about that fact. Up to 1779 the new metal was called magnesia (Bergman 1775; Scheffer 1775; Scheffer and Bergman 1776). The term „manganese" was used for the first time to describe this particular element in 1779 by Louis Guyton de Morveu, in his article entitled the *Observations*

d'une Manganèse étoilee artificielle, published in the journal *Observations et Memoires sur la Physique, sur L'Histoire Naturelle et sur les Arts et Métiers* (Morveau 1779).

Magnesium

A few chemists, pharmacists and physicians worked on the *magnesia alba* description since the beginning of the eighteenth century (Davis and Eklund 1972). The first successes in distinguishing of *magnesia alba* from other minerals are assigned to Friedrich Hoffman, who described his experiments in his book *Observationum physico-chemicarum selectiorum libri III* (Hoffman 1722), though the significance of the observation was not perhaps realized at this stage (Oldroyd 1973). However, it was Joseph Black in 1755 who is usually presented as the first scientist, who distinguished magnesia (magnesium oxide, MgO) from quicklime (calcium oxide, CaO). *Experiments upon Magnesia Alba, Quicklime, and some other Alcaline Substances"* was read in June 1755, and was first published in 1756 in *Essays and Observations, Physical and Literary,vol.II*. (Black 1756). What is most important in this case – he did not isolate the metal, but predicted "magnesia" as a separate "new earth". In 1808 Humphry Davy confirmed the isolation of the element he called „magnium", because for the description of manganese the name "magnesium" was still used in parallel (Davy, Humphry 1808). It wasn't until 1812 and the book *Elements of chemical philosophy* that Davy had changed his mind, following the "candid criticisms of some philosophical friends," and the new metal became known as magnesium (the information about this change appears at page 198 in the Philadelphia edition (Davy, Humphry 1812a) and at page 350 in the London edition (Davy, Humphry 1812b)).

Molybdenum

Molybdenum compounds have been known since antiquity, but they were perceived together with graphite and lead compounds. Molybdenite—black molybdenum (IV) sulfide, was used, similarly to graphite, for drawing. Its name comes from the times of ancient Greece, where, due to the similarity of molybdenite to lead ore—galena, it was called *molybdos*, which meant lead (Emsley 2003). Axel Cronstead in 1758 assumed that molybdite contains a "new earth" ((published anonymously) Cronstedt 1758). Also Bengt Andersson Qvist thought it contained new metal, but did not name it literally (Qvist 1754). In 1778 Carl Wilhelm Scheele conducted research on molybdenite and produced the oxide of a new element. He obtained also acid, which he named the "molybdenic acid" (acidum molybdænæ). He thus concluded that it did not contain lead, as had been suspected and reported that the mineral contained a new element that he, as the first one, called molybdenum, after the mineral. He published his findings in the article *Försök med Blyerts, Molybdæna* published in *Kongliga Vetenskaps Academiens Handlingar* (Scheele 1778). Scheele however, did not obtain the metallic element. The final isolation of molybdenum was described by Peter Jacob Hjelm in 1788 (Hjelm 1788).

Tungsten/wolfram

In 1781 Carl Wilhelm Scheele demonstrated that the mineral tungsten contains lime and in addition a salt of calcium and of a new, unknown, acid, which he called "tungstic acid". Torbern Bergman suggested obtaining of the corresponding metal by charcoal reduction

of the above mentioned acid. Both articles were presented in *Kongliga Vetenskaps Academiens Handlingar,* first entitled *Tungstens beståndsdelar* and the second *Tillåggning om Tungsten* (Bergman 1781; Scheele 1781). Independently, Juan José de Elhuyar and Fausto de Elhuyar discovered, isolated this element (in fact as the first) and described it in 1783 in the article *Analisis quimico del volfram y examen de un nuevo metal que entra en su composicion,* in which the name "volfram" was assigned to the discussed element for the first time. The paper was issued in the Spanish journal *Extractos de las Juntas Generales celebradas por la Real Sociedad Bascongada de los Amigos del País* (D'Elhuyar and D'Elhuyar 1783).Since that time both names are in use, depending on the language. In 1950 IUPAC accepted tungsten instead of wolfram for element #74, in deference to North American usage, while keeping W as the symbol (Rayner-Canham and Zheng 2008).

Barium, calcium, silicon, aluminium and their "earths"

The naming history of barium, calcium, silicon and aluminium is, in general, similar to magnesium/manganese. All of these elements had been known before isolation, as "earths", whose names functioned in literature earlier than the specific elements were discovered. The knowledge about those "earths" was systematized by Louis Guyton de Morveu starting with the *Elemens de chymie* from 1777 (Morveau 1777) and later, together with Lavoisier, in *Méthode de nomenclature chimique* (Morveau et al. 1787) in 1787 and by Lavoisier himself in *Traite elementaire de Chimie* in 1789 (Lavoisier 1789). The French scientists suspected that the "earths", which Lavoisier named "salifiable" (salt-forming—ores that could be made to react with acids to produce salts), may be oxides of fundamental chemical elements. The following salt-forming "earths" were distinguished: chaux (calcium oxide), magnésie (magnesia, magnesium oxide), baryte (barium sulfate), alumine (alumina, aluminium oxide), and silice (silica, silicon dioxide) (Lavoisier 1789).

Barium

The "new earth" in pyrolusite was discovered by Carl Wilhelm Scheele in 1772 and described in 1774 in the same paper as the description of manganese (Scheele 1774). However, Scheele did not name his new discovery. Since that time the names *terra ponderosa, or Schwerspat* functioned. The name *barote* for the next "simple earth" was proposed by Louis Gouton de Morveu in his paper from 1782, entitled *Mémoire sur les dénominations chimiques, la nécessité d'en perfectionner le système, et les règles pour y parvenir* published in *Observations et Mémoires sur la Physique, sur l'Histoire Naturelle et sur les Arts et Métiers* (Morveau 1782). In 1789 Lavoisier listed "baryte" as a "salifiable earth" (Lavoisier 1789). Finally, the element was isolated by using electrolysis and described as barium by Humpry Davy in one of his most influential papers, entitled *Electro-chemical researches, on the decomposition of the earths; with observations on the metals obtained from the alkaline earths, and on the amalgam procured from ammonia*, published in *Philosophical Transactions of the Royal Society of London* (Davy, Humphry 1808).

Calcium

Compounds of calcium, such as gypsum, marble or alabaster have been known for thousands of years. The name "calcium" itself originates from the Latin word calx, which means "lime." According to Oldroyd "Knowledge of calcareous earth as an individual substance dates back for centuries, and we cannot tell who was the first to recognize its individuality" (Oldroyd 1973). However, its chemical composition was not known until the 18th century. Around 1739 German chemist Johann Heinrich Pott, in his traitise *Observationes Et Animadversiones Chymicae: Praecipue Circa Sal Commune, Acidum Salis Vinosum Et Wismuthum Versantium,* recognised *"terra calcarea"* (calcerous earth) as an individual "earth" (p.18, 80 and below) (Pott 1739). In 1755 Joseph Black distinguished *magnesia* from limestone and in the same paper he showed that when heating limestone (calcarious earth), the weight of the sample is lost due to the release of "fixed air" (carbon dioxide) (Black 1756). One of the first attempts to describe "simple earths" was done by Louis Guyton de Morveu. In the first volume of his treaty *Elémens de chymie théorique et pratique* from 1777, in the chapter *Système Abrégé d'histoire naturelle*, he describes "terre calcaire" as one of four "espèces principales"(p. 100–108) (Morveau 1777). In 1781 Morveau introduced the term "terres simples" (simple earths), one of which was "terre calcaire". The article was entitled *Sur les Terres simples, & principalement sur celles qu'on nomme absorbantes; suivi d'un appendice sur une nouvelle preuve de l'existen ce du Phlogistique dans la chaux, & de quelques observations sur le Sel phosphorique calcaire ou substance osseuse régén* and issued in *Journal de physique, de chimie, d'histoire naturelle et des arts* (Morveau 1781). Later on, in 1787, such systematics was confirmed and grounded in the already cited work of Morveau, Lavoisier, Bertholet and Fourcroy *Méthode de nomenclature chimique*. They suggested that lime might be an oxide of a fundamental chemical element (Morveau et al. 1787). The first isolation of the pure calcium was performed by Humpry Davy, with the use of the electrochemical method. He described this experiment in 1808, in the already mentioned paper about "the decomposition of the earths", in which the name calcium appears (Davy, Humphry 1808).

Silicon

Silicon, both as a rock crystals and glass component, was known to ancient civilizations. The first works on silica started most likely in the second part of 17th century. It was Johann Joachim Becher, who identified silica as the "terra vitrescibilis" (Becher, Johann 1669). In the mid of 18th century Johann Heinrich Pott recognised silica as an individual "earth". In his traitise, cited before, he recognized four "primitive earths": calcareous, argillaceous, gypsous, and "vitrifiable," – the last one corresponding to silica (Pott 1739). Later on, Pott described its properties and gave it the name of a siliceous stone (Pott 1746). Louis Guyton de Morveau in his *Elémens de chymie théorique et pratique* described one of the simple earth as "le silex" or "terre quartzeuse" (Morveau 1777). "Terra silicea" was also the subject of the studies of i.e. Torben Bergman and his co-workers (Bergman and Grönlund 1779). Finally, in the *Méthode de nomenclature chimique,* the authors describe "silica" or "terra silicea" as a one of the "simple earths" (Morveau et al. 1787). Lavoisier, in his Traite elementaire de chimie, suggested that the element must exist from its compound. He proposed that a new chemical element could be found in quartz (Lavoisier 1789). However, it was Humpry Davy, who in 1808 proposed the name "silicium" for the

new element, which in fact he did not manage to isolate (Davy, Humphry 1808). The name "silicon" for the predicted element was proposed for the first time by Thomas Thomson in his book *System of Chemistry* in 1817 (p. 252) (Thomson 1817). However, even Berzelius, who managed to obtain the element in the elemental state and is credited with this discovery, persisted with the name "silicium" (Berzelius 1824a). Finally, the arguments about the resemblance to boron and carbon convinced the scientists to use the term silicon**.**

Aluminium/aluminum

The metal derives its name from the word *alumen*, which is the latin name for alum $KAl(SO_4)_2{\cdot}12H_2O$, a bitter mineral that had been used since ancient times as an antiseptic and for dyeing. It was Paracelsus who already recognized "aluminis" as separate entity from vitriol (Paracelsus 1570). Andreas Libavius, in the treatise *Alchemia* from 1597, proposed the name "alumina" for the undiscovered earth of alum (p.120) (Libavius 1597). In 1746 Johann Pott published treatise entitled *Chymische Untersuchungen Welche fürnehmlich von der Lithogeognosia oder Erkäntniß und Bearbeitung der gemeinen einfacheren Steine und Erden Ingleichen von Feuer und Licht handeln, (vol. 1),* in which he described *Terra aluminis* and by series of experiments distinguished alum from lime and chalk (Drozdov 2007; Pott 1746). In 1756 Andreas Marggraf published his achievements on precipitating a new substance from alum, which he believed was a new earth, and which he named *terre d'Alun* (Marggraf 1756a, b, c). An interesting fact is that Marggraf introduced the term *"aluminification"* in the first of the cited publications (p.39). The new isolated earth (which turned out to be Al_2O_3) was named *alumina* by Louis Guyton de Morveau in 1782, in his paper *Mémoire sur les dénominations chimiques, la nécessité d'en perfectionner le système, et les règles pour y parvenir* published in *Observations sur la physique, sur l'histoire naturelle et sur les arts* (Morveau 1782). It is worth to underline, that the statement, often quoted, which asserts that: "In 1761 de Morveau proposed the name "alumine" for the base in alum", cannot refer to the official paper of his, as Guyton the Morveau published his first paper in 1763, and the first scientific publication was read in 1768 (Smeaton 1957). Moreover, in his work *Elémens de chymie théorique et pratique* from 1777, he did not mention the term *"alumine"* although he did discuss *terre alumineuse and terre argilleuse* (Morveau 1777).

Although Humphry Davy failed to isolate the metal, he performed a number of experiments related to that matter and credited himself to name the element (a bit controversially) "alumium" in his already cited article from 1808, discussing electrochemical researches on the decomposition of the earths (Davy, Humphry 1808). The name was, however, not widely accepted. In 1811, in the *Report* summarizing scientific achievements of the year 1810, published in *The Critical Review, Or, Annals of Literature,* one of the Davy´s papers was described and the name "aluminium" was used, regardless of the fact that Davy did not use that term in the original lecture (Smollett 1811). This review is probably the first use of this term in an official way. However, the pioneer of using the name "aluminium" in original scientific work for the description of this element was Jöns Jacob Berzelius, who, in 1811, published the article entitled *Essai sur la nomenclature chimique* in the *Journal de physique, de chimie, et d'histoire naturelle,* in which he assigned "aluminium" to the group of "Metalla" (Berzelius 1811). In 1812 Humpry Davy changed his mind, and the new hypothetical metal (still not obtained in elemental state) was alternatively to Berzelius named "aluminum". The name appears in his book entitled *Elements of chemical philosophy* (at the p. 201 of the Philadelphia issue (Davy, Humphry 1812a) and at the p. 354 of the

London issue (Davy, Humphry 1812b)). Both name variations (aluminium/aluminum), are still in use in English, depending on country.

Finally, it was Hans Christian Ørsted who probably managed to prepare metallic aluminium. In 1825 he isolated a small sample of impure metal describing it as follows: "…en Metalklump, som i Farve og Glands noget nærmer sig Tinnet. " (… a lump of metal which in color and luster somewhat resembles tin). The isolation is questioned by some scientists, moreover, Ørsted in his paper did not even use the term aluminium or related (Örsted 1824). The first undisputed isolation of the pure metal was done by Friedrich Wöhler in 1827 (Wöhler 1827).

Boron

The word boron comes from the mineral borax, and has been used since the ancient times. The Arabs used the expression Bauraq (meaning "white") for a number of minerals including the compounds of boron. Louis Guyton de Morveau in his paper S*ur les dénominations chimiques, la nécessité d'en perfectionner le système, et les règles pour y parvenir* in 1782 introduced the term "radical" which described a multiatomic entity (Constable and Housecroft 2020; Morveau 1782). The term was later used to describe "boracic radical/radical boracique" in the already cited work *Méthode de nomenclature chimique* from 1787 (Morveau 1787). Joseph Gay-Lussac and Louis Jacques Thénard managed to partially isolate the element and in their work *Sur la décomposition et la recomposition de l'acide boracique* in *Annales de chimie; ou Recueil de mémoires concernant la chimie et les arts qui en dependent* they proposed the name "bore" for the newly obtained element (Gay-Lusac and Thenard 1808). One year later Humpry Davy obtained enough amount of the element to study it thoroughly and thus to confirm the discovery of a new element. In his typically distinct manner, he named it slightly differently from the French: "boracium" (Davy, Humphry 1809). Finally, as it turned out that the element is more nonmetallic, he "ventured to propose" name "boron" as more appropriate, especially in the English language. The proposal was made in 1812 in his treaty *Elements of chemical philosophy* at page 178 in the Philadelphian edition (Davy, Humphry 1812a) and at page 314 in the London edition (Davy, Humphry 1812b).

Zirconium

Zircon as mineral (zirconium silicate) has been known since the ancient times. Zirconium as an element was not known until Martin Klaproth analysed a jargon mineral acquired from Ceylon in 1789. Jargon is a name applied to those zircons which are fine enough to be cut as gemstones. Klaproth suspected that the mineral contained a new element. Indeed, he recognized a new entity as a "new earth" *Zirkonerde*, (in fact ZrO_2). The name "Zirkonerde" in this context was used for the first time in the article entitled *Chemische Untersuchung Des Zircons,* published in the *Schriften der Gesellschaft Naturforschender Freunde zu Berlin* (Klaproth 1789a). Although Sir Humphry Davy failed to isolate the metal, he suggested the name zirconium in the 1808, in the already cited article: *Electro-chemical researches, on the decomposition of the earths; with observations on the metals obtained from the alkaline earths, and on the amalgam procured from ammonia*, published in *Philosophical Transactions of the Royal Society of London*(Davy, Humphry 1808). Finally it was

Jöns Jakob Berzelius who obtained the metal and described its properties in 1824 (Berzelius 1824b).

Strontium

The name of mineral strontianite was proposed in 1791 by Friedrich Gabriel Sulzer and Johann Friedrich Blumenbach to honour Strontian – mining village in Scotland. They also came to the conclusion that it contained probably a "new earth" (Sulzer and Blumenbach 1791). In 1790 Adair Crawford independently concluded that the Scottish mineral is a new species of "earth", but no name was proposed (Crawford 1790; Partington 1942). On 4 November 1793 Thomas Hope read a paper entitled: *Account of a mineral from Strontian and of a peculiar species of earth which it contains* to the Royal Society of Edinburgh, which was summarised in the *Society's Transactions*in 1794 (but not published in full until 1798), and in which he called the "new earth" from Strontian "Strontites" (Hope 1798). At about the same time Martin Klaproth also studied Scottish mineral and suspected that the mineral contained a "new earth", for which he proposed the name "Strontianerde". His proposal was published in the article *Versuche über die Strontianerde* in *Chemische Annalen* in 1793 (Klaproth 1793). To sum up, in 1793 in both the Hope's speech and the Klaproth's publication a "new strontium earth" appeared. That is why at least those two authors may be credited for the new element name introduced as the "new earth" (Partington 1942). Fifteen years after Klaproth's publication and Hope's speech Humpry Davy isolated the element from its "earth". He described his research in already cited paper "on the decomposition of the earths" and named the new element strontium according to the rules of naming of the other alkaline earths (Davy, Humphry 1808).

Beryllium

The mineral beryl, which contains beryllium, has been used since at least the Ptolemaic dynasty of Egypt. Louis Nicolas Vauquelin discovered that both minerals emerald and beryl contain the same element as an essential constituent. Vacquelin stated in his article entitled: *De l'Aiguemarine, ou Béril; et découverie d'une terre nouvelle dans cette pierre,* published in *Annales de chimie,* "I haven't thought yet that I should give this earth a name; I'll wait until I know its properties better" (Vauquelin 1798a). Nevertheless, it must be noted that in the cited article, as well as in the following paper of Vauquelin, the term "la terre du beril" appeared several times (Vauquelin 1798a, b). However, the editors of the journal named the new earth "glucine" for the sweet taste of some of its compounds. The name „glucinum" in French had been in force until the middle of the 20th century. Martin Klaproth, who worked independently on the mineral emerald and beryl, concluded that it contain new element. He insisted as early as in 1800 (not in 1802, as it is commonly accepted) that the name "beryllina" to be introduced (Klaproth 1800). In his work entitled *Chemische Untersuchung des Gadolinits* published in *Allgemeines Journal der Chemie* Klaproth referred to the publication of Heinrich Link, who proposed the change of name "Glucine" into "Beryllerde" or "Berylline" in 1799, as "glucine" resembles glycine. (Link 1799). The term beryllium was used for the first time by Friedrich Wöhler who isolated the elemental metal in 1828, independently from Antoine-Alexandre-Brutus Bussy (Bussy 1828; Wöhler 1828).

The first of so-called rare earth elements: yttrium

Yttrium

The discovery of the "earth" of yttrium was first described by Johan Gadolin in 1794 (Gadolin 1794). The "earth" was found in the mineral discovered by Carl Axel Arrhenius in 1787, in the dumps of the Ytterby quarry and described by his friend Rainhold Geijer (Geijer 1788). Gadolin described the "new earth", but no name was proposed. The discovery of Gadolin was confirmed in 1797 by Andreas Ekeberg, who additionally proposed the Swedish and Latin names of "Ytterjord" and "yttria" in the paper entitled *Ytterligare undersökningar av den svarta stenarten frail Ytterby och den dari fundna egna jord*published in *Kungliga Svenska Vetenskapsakademiens Handlingar* (Ekeberg 1797). Finally Friedrich Wöhler isolated the metal yttrium and described it in 1828 (Wöhler 1828).

The first gaseous elements: nitrogen, oxygen and hydrogen

Nitrogen/ Azote

The widely accepted year of the nitrogen discovery is 1772, when Daniel Rutheford, in his dissertation *Dissertatio inauguralis de aere fixo dicto aut mephitico,* described "mephitic air"—noxious air (Rutherford 1772). However, the name "azote", was not proposed until 1787, when it appeared in the *Méthode de nomenclature chimie,* in the chapter of Guyton de Morveau (p. 36) (Morveau 1787). The name nitrogene was proposed even later by Jean Antoine Chaptal, in *Éléments de chimique* in 1790. In the preliminary speech (page XL—XLI) he proposed the name "nitrogène" as deduced from "a characteristic and exclusive property of this gas which forms the radical of nitric acid" and described nitrogen in the second chapter of the book (pp. 124–126) (Chaptal 1790).

Oxygen

Oxygen was discovered independently by Carl-Wilhelm Scheele in 1771 and Joseph Priestley in 1774. However, it was Antoine Lavoisier who officially proposed the name. At first it appeared as „ principe oxigine" in 1778, in the article *Considerations générales sur la nature des acides, et sur les principes dout ils sont composés,* published in *Histoire de l'Académie royale des sciences, avec les mémoires de mathématique et de physique* (Lavoisier 1778). At this stage, Lavoisier had a preference for the word "principle" rather than "element" (Eddy 2004; Hartley 1947). By 1787, when the collaborative *Methode de Nomenclature chimique* was published, "oxigine" had become "oxigène" (Morveau 1787). Finally Lavoisier named the element the "oxygene" in his *Traité élémentaire de chimie* in 1789 (Lavoisier 1789).

Hydrogen

Henry Cavendish collected the new gas and subjected it to systematic study. He reported his findings to the Royal Society in 1766. However, he described the gas only as "inflammable air from the metals" (Cavendish 1766). The biography of Lavoisier (Hartley 1947) marks the year 1787 as the time of introduction of the name "hydrogene". It says: "The name of hydrogen was not adopted until the whole nomenclature was revised four years later [after Lavoisier's experiments with balloon dated 1783 – author's footnote]". Indeed, an analysis of Lavoisier's articles prior to 1787 shows that he used the term "inflammable air" when referring to hydrogen. That is why it can be assumed that the term "hydrogene" was introduced for the first time in the *Méthode de nomenclature chimie* in the chapter of Guyton de Morveau (p. 33) (Morveau et al. 1787).

At this point one need to take a look forward and note the names´ proposals for two isotopes of hydrogen: deuterium and tritium. The name deuterium was proposed by its discoverer Urey and Murphy in 1933 in the letter to the Editor of the *Journal of Chemical Physics*, entitled *A Name and Symbol for* H^2 (Urey et al. 1933). The Name for H^3 isotope was proposed in the same article, but tritium was detected later—in 1934, by Ernest Rutherford, Mark Oliphant, and Paul Harteck, that is after the name proposal (Oliphant et al. 1934).

Elements of the last decade of the 18th century

Tellurium

Tellurium was discovered in 1782 and described a year later by the Austrian mineralogist Franz Joseph Müller von Reichenstein (Müller von Reichenstein 1783). As he was not able to identify and isolate the new element from the ore, he named it aurum paradoxum (paradoxical gold) and metallum problematicum (problematic metal). It was Martin Heinrich Klaproth who named the new element after the Latin word for "earth" in 1798. He isolated new element from the mineral calaverite, and described it in the article entitled *"Ueber die siebenbürgischen Golderze, und das in selbigen enthaltene neue Metall"* published in *Chemische Annalen für die Freunde der Naturlehre, Arzneygelahrtheit, Haushaltungskunst und Manufakturen* (Klaproth 1798)**.**

Titanium

Titanum was discovered in 1791 by William Gregor. He isolated the calx of an unknown metal which he named "manaccanite" (Gregor 1791). Unfortunately for Gregor, Martin Heinrich Klaproth independently discovered the same element in the mineral rutile and named it titanium, which was described in his book *Beiträge zur chemischen Kenntniss der Mineralkörper,* in the chapter *Chemische Untersuchung des sogenannten hungarischen rothen Schörls*. The name titanium appears at page 244 (Klaproth 1795). Despite the fact that Gregor was finally credited with the discovery, the element kept the name chosen by Klaproth.

Uranium

Martin Heinrich Klaproth is accepted to be the discoverer of uranium. He was sure he had discovered a new element in pitchblende in 1789. Therefore he gave the name "uranit" to the new element in honor of the planet Uranus. He described his discovery in *Chemische Annalen für die Freunde der Naturlehre* in the paper entitled: *Chemische Untersuchung des Uranits, einer neuentdeckten metallischen Substanz* (Klaproth 1789b). In the following years he changed the name into uranium in order to conform with the names of other metals (Fontani et al. 2015). More than fifty years later Eugène Melchior Peligot proved that the substance obtained by Klaproth was in fact UO_2 and it was Peligot who managed to obtain the metallic uranium in 1841 (Peligot 1841; Wisniak 2009).

Chromium

In 1797 Louis Nicolas Vauquelin analyzed the correct composition of crocoite. During his experiments both the solutions and precipitates repeatedly changed colors. That is why he (encouraged by Antoine François Fourcroy and René-Just Hauy) named the obtained metal "chrome" from Greek *chroma,* meaning "color". Vauquelin discussed the preparation of chromium in two articles published in the same volume of *Annales de Chimie*. The name of the metal appears in the title of the first article (and only there): *Sur une nouvelle substance métallique contenue dans le plomb rouge de siberie, et qu'on propose d'appeler chrôme a cause de la propriété qu'il a de colorer les combinaisons ou il entre* (Vauquelin 1798c). The reasons for choosing the name were explained in the second article entitled: *Sur le métal contenu dans le plomb rouge de Siberie* (Vauquelin 1798d). One must note that the first article was delivered as a lecture on November 1st, 1797 (11th Brumair of year 6 of the French Republican calendar) in the *l'Institut national des sciences et des arts.* Chromium was thus the last element named in the 18th century.

Summary

Till the end of 18th century 37 elements had been recognized and named. This period is probably the most confusing and controversial in terms of the nomenclature of elements. In many cases, the name has existed in the past and the definition of a chemical element has only just emerged. This is especially true of elements and their compounds ("earths") known from antiquity and the Middle Ages. Therefore, it was extremely difficult to determine when a given name began to refer to a specific entity, meaning a chemical element in the modern sense of this word. In a few cases researchers, although they were unable to isolate a simple substance, gave it a name, as well as its "earth". The naming rules were just taking shape and one can get the impression that there was a certain freedom in terms of names in the pursuit of new discoveries. Hence, for many elements, at least a few publications are given that could aspire to be the "first" with a given name (i.e. aluminum, silicon, calcium). Fortunately for the naming issue, the race to discover and naming new elements in the last decade of the 18th century began to be more systematic, mainly thanks to the works of Lavoisier and his associates, and in particular, thanks to the publication of two treatises: *Méthode de nomenclature chimique* (1787) and *Traité Élémentaire de Chimie* (1789). Thus, with this baggage of experience, scientists entered the 19th century.

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