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Shaping the Periodic Classification in Portugal Through (Text)books and Charts

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Abstract. In the current paper, we present an investigation carried out to map the reception and use of Mendeleev's periodic classification in the Portuguese education system, from 1850 to 1975 while being confronted with other classifications. We present protagonists and documents to demonstrate the attention that the topic received. The research involved the identification of textbooks, programs and graphic presentations used in higher and secondary education levels within this time frame. During the 1880s, Mendeleev's classification appears in higher-level (text)books and programs. Secondary school textbooks however remained faithful to earlier classifications for some more decades, with the exception of the first occurrence found in a textbook for advanced high school in 1906. It does not seem that the periodic system was integrated in the official secondary programs before 1938. The oldest use of periodic charts seems to be from after 1891 at the University of Coimbra, the oldest surviving one dating back to the second quarter of the twentieth century. The periodic table wall charts seem to have entered the secondary classroom in Portugal by the 1960s. This survey of the use of the periodic system in Portugal demonstrates how the different contexts of reception have shaped its introduction in the educational system of what we now regard as the indispensable tool for chemistry. While there was relatively little scientific debate on the periodic law and system, as far as it was found, Mendeleev's classification was appropriated at different speed and stages through textbooks and charts, responding to different pedagogical needs and usage.

Keywords. Periodic classification, Mendeleev, Portugal, textbooks, charts.

1. INTRODUCTION

The publication of the periodic system in 1869 by Dmitri Mendeleev (1834-1907) triggered its widespread circulation and appropriation of the proposed classification of chemical elements in different countries, a subject dealt with in the book *Early Responses to the Periodic System* (2015). Since its beginning, the periodic system was meant to serve both as a support for the conceptual understanding of the periodicity and similitude of the properties of the elements known at the time, and as a pedagogical tool for chemistry students. The current paper stems from one of the chapters of the aforementioned book – "Echoes from the reception of the Periodic Classification in

Portugal"[1] and attempts to go beyond the period already studied, following up on the mention, presence and discussion of the periodic system and classification in books, textbooks, programs, and charts in secondary and higher education, in the period between 1850 and 1975.

The paper begins with the account of an early response in a booklet printed in 1880 dealing with atomic theory and the periodic law of Mendeleev, published at the fringe of a higher education institution, the Porto Polytechnic Academy. After a brief description of the Portuguese higher education system, the next section deals with professors, programs and/or textbooks in the three Portuguese higher education institutions: the Lisbon Polytechnic School, the Porto Polytechnic Academy, and the University of Coimbra where the first mentions of use appear from 1880 onwards. One of the earliest references is the topic of "Mendeleev's law" given as a subject of a dissertation at the Faculty of Natural Philosophy in Coimbra.

Before the periodic system, textbooks and teachers were using other classifications. In a separate section, the impact of the pre-Mendeleev and Mendeleev's classification at university and secondary school level is thus examined and analyzed through different textbooks in use until 1975.

Finally, we traced back what is probably the first use of a Mendeleev periodic chart in a Portuguese university classroom context, linked to the adoption of the periodic system as a pedagogical tool at the University of Coimbra, and what seems to be the oldest surviving Portuguese wall chart, hanging today in the Science Museum, also in Coimbra.

We conclude on the diversity of response, related to each context, and how these various contexts shaped the variety of reception of the periodic classification in Portugal.

2. FIRST RESPONSE TO MENDELEEV'S PROPOSAL: THE UNITY OF MATTER AT THE MARGINS OF ACADEMIA

The first Portuguese publication explicitly mentioning the periodic law dates back to 1880, but to fully understand the context in which it appeared it is necessary to briefly describe a book dated 1876 but only published in 1879, in Porto. *A theoria dos átomos e os limites da sciencia* (The theory of atoms and the limits of science), authored by António Luiz Ferreira Girão (1823-1876) does not make any references to Mendeleev or any other periodic classification for that matter, but sets the scene for the conceptual context in which it will be discussed a year after.[2] Relying mostly on philosophical arguments, Ferreira Girão developed different considerations on the question of the ultimate atom and the creation of matter, surveying the whole of the historical background from Greek times to the most recent developments.[3] Ferreira Girão pursued his historical examples, showing that the idea of considering the simple bodies as compounds was very old, but when alchemy stepped down, it took away with it the underlying belief in the unity of matter. Coeval discoveries and hypotheses (e.g. those of cyanogen and ammonium radicals, and facts relating to isomerism) brought the unity of matter to the fore again, although these theoretical speculations had not been experimentally confirmed. Indeed, even though William Prout's (1785-1850) ideas on the unity of matter seemed to be refuted after Jean-Servais Stas' (1813-1891) accurate determinations of several atomic weights at mid-century, this did not deter the author. According to him, one is in fact led to pursue the direct analysis to see if it is possible to go further and beyond the chemical atoms such as hydrogen, iron or copper, on the basis of evidence relating to the body's free fall, optical phenomena, the dissociation of gases at high temperatures, and the spectral analysis of celestial bodies.

Ferreira Girão presents examples of well-known experiments by different authors, systematizes them, and discusses a certain number of objections to the unity of matter and the existence of prime atoms, convinced that Marcellin Berthelot (1827-1907)'s objections are not sufficiently strong to destroy the hypothesis of the simplicity of matter. The only admissible conclusion in his eyes is that the chemist's atoms are already the result of arrangements of prime atoms. In this way, the existence of prime atoms, and the unity of matter, seems to be beyond doubt to the author. He concludes that, "if reason and experiment lead us to infer that chemical atoms cannot be the last expression of the divisibility of matter, it does not follow that we know what the nature and properties of the first principles are."[4]

While Ferreira Girão cites neither Mendeleev nor the periodic classification, he raises the question on how the huge number of different minerals to be found in the Earth's crust, could be formed by only sixty-five elementary or simple bodies.[5]

The quest was soon taken up by a student, D. Agostinho de Sousa (unknown dates) who published a small booklet in 1880 in which he presents Mendeleev's ideas: *La loi périodique–de M. Mendéléjeff en ce qui concerne le problème de l'unité de la matière et la théorie de l'atomicité*.[6] Little is known about the author and the circumstances: the author introduces himself in the title page as a student at the Porto Polytechnic Academy (and in the text as a student of Ferreira Girão). His use of the title "D." indicates that he was a clergyman but it remains unclear why he uses the French language, which seems to target an undefined foreign audience. The fifty-two pages work consists of an introduction and two chapters, and considers that chemistry is on the verge of a revolution. The first one is entitled *La loi périodique et la question de l'unité de la matière*, and the second chapter, *La théorie de l'atomicité et M. Mendéléjeff*. The author frames the discussion in the field of the unity of matter and atomicity[7] and refers to various recent foreign publications on that topic.

To start with, the author states the tendency of chemistry, physics, and astronomy to establish the unity of matter, despite the brilliant opposition of chemists like Stas and Berthelot. The spectral analysis of nebulae demonstrated, in his opinion, the generation of simple bodies from hydrogen. Further, the author believes, the periodic classification gives an unexpected support to Prout's theory even though Mendeleev would not agree with that conclusion. Agostinho de Sousa proceeds saying that Mendeleev's endeavour is supported by the previous proposals of classification by Jean-Baptiste Dumas (1800-1884), Jean Charles Galissard de Marignac (1817-1894), and Julius Lothar Meyer (1830-1895). Admitting imperfections, he sees them as inherent to a subject both complex and difficult. Agostinho de Sousa prefers to look at it as a whole and in this respect, he is convinced that the periodic law is a broad synthesis, a rational history of simple bodies, but principally a powerful affirmation of the unity of matter. Dumas[8,9] had established the natural families of simple bodies, but he did not know the link connecting one group to another, what Mendeleev made appear. He filled the gap, noting that the difference between the atomic weights of two neighboring bodies does not surpass an average of two or three units, and where this interval is greater, there are gaps to be filled by later discoveries, as recently confirmed with *gallium* (1875) and *scandium* (1879). Facing all this, Agostinho de Sousa considers that Mendeleev came to the aid of Prout's thesis, and to the support of his own opinion on the unity of matter.[10] In that way, and in his opinion, Mendeleev has shaken the theory of atomicity by recognizing that hydrogen, chlorine, and oxygen cannot serve as a standard for measuring the atomicity of elements. Moving on to Berthelot, Agostinho de Sousa states that only when chemistry will relate its laws to those of pure mechanics and the physical sciences, then it will raise itself to the level of the positive physical sciences and, concurrently, will contribute to reaching the unity of the universal law of movements and natural forces. It is thus no coincidence that the insistence of this booklet is not so much on the classification or the system than on the periodic law, which has to be seen as a law of nature, as coincidentally Mendeleev himself hoped it to be.

3. THE CONTEXT OF PORTUGUESE HIGHER ACADEMIC EDUCATION IN CHEMISTRY

This application of the periodic law was published at the margins of the institutions where chemistry was taught. To situate the other mentions of Mendeleev's work in the academic setting, it is important to understand the Portuguese context of higher academic education in chemistry. The institutionalization of chemistry as an independent scientific discipline in Portugal occurred with the 1772 reform of the University of Coimbra which was by then the only institution for higher education in Portugal. The reform of 1844 initiated an innovative approach in the study of chemistry, which introduced three new courses (Analise e Philosophia Chymica, Chymica Inorganica and Chymica Organica) in the chemistry curriculum, following similar developments abroad. By 1851, the Coimbra professor Joaquim Augusto Simões de Carvalho (1822–1902) objected about the use of French textbooks in the study of chemistry. He published a modern textbook *Lições de Philosophia Chimica* (Lessons of chemical philosophy) that included in the chemical lessons recent research achievements and defended greater "attention to the daytoday communications in scientific journals and newsletters than to more complete and extensive manuals" should be given.[11]

After the end of the Portuguese civil war (1834), the country flourished politically and economically. Naturally, those developments influenced on the reform of the curricula of the university. In the case of chemistry, some of its professors went abroad to be updated with the modern experimental techniques, and at the same time, some foreign staff were hired, such as Bernhard Christian Gottfried Tollens (1841-1918).

Focusing on this period, the Portuguese historian of chemistry Amorim da Costa (1939-) considered that although the teaching of chemistry at the university was not outdated, there was no connection whatsoever between experimental teaching and the research underway. The insufficient governmental financial support and the insignificant links to a weak industrial milieu were the two main reasons for that state of affairs.[12] From the 1830s, there was a particular emphasis on teaching emerging from those efforts a secondary school system. One of the aims was the scientific and technical preparation of younger middle-class students intended to serve a modernized Portuguese society. As was the case abroad, all the education reforms were meant to broaden the preparation of the younger generation taking into account, namely the progresses in science and technology. At the secondary level, several disciplines were introduced, in particular the first scientific and technical elements of mathematics, physics, chemistry, natural history, political economy, public administration, and commerce were taught.[13] Later in the century, industrial and agricultural curricula were restructured, both of which were becoming more practical.

By the middle of the century, two institutions stood out: the Polytechnic School in Lisbon, and the Porto Polytechnic Academy, both founded in 1837. The creation of these Polytechnic institutions aimed at developing the industrial sciences. Their goals were to prepare students for the practice of agriculture, industry and commerce and for the first two, chemistry was considered of utmost importance. A specific diploma was also created for chemists establishing their license to manufacture and handle chemical products.[14]

The setting up of the Porto Municipal Chemical Laboratory (1884/87) with António Joaquim Ferreira da Silva (1853–1923), needs to be emphasized as it updated the practical and theoretical chemistry teaching. A similar situation occurred at the Lisbon Polytechnic School, where, during its first years, the teaching of chemistry was mainly expository and speculative, and whose organization and main features did not differ much from the chemistry teaching at the University of Coimbra in the same period. Nevertheless, the Polytechnic had "younger and much more motivated and possibly better-prepared professors," including Agostinho Lourenço (1822–1893), António Augusto de Aguiar (1838–1887), José Júlio Rodrigues (1843–1893), Roberto Duarte Silva (1837–1889), and Achilles Machado (1896–1932), who updated their laboratories, and published textbooks.[15]

3.1. Porto Polytechnic Academy

In 1876, Ferreira da Silva succeeded Ferreira Girão at the Porto Polytechnic Academy, developed a reputable career and took chemistry to a higher level both at the Academy and at the Municipal Laboratory, where there was significant teaching of practical chemistry. Among the recommended textbooks was Ferreira da Silva's *Tratado de Chimica Elementar* (Treatise of Elementary Chemistry).[16] In the second edition (1895) the author states that the structure of mineral chemistry was largely similar to that in the first edition (1884), but some more recent topics were included, and some doctrines of general chemistry were enlarged, namely those concerning the periodic law of elements.

From the first edition, we know that the textbook was intended to prepare the students taking the chemistry course at Porto Polytechnic Academy and that it was written in a simple way, to help ease the learning of the basics of chemistry.

When referring to the atomic theory, Ferreira da Silva points out that "the atomic theory in chemistry is independent of the general theories usually admitted on the constitution of matter. But the exposition method followed in the elementary books, even the more popular ones, hides rather than presents this truth, as admitted by the leader of this doctrine in France, Mr. Wurtz, and even more clearly expressed by another savant of the same school, P. Schutzenberger, professor at the College of France."[17] According to Ferreira da Silva, the position of these two eminent French chemists could explain why it was difficult to introduce the atomic theory in the secondary level.

Next, Ferreira da Silva mentions that he aims to introduce the atomic theory without relying on the controversial hypothesis about the constitution of matter, and doing so it remains possible to compare it with the theory of equivalents. Concerning the atomicity, he concludes that it is a valuable concept when purged of the hypothesis that plagues it.

In the second edition (1895), Mendeleev's periodic classification is presented in six pages, beginning with the "Relations between the elements properties and their atomic weight." Keeping hydrogen as a separate element, the author compares the properties (physical and chemical) of the elements along the different rows of the table, noting that there is a regularity and similitude of the properties. Moreover, when the rows are aligned the set of elements in each column formed is very similar to the so-called natural families. He quotes Mendeleev's law as "the properties of the simple bodies, the constitution and properties of their combinations are periodic functions of their atomic weights,"[18] presents the periodic table, reaffirms that the periodic law is expressed in the similitude of the physical properties (not just the chemical ones), namely the specific weight, the atomic volume, fusibility, tenacity, malleability, volatility, specific heat, and heat and electrical conductibility, and concludes just showing a Lothar Meyer's curve taken from *Les théories modernes de la chimie*,[19] translated in French from the original 5th edition.

In a last paragraph, Ferreira da Silva states his position concerning the periodic classification:

Some reservations should be maintained regarding Mendeleev's classification of the place occupied by some metals, like gold, which usually acts as trivalent and not as monovalent. But as it is organized, it represents a great and happy attempt. It enabled this author to foresee the existence and the properties of some new elements, which were missing in the table; three of these bodies were discovered: gallium (Mendeleev's ekaluminium), germanium (ekasilicium), and scandium (ekaboron). It also enabled the atomic weights of many little known elements to be corrected, weights which were confirmed by new experimental determinations (uranium, cerium, etc.)."[20] Looking inside the third edition of his Tratado de Chimica Elementar (1903), Ferreira da Silva points out to some continuing difficulties with the periodic classification, namely as regards the noble gases, concluding: "For this reason, the principle that underpins Mendeleev's classification does not seem to be a natural law.[21]

3.2. Lisbon Polytechnic School

Considering now what was going on at the Lisbon Polytechnic School, in 1850, we find Júlio Máximo Oliveira Pimentel (1809-1884) as the professor of chemistry and in his book *Lições de Chymica Geral* (General Chemistry Lessons),[22] he considers the ten natural families of the elements as many contemporary textbook authors did, when providing an overview of the chemistry of the known elements (Table 1). This way of organizing teaching continued until a younger teacher entered the scene.

Eduardo Burnay (1853–1924), substitute professor of chemistry at Lisbon Polytechnic School in 1888, became full professor in 1893 and very early in his teaching career he produced a set of extended summaries of some of his lectures – *Introducção Theorica ao Estudo da Chimica* (Theoretical Introduction to the Study of Chemistry) (1888).[26] He starts considering that bodies can be either simple or compound which goes back to Lavoisier and even before, noting that the simple bodies have been classified either in natural families or on various other bases: the electrochemical character, the atomic weight, the atomicity and the natural physicochemical properties. Then he presents Mendeleev's classification in two-pages with a table of elements where density and atomic weight are provided (Figure 1).

He highlights what he calls the typical period (the first one, containing Li, Gl, Bo,[27] C, Az,[28] O, Fl[29]), the small periods (where density attains a maximum that sometimes is the first term, and then decreases), and the great periods (where density increases progressively) with examples; he then mentions the vertical sequences as the true natural chemical families.[30] He asserts that this taxonomic display of the elements offers a certain plausibility, although possessing some imperfections and exceptions. The gaps that appear should correspond to yet unknown bodies, as was demonstrated with the case of *gallium* (the *ékaluminium* Mendeleev forecasted) discovered by Lecoq de Boisbaudran. He refers to several metals: *decipium,[31] philipium,[32] mosandrum,[33] iterbium, scandium, holmium, thulium, samarium, davyum[34]* and *norwegium,[35]* the existence of which is only suspected at the time.[36]

The next full professor of chemistry (1896) at the Lisbon Polytechnic School was Achilles Machado (1862–

Table 1. Authors' table of the ten natural families as they are described in J. M. O. Pimentel's book (ref. 22).

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
F	O	N	C	Na	Mg	Al	Fe	Cd	Ag
Cl	S	P	B	K	Ca	Gl (glucinium[23])	Mn	Cu	Pt
Br	Se	As	Si	Li	Sr	Zr	Co	Sn	Au
I	Te	Sb	Ti	AzH_3 (ammonia)	Ba	Th	Ni	Mo	Pd
			Ta		Pb	Y	Cr	W	Rh
							Zn	Nb	Ir
								Pp (pelopium[24])	Os
								Il (ilmenium[25])	Ru
								V	
								U	
								Bi	
								Hg	

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CLASSIFICAÇÃO DE MENDÉLÉEFF

H = 1	Li	Gl	Bo	C	Az	O	Fl			
Peso atomico	7,02	9,3	11,0	12	14,04	15,96	19,1			
Densidade . .	0,59	2,1	2,68	3,3	»	»	»			
	Na	Mg	Al	Si	Ph	S	Cl			
Peso atomico	23	24	27,3	28	31	32	35,5			
Densidade . .	0,97	1,74	2,49	2,56	2,3	2,04	1,38			
	K	Ca	?	Ti	V	Cr	Mn	Fe	Co	Ni
Peso atomico	39,14	39,90	»	48	51,2	52,4	54,8	55,9	58,6	58,6
Densidade . .	0,86	1,57	»	»	5,5	6,8	8,0	7,8	8,5	8,8
	Cp	Zn	Ga	?	As	Se	Br			
Peso atomico	63,3	64,9	69,9	72	74,9	78	79,75			
Densidade . .	8,8	7,15	5,96	»	5,67	4,6	2,97			
	Rb	Sr	Y	Zr	Nb	Mo	?	Ru	Rh	Pd
Peso atomico	85,2	87,2	89,6	90	94	95,8	»	103,5	104,2	106,2
Densidade . .	1,52	2,50	»	4,15	6,27	8,6	»	11,3	12,1	11,5
	Ag	Cd	In	Sn	Sb	Te	I			
Peso atomico	108	111,6	113,4	117,8	122	128?	127			
Densidade . .	10,5	8,65	7,42	7,29	6,7	6,25	4,95			
	Cs	Ba	Ce	La	?	Di				
Peso atomico	132,15	136,8	137	139	»	147				
Densidade . .	»	3,75	»	»	»	»				
	?	?	Er	?	Ta	W	?	Os	Ir	Pt
Peso atomico	»	»	170,6	»	182	184	»	198,6	196,7	196,7
Densidade . .	»	»	»	»	10,8?	19,13		21,4	21,15	21,15
	Au	Hg	Tl	Pb	Bi					
Peso atomico	196,2	200	203,6	206,4	210					
Densidade . .	19,3	13,59	11,86	11,83	9,82					
	?	?	?	Th		U				
Peso atomico	»	»	»	233,9		240?				
Densidade . .	»	»	»	7,7		18,3				

Figure 1. Classification of Mendeleev, printed in Eduardo Burnay's book (ref. 26, p. 91).

1940). In 1897, he published a comprehensive teaching program based on his notes on chemistry – *Apontamentos de chimica: 6ª cadeira (Chimica Mineral)* [da Escola Politecnica], with greater focus on modern theoretical notions than had previously been the case, and including Mendeleev's classification.[37] Besides publishing for his students at the Polytechnic, he had co-authored a textbook five years earlier with his brother Virgílio Machado (1859-1927), - *Chimica Geral e Análise Chimica* (General Chemistry and Chemical Analysis) (1892),[38] which was used in both the Polytechnic and the Industrial School in Lisbon. In it, they briefly explained Mendeleev's classification.[39] Achilles also published several official textbooks for secondary levels.

Between 1930 and 1960, professor António Pereira Forjaz (1893-1972), later director of the Lisbon Polytechnic School, published more than fifty chemistry books. In two of them only (1937, 1940),[40,41] the fundamentals of the periodic classification of Mendeleev are shown.

3.3. University of Coimbra

Despite the importance both Polytechnic Schools had in the academic Portuguese milieu, we cannot forget what was happening at the University of Coimbra, then the unique university in function. Both Ferreira Girão and Ferreira Silva were alumni of the University of Coimbra.

Dated February 13th, 1886, we find that the Faculty Congregation decided that the first graduated from the Faculty of Natural Philosophy should have "the Mendeleev's law" as topic of his dissertation. As far as it was possible to follow this was the first time such a subject appears registered in the Congregation *Acta*.[42]

However, the access to a rare textbook - *Lições de Chimica Inorganica* (Lessons of Inorganic Chemistry), by Francisco Augusto Corrêa Barata (1847-1900), published in 1880, of which only two incomplete copies are known, sheds light on what was happening with the chemistry lessons at the university. Barata was professor of chemistry in 1880,[43] and in his book explicitly mentions Mendeleev and his periodic law, in the following terms:

> *The highest combination forms of an element with hydrogen and with oxygen, or with equivalent elements, are a periodic function of the atomic weight, being so determined by it. This law regulates the limiting forms, making restrictions to the diversity of possible forms; and establishes a dependence among those forms, and so between atomicity and its atomic weight.*
> *Considering its importance, we are going to present it in a separated chapter.*[44]

Next, the author presents what we believe to be the first periodic table ever published in a Portuguese university textbook. There, three properties are mentioned: atomic weight (P.at.), density (D) and atomic volume (V. at.).

A few years later, Francisco José Sousa Gomes (1860-1911), professor of chemistry, wrote a *Nota sobre o ensino da Chimica na Universidade de Coimbra* (Note on the teaching of chemistry at the University of Coimbra),[45] presented to the Hispano-Portuguese-American Pedagogical Congress, and published in 1892.

Beginning with a contextualization of the origins of chemistry as an independent academic discipline in Portugal, he quickly comes, in his *Note,* to recount his own last three years of teaching experience. The insufficient training in experimentation in secondary school education led him to make some decisions relating to his own teaching. Instead of lengthy explanations of fundamental

LEI PERIODICA DOS ELEMENTOS 81

H=1

Series		Grupos I R^2O	II RO	III R^2O^3	IV RO^2 RH^4	V R^2O^5 RH^3	VI RO^3 RH^2	VII R^2O^7 RH	VIII RO^4		
		Li	Gl	B	C	Az	O	Fl			
	P. at.	7	9.4	11	12	14	16	19			
1	D.	0.59	2.1	2.68	3.3						
	V. at.	11.9	4.4	4.1	3.6						
		Na	Mg	Al	Si	Ph	S	Cl			
	P. at.	23	24	27.3	28	31	32	35.5			
2	D.	0.97	1.74	2.49	2.56	2.3	2.04				
	V. at.	23.7	13.8	10.7	11.2	13.5	15.7				
		K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni
	P. at.	39	40	45	48	51	52	55	56	59	59
3	D.	0.86	1.57			5.5	6.8	8	7.8	8.5	8.8
	V. at.	45.4	25.4			9.3	7.7	6.9	7.2	6.9	6.7
		Cu	Zn	Ga		As	Se	Br			
	P. at.	63	65	70	72	75	78	80			
4	D.	8.8	7.1	5.9		5.7	4.6	2.9			
	V. at.	7.2	9.1	11.7		13.2	16.9	27.5			
		Rb	Sr	Y	Zr	Nb	Mo		Ru	Rh	Pd
	P. at.	85	87	89.5	90	94	96	100	104	104	106
5	D.	1.52	2.5		4.15	6.27	8.6		11.3	12 1	11.5
	V. at.	55 9	34.9		21.7	15	11.1		9.2	8.6	9.2

CHIM. INORG. 6

82 LEI PERIODICA DOS ELEMENTOS

H=1

Series		Grupos I R^2O	II RO	III R^2O^3	IV RO^2 RH^4	V R^2O^5 RH^3	VI RO^3 RH^2	VII R^2O^7 RH	VIII RO^4		
		Ag	Cd	In	Sn	Sb	Te	I			
	P. at.	108	112	113	118	122	125	127			
6	D.	10.5	8.65	7.42	7.29	6.7	6.2	4.95			
	V. at.	10.3	12.9	15.3	16.1	18.2	20.1	25.6			
		Cs	Ba	Ce	La		Di				
	P. at.	133	137	137	139		147				
7	D.		3.75								
	V. at.		36.5								
				Er		Ta	W		Ir	Pt	Os
	P. at.			171		182	184		197	197	199
8	D.					10.8	19.1		21.15	21.15	21.4
	V. at.					16.9	9.6		9.3	9.3	9.3
		Au	Hg	Tl	Pb	Bi					
	P. at.	199	200	204	207	210					
9	D.	19.3	13.59	11.86	11.83	9.8					
	V. at.	10.3	14.7	17.1	18 1	21 4					
					Th		U				
	P. at.				234		240				
10	D.				7.7		18.3				
	V. at.				30.4		13.1				

Figure 2. Possibly the first periodic table published in a Portuguese university textbook. Francisco Augusto Corrêa Barata's book, 1880 (ref. 44, pp. 81-82).

laws, he decided to favor the use of chemical notation, equations and formulas and based it on a table of atomic weight.

In that frame, Mendeleev's periodic classification played an important role. Sousa Gomes clearly mentions his adoption of Mendeleev's periodic classification, and presents his reasons: it enables the summarized presentation of several properties, reactions, and processes of preparation, that are repeated in each group and are therefore bridgeable in a general schema.

From his *Note*, we learn that the classification had been adopted from the time he entered as professor of mineral chemistry (academic year 1888-1889) and that he used a German translation (1891) of Mendeleev's textbook as a guide in his teaching.[46] Later in 1895, he published his book *Lições de Chimica I* where there was a first part concerning chemical philosophy and a second part dealing with the properties of elements and compounds organized according the Mendeleev's periodic classification. In assessing its use, Sousa Gomes considers that students learn all the related facts more easily when using Mendeleev's classification in contrast to when they were taught descriptive chemistry in a disconnected manner based on the old arbitrary classifications.

Another concern of Sousa Gomes was the implementation of a student-centered learning methodology, contrary to what was usual, and according to the method nicknamed heurism proposed by the British chemist Harry Edwards Armstrong, professor at the Central Technical College of London, who introduced it in 1884.[47]

The pedagogical use of the periodic classification and other previous classifications of the elements will be further described in the next section devoted to (text) books aimed to the secondary (basic and upper) and college levels.

Table 2. Thénard's & Régnault's classification for metals in six sections (authors' table).

1st	2nd	3rd	4th	5th	6th
Li	Mg	Fe	Sn	As	Hg
Na	Al	Zn	Sb	Cu	Ag
K	Mn	Ni	W	Pb	Au
Sr	Gl	Co	Mo	Te	Pt
Ca	Zr	Cr	Os	Bi	Pd
	Y	V	Ta		Rh
	Th	Cd	Ti		Ir
	Ce	U	Nb		Ru
	La		Il		
	Di		Pp		
	Er				
	Tb				

4. CLASSIFICATIONS IN (TEXT)BOOKS

4.1. Introduction

In the previous sections, the impact of Mendeleev's classification on the higher education schools in Portugal was examined, and is here presented in a condensed manner in Table 4, while also systematizing the appearance of the different pre-Mendeleev's classifications of the elements in Portuguese (text)books for the different levels.

The Portuguese secondary school system, included the teaching of science subjects, and developed consistently from the mid-nineteenth century, with an increasing number of schools around the country, beyond Coimbra, Lisbon, and Porto. Chemistry, along with physics, was taught during the last five years of secondary school.

In the two final years of the secondary level that will be referred to as the upper secondary, the subjects were dealt with more detail than before. When reading textbooks from that time, one realizes that the methodological advice was to teach practical knowledge, and the laws already established. In this section, we will focus on the classifications used for elements.

4.2. Metals and metalloids

In all textbooks intended for basic secondary schools (Table 3), the simple classification in metals and metalloids was the only one used in the period spanning from 1850 to 1967.

In 1854, João Ignacio Ferreira Lapa (1823-1892) published a book for the basic secondary courses with the classification of the elements as either metals or metalloids, being more specific about metals following Louis Jacques Thénard (1777-1857)'s and Henri Victor Regnault (1810-1878)'s classification (Table 2).[48] According to this classification, the metals are divided in six groups, depending on the following properties: affinity to the oxygen of the air, ability to decompose water, decomposition of their oxides by heat, and ability to decompose water when mixed with an acid.

One of the official textbooks used in 1893, for upper secondary schools, was from Francisco Ribeiro Nobre (1858-19??). After some preliminary considerations on chemistry, affinity, classification and nomenclature, and chemical theories, the author moves to metals, metalloids, and their compounds, ending up with organic chemistry.[49] Basically, the structure of secondary school textbooks had not evolved since Ferreira Lapa.

The official secondary school program (1895), concerning chemistry, recommended the examination of the bodies, experimentation, the use of equipment, and the inspection of appropriate pictures, using a clear and simple language.[50]

Along with the official textbooks, some booklets (64-pages each) of a well-known popular collection, the - *Bibliotheca do Povo e das Escholas* (People and Schools Library) - were published showing explicitly that they were in accordance with the official programs, to be used either in Portugal or in Brazil. This collection started in 1881 and stayed alive for more than thirty years. For the four books devoted to chemistry, only three deal with classification of the elements, but neither of them includes the periodic system. In *Introdução às Sciencias Physico-Naturaes* (Introduction to the Physico-Natural Sciences) (1881),[51] the author, João Cesário de Lacerda (1841-1903) classifies the elements into metals and metalloids in a single page of the chapter on the first notions of chemistry. In *Principios Geraes de Chimica* (General Principles of Chemistry) (1881),[52] only one page is devoted to the classification of metals and metalloids, distributed in five groups according to the atomicity of the elements. In *Chimica Inorganica* (Inorganic Chemistry) (1st ed. 1882, 5th ed. 1907), José Maria Greenfield de Mello (1848-1905), besides classifying the elements in metals and metalloids, elaborates about "The atomic theory and its adversaries." He points out that as the collection was aimed for the public, he had to simplify the presentation, deciding to follow the notation and nomenclature based on the reasoning of the atomic theory, even though not all renowned chemists had yet unanimously accepted that hypothesis.[53]

In three cases, a more specific classification for both metalloids and metals, according to the atomicity, was

Table 3. Classification of elements in Portuguese textbooks from 1850 to 1967.

Metals	Teaching level	Metalloids		Metals	
Júlio Máximo de Oliveira Pimentel[54] (1850)	Polytechnic (Lisbon)[55]	10 natural families			
		Atomicity	Dumas	Thénard & Regnault	"Natural"
João Ignacio Ferreira Lapa[56] (1854)	Basic Secondary	No	No	Yes	No
Antonio Xavier Corrêa Barreto[57] (1874)	Upper Secondary	Yes	No	Yes	Yes
Miguel Arcanjo Marques Lobo[58] (1875)	Upper Secondary	Yes	Yes	Yes	Yes
João Cesário de Lacerda[59] (1881)	Basic Secondary	No	No	No	No
João M. Greenfield de Mello[60] (1881)	Basic Secondary	No	No	No	No
Adriano Augusto de Pina Vidal & Carlos Augusto Morais d'Almeida[61] (1883)	Upper Secondary	Yes	No	Yes	Yes
Antonio Xavier Corrêa Barreto,[62] (1883)	Upper Secondary	Yes	No	No	Yes
Antonio Joaquim Ferreira da Silva[63] (1884)	Polytechnic (Porto)	Yes	Yes	Yes	Yes
Virgílio Machado & Achilles Machado[64] (1892)	Industrial School	Yes	Yes	Yes	Yes
Eduardo Burnay[65] (1888)	Polytechnic (Lisbon)	Yes	No	No	Yes
Francisco Ribeiro Nobre[66] (1893)	Basic Secondary	Yes	No	No	Yes
Francisco Sousa Gomez[67] (1903)	Basic Secondary	Yes	No	No	Yes
Achilles Machado[68] (1906)	Basic Secondary	No	No	No	No
Achilles Machado[69] (1906)	Basic Secondary	No	No	No	No
Achilles Machado[70] (1906)	Basic Secondary	No	No	No	No
João Greenfield de Mello[71] (1907)	Basic Secondary	No	No	No	No
Francisco de Sousa Gomes[72] (1907)	Upper Secondary	Yes	No	No	Yes
L. Troost,[73] translated by Ramiz Galvão (1910) from 29 th ed.	University[74] (Coimbra)	Yes	No	Yes	No
Alexander Smith[75], translated by Sousa Gomes (1911)	University (Coimbra)	No	No	No	No
Francisco de Sousa Gomes & Antonio Joaquim Ferreira da Silva[76] (1914)	Basic Secondary	Yes	No	No	Yes
Biblioteca de Instrução Profissional[77] (1924)	Basic Secondary	No	No	No	No
Francisco R. Nobre[78] (1933)	Basic Secondary	Yes	Yes	Yes	Yes
Riley da Motta & Rómulo de Carvalho[79] (1950)	Basic Secondary	No	No	No	No
José A. Teixeira[80] (1967)	Basic Secondary	Yes	No	No	Yes

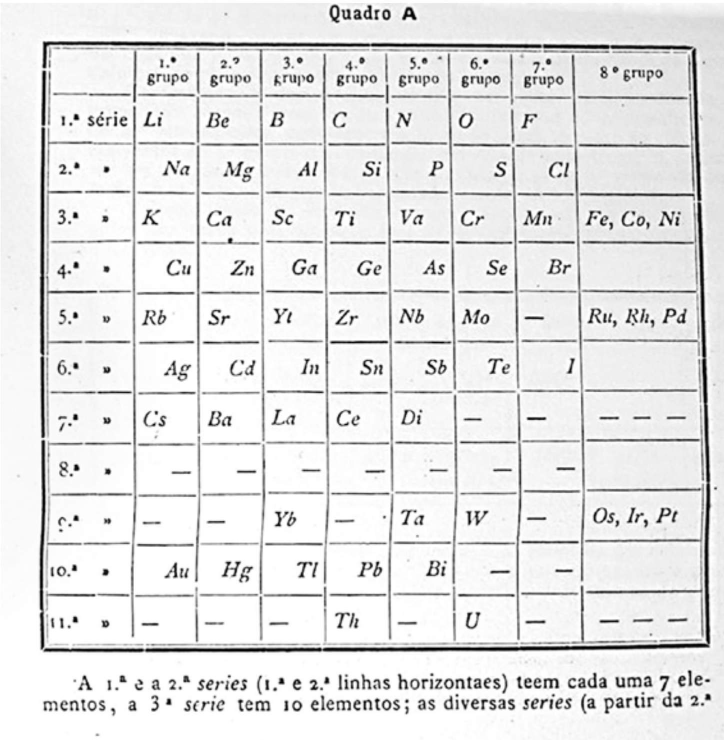
used, called "natural" classification in the case of metals. In two cases, metals were classified according to Thénard's & Régnault's.

However, focusing on textbooks recommended for upper secondary schools, industrial school, and higher education, there we find that they used the distinctive categories for metals and metalloids at least until 1933 (Table 3). All but one use the atomicity and/or Dumas classification for metalloids and Thénard's & Regnault's and/or the "natural" classification for the metals.

4.3. Mendeleev´s classification

The periodic classification only appears officially in 1948 as a topic to be taught in the secondary school programs.[81] This does not mean, however, that the subject was unknown at this level in the preceding decades. Frequently, in those years, some university/polytechnic professors were involved in the production of textbooks and sometimes gave classes either in the secondary or in the industrial schools. Achilles Machado was one such example. His books were used either as the unique official textbook, or with others, for secondary level and for several decades (Table 4). As far as it is known, the first periodic table for upper secondary school was included in one of Achilles Machado's textbooks, published in 1906, as a supplementary reading material.[82] It contained two items—"Relations between the properties of different elements and their atomic weights, Mendeleev's classification" and "Applications of the periodic law", discussed in eight pages (Figure 3).

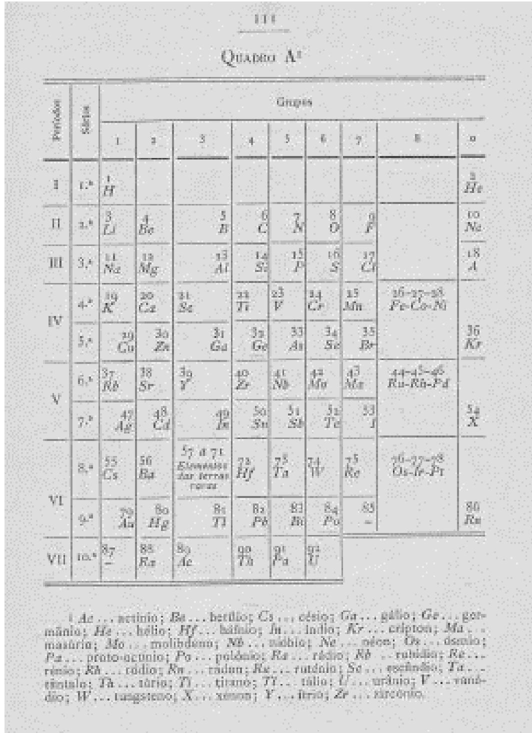
A bigger emphasis on the periodic classification occurs in 1975, but the textbook by Sena Esteves, in 1946, is certainly the most informative one, considering the level to which it was proposed. As far as we could find, it is the only one that includes a folding and very



Quadro A

	1.° grupo	2.° grupo	3.° grupo	4.° grupo	5.° grupo	6.° grupo	7.° grupo	8.° grupo
1.ª série	Li	Be	B	C	N	O	F	
2.ª »	Na	Mg	Al	Si	P	S	Cl	
3.ª »	K	Ca	Sc	Ti	Va	Cr	Mn	Fe, Co, Ni
4.ª »	Cu	Zn	Ga	Ge	As	Se	Br	
5.ª »	Rb	Sr	Yt	Zr	Nb	Mo	—	Ru, Rh, Pd
6.ª »	Ag	Cd	In	Sn	Sb	Te	I	
7.ª »	Cs	Ba	La	Ce	Di	—	—	— — —
8.ª »	—	—	—	—	—	—	—	
9.ª »	—	—	Yb	—	Ta	W	—	Os, Ir, Pt
10.ª »	Au	Hg	Tl	Pb	Bi	—	—	
11.ª »	—	—	—	Th	—	U	—	— — —

A 1.ª e a 2.ª *series* (1.ª e 2.ª linhas horizontaes) teem cada uma 7 elementos, a 3.ª *serie* tem 10 elementos; as diversas *series* (a partir da 2.ª



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QUADRO A[1]

Períodos	Séries	Grupos 1	2	3	4	5	6	7	8	0
I	1.ª	1 H								2 He
II	2.ª	3 Li	4 Be	5 B	6 C	7 N	8 O	9 F		10 Ne
III	3.ª	11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl		18 A
IV	4.ª	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26-27-28 Fe-Co-Ni	
	5.ª	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br		36 Kr
V	6.ª	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Ma	44-45-46 Ru-Rh-Pd	
	7.ª	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I		54 X
VI	8.ª	55 Cs	56 Ba	57 a 71 Elementos das terras raras	72 Hf	73 Ta	74 W	75 Re	76-77-78 Os-Ir-Pt	
	9.ª	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 –		86 Rn
VII	10.ª	87 –	88 Ra	89 Ac	90 Th	91 Pa	92 U			

[1] *Ac* ... actínio; *Be* ... berílio; *Cs* ... césio; *Ga* ... gálio; *Ge* ... germânio; *He* ... hélio; *Hf* ... háfnio; *In* ... índio; *Kr* ... cripton; *Ma* ... masúrio; *Mo* ... molibdeno; *Nb* ... nióbio; *Ne* ... néon; *Os* ... ósmio; *Pa* ... proto-actínio; *Po* ... polónio; *Ra* ... rádio; *Rb* ... rubídio; *Re* ... rénio; *Rh* ... ródio; *Rn* ... radon; *Ru* ... ruténio; *Sc* ... escândio; *Ta* ... tântalo; *Th* ... tório; *Ti* ... titano; *Tl* ... tálio; *U* ... urânio; *V* ... vanádio; *W* ... tungsténio; *X* ... xénon; *Y* ... ítrio; *Zr* ... zircónio.

Figure 3. Two presentations of the periodic classification in textbooks from the same author, the first in 1906 from Achilles Machado, *op. cit*, (ref. 87, pp. 95-98) and the second in 1938, in Achilles Machado, *op. cit.* (ref. 91, pp. 108-121).

complete periodic table for student's use, which we will analyze here later (Figures 4a and 4b).

With more detail, it is interesting to look at the evolutionary arrangement of the elements in the periodic classifications presented. Table 4 shows the list of these books according to the number of pages dedicated to the subject/total number of pages of the book, number of series or periods (rows) and groups (columns), and the presence of Lothar Meyer's curve (plot of the atomic volume versus atomic weight).

Of the thirty-nine books examined, which span from 1850 to 1975, fifteen were published during the nineteenth century. Some were addressed to people with no formal education, others for teaching at the secondary level, and finally the rest for polytechnic and university level. Concerning the classification of the elements there are clearly two options: the classification into metals and metalloids is present in twenty five books, five for university/Polytechnic, but only two dating from the first decade of the twentieth century, and Mendeleev's is mentioned in fifteen books, none of them for the Basic Secondary. It should be emphasized that three of the books, published between 1888 and 1910, present both classifications.

5. PERIODIC SYSTEM CHARTS

We cannot imagine a chemistry room without a periodic table, and more recently the habit is that students have their own periodic chart on top of their chemistry textbooks. This section describes the charts found for the chronological period under investigation. At the University of Coimbra, from 1872 onwards, the Chemical Analysis course was taught independently from the Organic Chemistry course and, by law of 1890, it became mandatory to be taught at a practical level. The teaching room of the laboratory building had two wall charts: one with the names and symbols of the elements, along with some properties, such as "atomic weights, equivalents, specific heats, densities, molecular composition, etc."; the other one the scheme of Mendeleev's periodic law" (69 elements).[100] Although we could not find these charts, we think they were probably similar to those published in the German edition of Mendeleev's book (1891),[101] (Figure 4) as the professor in charge since 1888, Francisco Sousa Gomes, used this book in his lectures. As other clues are missing, we do not know if the tables were reproduced or translated into Portuguese.

Table 4. Mentions of Mendeleev's classification in the Portuguese textbooks analysed from 1880 (first mention found) to 1975.

Book	Teaching level	Number of pages	Lothar Meyer's curve	Periods	Groups
Francisco Corrêa Barata[83] (1880)	University (Coimbra)	c.20/96 known	Yes (description)	10 series	8
Virgílio Machado & Achilles Machado[84] (1892)	Polytechnic (Lisbon)	2/666 1/640	No	8	7
Eduardo Burnay[85] (1888)	Polytechnic (Lisbon)	2/115	--	10	7
Francisco Sousa Gomes (1895)[86]	University (Coimbra)	40/590	Yes	12 series	8
Achilles Machado[87] (1906)	Upper Secondary	8/c.250	No	11 series	8
L. Troost,[88] translated by Ramiz Galvão (1910) from 29th ed.	University (Coimbra)	2/428	No	10 series	8
Achilles Machado[89] (1916)	Upper Secondary	9/276	Yes	11 series	8
Pereira Forjaz, Ferreira de Mira & Kurt Jacobson (1937)[90]	University (Lisbon)	3/235	No	7	8+1 (Group zero)
Achilles Machado[91] (1938)	Upper Secondary	14/151	Yes	7	8+1 (Group zero)
Pereira Forjaz (1940)[92]	University (Lisbon)	3/110	No	-	7
Carlos de Azevedo Coutinho Braga[93] (1944)	University (Porto)	0,5/111	No	7	8
Sena Esteves[94] (1946)	Upper Secondary	13/ 271	Yes (extended after Ce by Nernst)	7	8
Rómulo de Carvalho[95] (1950)	Upper Secondary	9/359	Yes	12 series	8+1 (Group zero)
Alice Maia Magalhães & Túlio Lopes Tomás[96] (1961)	Upper Secondary	1/344	No	-	8
Helena Côncio de Sousa[97] (1973)	Upper Secondary	8/90	Yes	-	-
José A. Teixeira e Adriana Sousa Nunes[98] (1973)	Basic Secondary	4/236	No	7	8
Helena Côncio de Sousa[99] (1975)	Upper Secondary	34/159	Yes	7	8+1 (Group zero)

Another periodic chart that is now displayed at the Science Museum of the University of Coimbra is probably the oldest surviving one used in the university teaching in Portugal (Figure 5). It is in Portuguese, listing 92 elements, from which two of them were not yet discovered (85 *astatine* and 87 *francium*). To the best of our knowledge, the details of its production are unknown. Concerning its date, it seems to span from 1926 to 1937. It should be mentioned that we found a picture of this table referring the date of 1931, but without any supporting evidence either in the text or in the bibliography.[102]

The layout consists of seven periods, eight groups plus a zero group for the noble gases. For the periods IV, V, and VI there are two rows (two series), a and b, one above the other.

As it shows *illinium* Il (as element 61), allegedly discovered in 1926, also named *florentium* Fl, by Luigi Rocca (1926) and later to be named *promethium* Pm (1945, but only announced in 1947) by IUPAC, this sets the lower time limit to 1926.

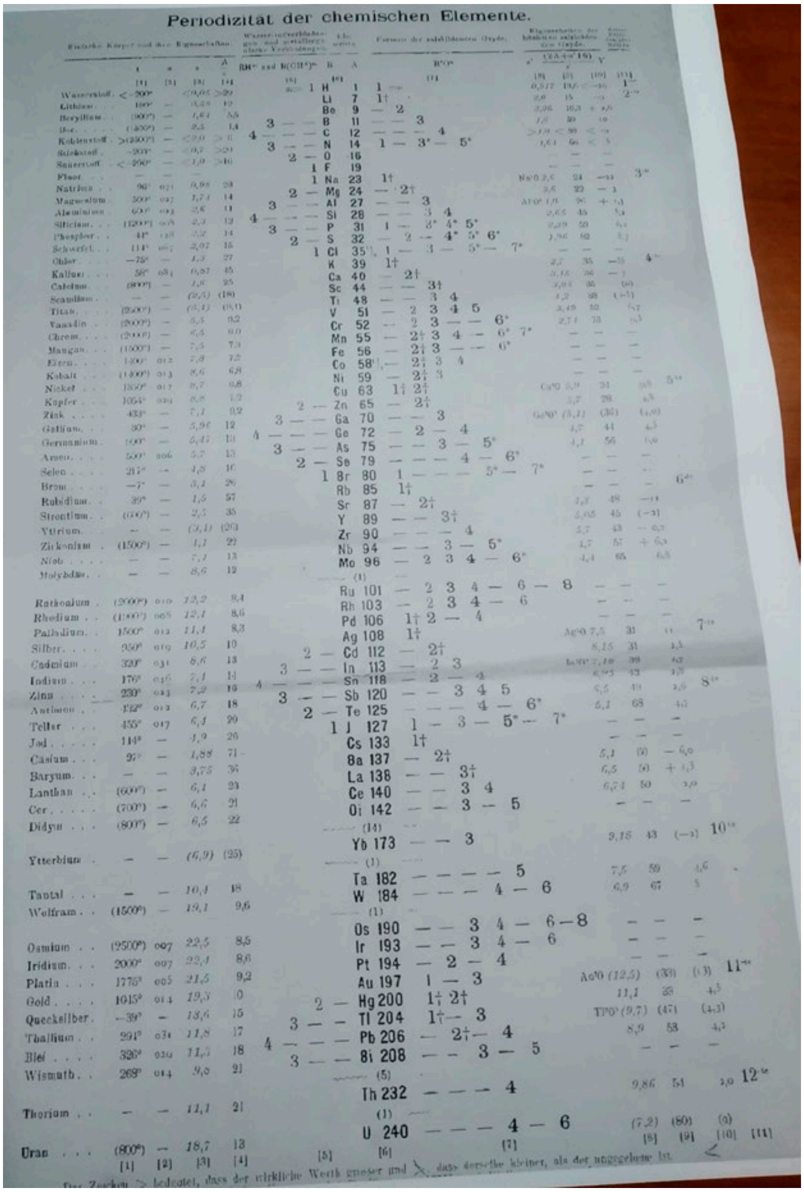
The fact that there is no indication of the atomic weight of *protactinium* Pa, first measured in 1934[103] by Aristid von Grosse (1905-1985), and only shown in an official table of atomic weights of the International Union of Chemistry, in 1937,[104] can be an argument to set the upper limit to 1937.

The last atomic number shown is 92, which corresponds to *uranium*. The next two elements, *neptunium* 93, and *plutonium* 94 were only discovered/synthetized in 1940, and their discovery being only shared after the war.

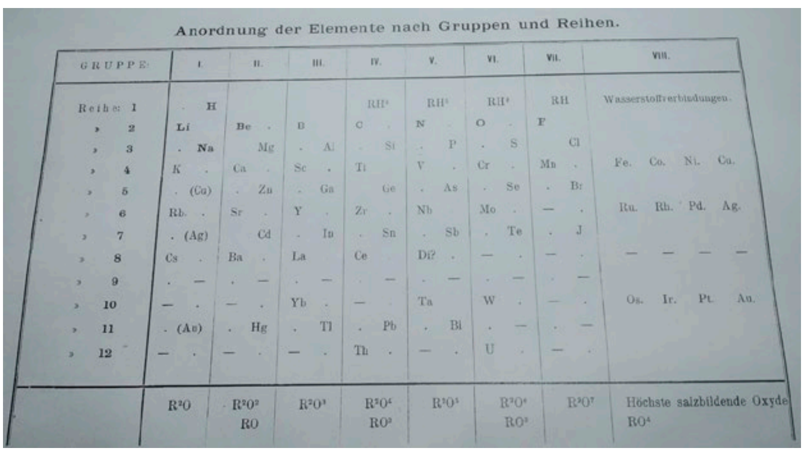
There is another interesting fact about this table. Element 86, with atomic mass of 222 is *radon*, and one early name was *niton*. However, its symbol is listed here as Em. It corresponds to the designation of 'emanation', which was used commonly until the late 1960s (despite IUPAC's decision in 1923 that element 86 is radon).

There is clearly a misprint as elements 37 and 45 have the same symbol Rb, since 37 is *rubidium* (Rb) and 45 is *rhodium* (Rh). Element 69 *thullium* is symbolized as Tu, in Portuguese, as well as in the periodic table of Meyer (1918),[105] while it seems that there was a widespread use of the actual symbol Tm.

It still presents the symbol Ma (*masurium*) for element 43 whose discovery was announced in 1925 but not confirmed experimentally. Since 1947, element 43 is named *technetium* (Tc) after it was artificially produced in 1937.



Periodizität der chemischen Elemente.



Anordnung der Elemente nach Gruppen und Reihen.

GRUPPE:	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Reihe: 1	H			RH⁴	RH³	RH²	RH	Wasserstoffverbindungen.
» 2	Li	Be	B	C	N	O	F	
» 3	Na	Mg	Al	Si	P	S	Cl	
» 4	K	Ca	Sc	Ti	V	Cr	Mn	Fe. Co. Ni. Cu.
» 5	(Cu)	Zn	Ga	Ge	As	Se	Br	
» 6	Rb	Sr	Y	Zr	Nb	Mo	—	Ru. Rh. Pd. Ag.
» 7	(Ag)	Cd	In	Sn	Sb	Te	J	
» 8	Cs	Ba	La	Ce	Di?	—	—	— — — —
» 9	—	—	—	—	—	—	—	
» 10	—	—	Yb	—	Ta	W	—	Os. Ir. Pt. Au.
» 11	(Au)	Hg	Tl	Pb	Bi	—	—	
» 12	—	—	—	Th	—	U	—	
	R²O	R²O² RO	R²O³	R²O⁴ RO²	R²O⁵	R²O⁶ RO³	R²O⁷	Höchste salzbildende Oxyde RO⁴

Figure 4. Tables inserted in D. Mendelejeff, *Grundlagen der Chemie*, 1891 (ref. 101, tables not paginated)

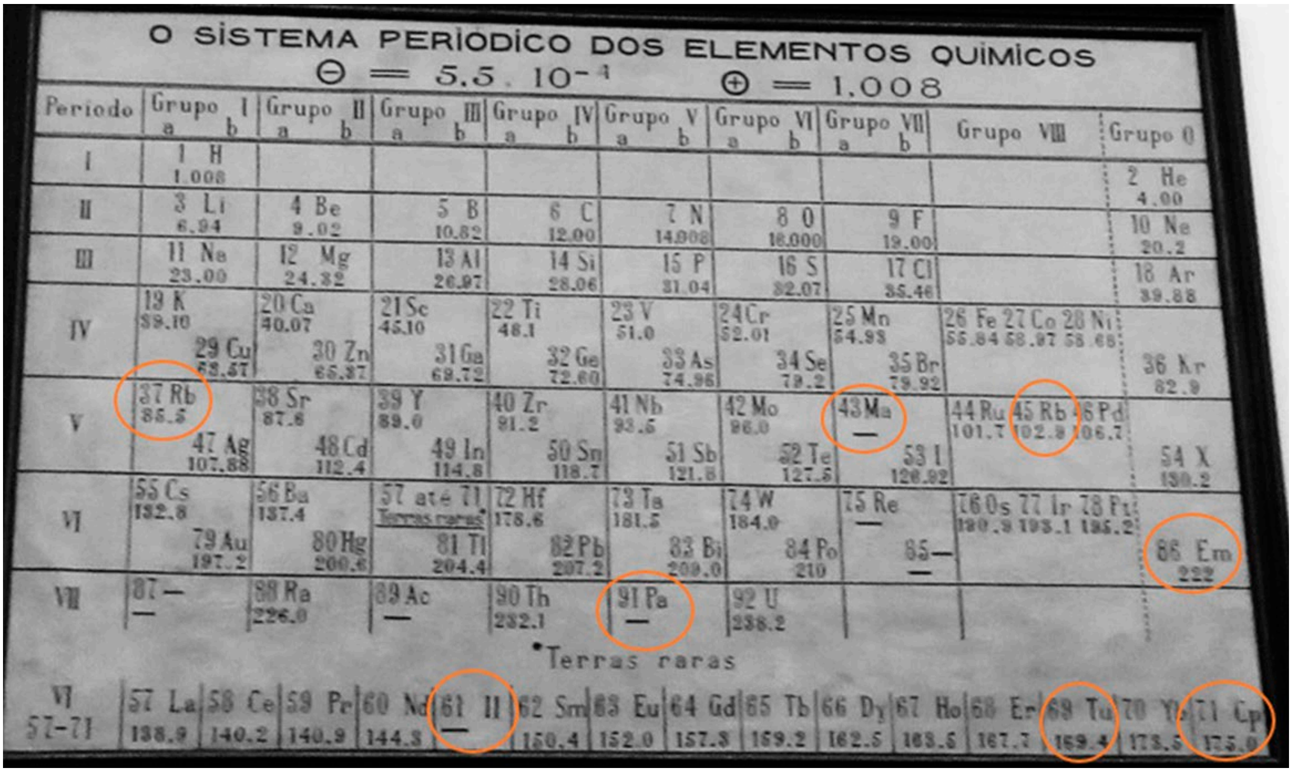


Figure 5. Periodic table in display at the Science Museum, University of Coimbra. Photo by Isabel Malaquias.

As a last note, element 71 (*lutetium*) is still symbolized as Cp (*cassiopeium*), denoting some German influence. German scientists continued to name it *cassiopeium* until World War II.[106]

Analyzing the textbooks for upper secondary, it is interesting to observe the folding periodic table inserted in Sena Esteves' textbook (1946).[107] The chart is in Portuguese (Figure 6a), and is accompanied by a detailed 13-pages description (with two inserted diagrams). In a footnote the author mentions that a professor of the University of Lisbon, Manuel Valadares (1904-1982), who got his PhD under the supervision of Madame Curie and had been working in Geneva and Italy before returning to Portugal (1940), discovered the element 87 (1941).[108] From his work in Italy, Valadares published a series of papers dealing with the observation of new characteristic lines of element 85, and not 87, as referred in Sena Esteves' book.[109] The folding chart is inserted between pages 168 and 169. It shows seven periods and eight groups, the group zero starting with the neutron and followed by the noble gases. Considering the periods, it mentions the short periods: the first one, presenting neutron and hydrogen, the second and third period with eight elements; the seventh period with "sete (ou mais) elementos" (seven (or more) elements). For the large periods, IV, V and VI, each cell contains the A and B elements. Some cells have the indication of the elements known, although without a name (85 and 87). Element 61 is still named *florentium* (Fl), element 43 is *masurium*, occurring its change to *technetium* in 1947, and for *plutonium* (94), it appears a question mark for the symbol. In the reverse page, the periodic table is presented in full extension, i.e. showing all the elements of each period in a unique row (Figure 6b), group zero being the first one. It is mentioned that hydrogen should form a special group. There exists a separation between metals and non-metals and ten series, each two corresponding to groups IV, V, and VI. The author mentions that some elements, like Ge, Sb, etc., although present among metals could also be positioned among non-metals, such as Si and As.

By 1965, Portuguese upper secondary school students were able to purchase a periodic classification chart, similar to the one in Figure 7, by E. H. Sargent & Co. It is interesting to note that while the classes were held in Portuguese, the table was in English, foreseeing its future use at the university. Its handwritten notes were added while the student was taking Organometallic Chemistry at the Lisbon Technical University.[110]

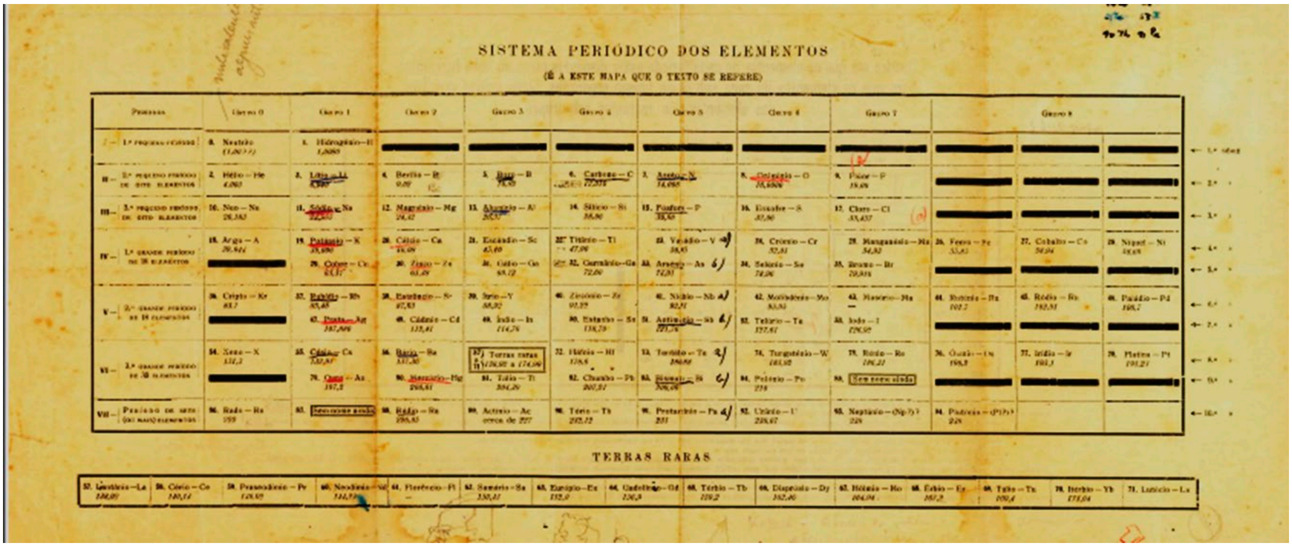


Figure 6a. Recto of the unfolding chart with periodic classification system included in F. Sena Esteves' textbook (ref. 94).

Figure 6b. Verso of the unfolding chart with periodic classification system included in F. Sena Esteves' textbook (ref. 94).

Nowadays, and according to the recommendations of IUPAC, the periodic table used in Portuguese classrooms has 18 groups, but this numbering system is not yet in wide use.[111] The traditional system involved the use of the letters A and B. The first two groups were IA and IIA, while the last six groups were IIA through VIIA. The middle groups use B in their titles and Group VIII was in between VIIB and IB. Noble gases were considered a separate group. In the early part of the twentieth century groups A and B were shown in the same slot, with or without explicit mention, and this is the reason why most of the books only show nine groups (eight plus group zero of the noble gases).

6. FINAL REMARKS

Based on the historical sources analyzed, it is possible to conclude about the early Portuguese acquaintance with Mendeleev´s classification and its reception and circulation. The Mendeleev's classification was more or less commonly known during the 1880 decade in Portuguese

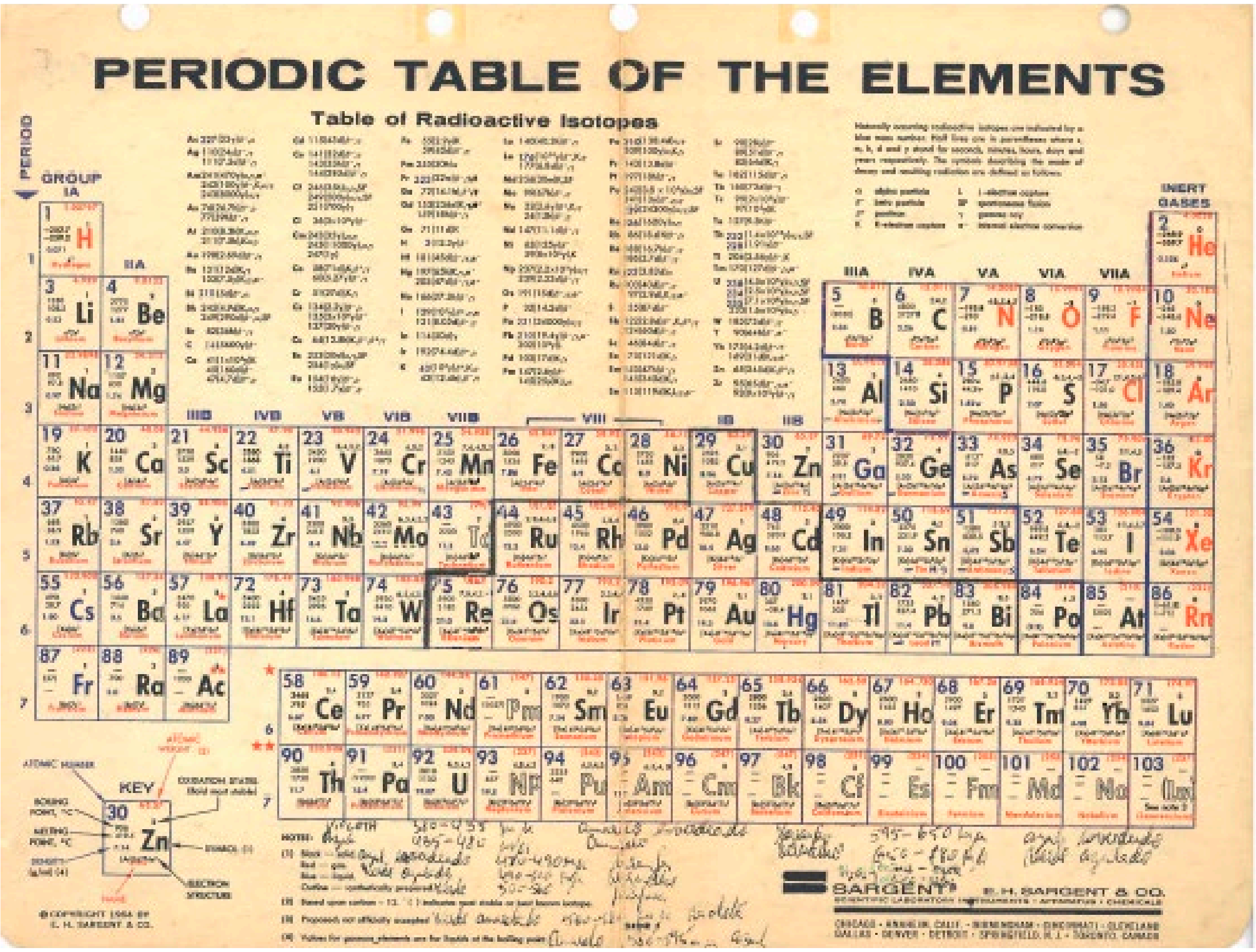


Figure 7. Periodic classification chart by E. H. Sargent & Co. Photo by João Oliveira.

higher education, and acknowledged and used by its professors.

The first mention in 1880 is framed in the discussion of primeval matter and a version of atomic theory based on Prout's hypothesis: Mendeleev is mentioned for his law, as a support to the unity of matter. In teaching manuals, there was the idea of avoiding the more philosophical theories from the chemistry presentation; even when some authors mention the atomic theory, they insist on taking a pragmatic approach. Very recently, we had access to a truncated version of a textbook published at the University of Coimbra in 1880, where clearly the author presents Mendeleev's law as accepted. From 1888 onwards, it was mostly used as a classification and a pedagogical tool, as it enabled a more rational presentation of chemistry to the students according to some professors' testimony.

For secondary level, the first presentation of Mendeleev's table occurs as an extra reading at the beginning of the twentieth century, but the situation in secondary school is split. Textbooks for basic secondary level did not address Mendeleev's classification, keeping instead a general division in metals and metalloids, with sometimes more detailed classification inspired by early 19th century chemists, and this was the case at least until 1967. The official programs for upper secondary included explicitly the periodic classification by the middle of 1940 decade. Unlike what happens for the basic level, and starting in 1892, one finds the presentation of the periodic classification in textbooks by Achilles Machado (1906-1938) for the upper secondary. After the reform in 1936 and until 1975, the periodic classification became a subject being taught and is from then on included in textbooks even though the amount of pages dedicated to its explanation can be very scarce in some cases.

The use of periodic classification wall charts started at the University of Coimbra in the 1890 decade, while the oldest surviving one appears to be produced between 1926 and 1937.

Interestingly, there is no printed periodic table for upper secondary level in textbooks before 1906. It took forty more years to include an updated configuration with a layout similar to the ones presently used. From then on until 1975, this subject entered the official programs and the textbooks included it systematically.

Through this study of the mention of Mendeleev's system, it is clear that the different contexts have triggered different interests for what we now regard as the indispensable tool for chemistry, and these contexts have shaped different responses, either philosophical or pedagogical. As a result, the appropriation of Mendeleev's classification occurred at different speed and stages depending on the usage it could be put to.

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19. Probably a copy of the French translation from the 5th German edition made by Albert Bloch *Les théories modernes de la chimie et leur application à la mécanique chimique* par Lothar Meyer; ouvrage traduit de l'allemand sur la 5e édition, par M. Albert Bloch et J. Meunier., G. Carré, Paris, **1887**, still existent in Coimbra.
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22. J. M. O. Pimentel, *Lições de Chymica Geral*, Casa de J. P. Lavado, Lisboa, **1850**.
23. Gl – *glucinium*, later designated *beryllium*. On spurious elements, see M. Fontani, M. Costa, M. V. Orna, *The lost elements: the periodic table's shadow side*, Oxford University Press, Oxford, 2014.
24. Pp – *pelopium*, later found to be either identical to niobium or mixtures of niobium and tantalum. Cfr. *The lost elements*, ref. in note 23.
25. Il – *ilmenium*, later found to be either identical to niobium or mixtures of niobium and tantalum. Cfr. *The lost elements*, ref. in note 23.
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27. Bo – *boracium*, later designated *boron*.
28. Az – *azote*, later designated *nitrogen*.
29. Fl – *fluore*, later designated *fluorine*.
30. Malaquias, *op. cit.*, p. 249.
31. Decipium was shown to be a mixture of samarium and other rare earth elements. Cfr. *The lost elements,* ref. in note 23.

32. Later to be found identical to another recently discovered element, *holmium*. Cfr. *The lost elements,* ref. in note 23.
33. Described as occurring with the cerium earths, like *decipium* and *philipium*. Cfr *The lost elements,* ref. in note 23.
34. Later shown to be a mixture of *iridium* and *rhodium*. Cfr *The lost elements,* ref. in note 23.
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