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Heat and Kinetic Theory in 19th-Century Physics Textbooks: The Case of Spain

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ABSTRACT. Spain was a scientifically backward country in the early 19th century. The causes were various political events, the War of Independence, and the reign of Fernando VII. The introduction of contemporary physics into textbooks was therefore a slow process. An analysis of the contents of 19th-century Spanish textbooks is presented here, centred on imponderable fluids, the concept of energy, the mechanical theory of heat, and the kinetic theory of gases.

1. INTRODUCTION

The period of Enlightenment was a time when Spanish physics, which had been lagging behind the level of the rest of Europe, was able to recover. However, the political events of the end of the 18th century, the War of Independence, and then the reign of Fernando VII ruined the panorama of Spanish science. History was sadly to repeat itself with the Spanish Civil War of 1936, which brought to nothing the efforts of physicists and mathematicians of the end of the 19th and the beginning of the 20th centuries to regain the time lost during the reign of Fernando VII until the 'generation of '98'.

Part of the disastrous situation during the 19th century can be traced back to the legislation and curricular plans of Spain's universities. The Faculty of Exact, Physical, and Natural Sciences was not created until 1857, with the Ley (Law) Moyano. Physics had been relegated to a minor faculty, that of Arts, as preparation for the major faculties, and formed part of the 'Philosophical Institutions' which were studied in the following order: I. History of philosophy and elements of mathematics; II. Logic and metaphysics; III. General physics; IV. Special physics. All was in a Latin which had become progressively less suited to teaching, so that enlightened reformers always attempted to publish textbooks in Spanish. Physics texts in Latin were still being imposed on students even up to the time of the absolutist period of Fernando VII (Moreno González 1988).

After the death of Fernando VII, an ordinance regulating printing was promulgated in 1834 which allowed a certain freedom in publication, in particular in scientific publishing. One of the consequences of the centralization of curricular plans, such as the Plan Pidal, was the impulse given to the production of textbooks associated with the new programs of study. They were original productions as well as translations of foreign authors, and formed the beginning of a national scientific output which

was to be of greater or lesser quality according to each particular case. The study plans usually counselled the use of certain textbooks which most closely approached the spirit of the courses. The procedure consisted in appointing committees to decide on the most suitable texts which then put forward a number of them to be chosen from.

In the meantime, Europe was seeing a major change in vision towards atomism thanks to such personalities as Herapath, Waterston, Clausius, Van der Waals, Maxwell, and Boltzmann (Bruh 1986). Imponderable fluids had been abandoned as the explanation of physical phenomena, and Mechanics, Heat, Electromagnetism, and Optics had been unified by the concept of energy. Teaching was based on a program of mechanical explanations (Harman 1982).

The goal of the present communication is to analyze the impact of modern ideas concerning energy and the constitution of matter on the textbooks of 19th-century Spain. We have examined 45 works on general physics at secondary and university education levels, with publication dates from the mid 19th century to the early 20th century. One of the first things that struck us was the great similarity between the books of different authors. With centralism, teachers were encouraged to write their own textbooks and, indeed, were rewarded for doing so. At the same time, the administration's goal was for teaching to be uniform nationwide. The result was that textbooks were written essentially with the Ministerio de Fomento's (Ministry of Development) official program as the Table of Contents, and that the texts served solely to expound known science and in no way to serve as the basis for further research. There were those who, being interested in science teaching, protested about the policy concerning textbooks. Representative of them was Eduardo Lozano y Ponce de León. Under the pseudonym L. Opando y Uceda, Lozano published 'Programas y Libros de Texto' (Programs and Textbooks) in *Revista de la Sociedad de Profesores de Ciencias* (Opando y Uceda 1875), and under the pseudonym 'Un Extremeño' the same article in the journal *El Magisterio Extremeño* (*The Extremeñan Schoolmaster*) (Extremeño 1875). In this same journal and on the same theme, Ildefonso Fernández Sánchez published another critical article (Fernández Sánchez 1876). In his writings Lozano asked for the programs to have reference strictly to the subject matter to be dealt with and not to the methods to be used, and that the programs should include suggestions of the books that were best suited to the subject, but without the obligation of following them.

The immediate consequence of that educational policy was that the different editions of textbooks seemed rather to be reprintings: textbook 'immutability' from one edition to another was astonishing. Let us take two cases as example. The *Traité Élémentaire de Physique* (*Elementary Treatise on Physics*) by A. Ganot was used in many Spanish and European Institutes (secondary education) and Universities. The first Spanish language edition dates from 1853. The 18th Spanish edition was printed in 1923, and even as late as 1945 an edition was published in San Sebastián

(Moreno González 1988). In all this time there were only small modifications made with respect to the first French edition. An even more extreme example, since it was a work with even more antiquated ways of putting the material than Ganot, was the textbook of González Valledor and Chávarri. The 2nd edition dates from 1851 (González Valledor and Chávarri 1851) and the 10th edition from 1870 (González Valledor and Chávarri 1870). In these twenty years and eight new editions the work remained without a single significant change, notwithstanding the archaic ways of setting forth the subject matter of the first editions. A third example is less disappointing: *Elementos de Física* (*Elements of Physics*) by Enrique Iglesias Ejarque. The first edition of 1897 (Iglesias Ejarque 1897) has quite a modern manner of exposition. Nevertheless, while the following editions introduce small amounts of additional material into the text, there are never any significant changes. The 8th edition dates from 1924 (Iglesias Ejarque 1924) and the last that we can find a reference to is the 10th edition in 1933. Clearly one may conclude that physics textbooks had quite a long effective lifetime.

While there was a certain degree of difficulty in introducing new material into the textbooks, the great problem was to eliminate content which was included by tradition even though it was antiquated. The case of Eduardo Sánchez Pardo, the translator of Ganot's work, is significant. In the prologue to that popularly used book:

> The editor D. Cárlos Bailly-Baillière being for his part desirous that our public in general, and the pupils of our Institutes and Faculties in particular, follow science in her latest advances, charged us with the translation of the latest edition of the cited Treatise on Physics. On taking on this commitment, with the object that the Spanish edition be more complete, we judged it convenient, corresponding thereby also to the wishes of the editor, to conserve certain theories, the exposition of various experiments, and the description of some of the instruments or apparatus that had figured in earlier editions of the foremen-tioned work, and that in the latest edition had been totally or partially suppressed. (Ganot 1876, p. v)[1,2]

Another of the characteristics of Spanish physics textbooks was their orientation to student success in tests and examinations. Works that are halfway between textbook and simple program of the curriculum abound. Secondary education teachers often encouraged the students to think little about the physical phenomena themselves but to learn definitions, laws, and descriptions of apparatus. As clear examples we could cite, amongst several works, the *Resumen de Física y Nociones de Química* (*A Summary of Physics and Notions of Chemistry*) (Santos de Castro 1865), and *Definiciones, Principios y Leyes de la Física* (*Definitions, Principles, and Laws of Physics*) (Paz Sabugo 1892). Hence, for most students learning was not meaningful but purely memorization. Together with the lack of practical classes, this may have been one of the causes of Spanish physics' slow rate of development during the 19th century.

2. ANALYSIS OF THE TEXTBOOKS

In order to analyze what we understand to have been the introduction of modern physics into Spanish textbooks, we asked ourselves the following questions relative to the works that we consulted:

1. Are imponderable fluids studied in the textbook?
2. Is the term caloric used to refer to heat?
3. Does the concept of energy appear in a general form?
4. Does the mechanical theory of heat appear?
5. Does the kinetic theory of gases appear?

Affirmative responses to the first two questions would indicate traditionalism, and to the last three, modernity. We would classify a textbook as modern if questions 3 and 4 are answered affirmatively. If the kinetic theory of gases appears as well (question 5), then we would consider the textbook to be quite complete. Table I lists the responses to these questions for the 19th-century textbooks to which we had access. The works are ordered by publication date. When the edition is not given, reference is to the first edition.

Most of the works consulted belong to the library of the Real Sociedad Económica de Amigos del País in Badajoz (Spain). While not exhaustive, the sample is significant, since students of the city of Badajoz in the 19th-century were prepared in this centre for the entrance examinations of the Schools of Engineering (high-level technical degree courses, rather than purely Engineering in the English language sense) or Military Academies.

Some comments are necessary concerning Table I. The books that were published in Spain in the 1840s studied imponderable fluids, and dealt neither with energy, nor with the mechanical theory of heat, nor with the kinetic theory of gases. This situation was natural since these concepts were only being developed in Europe at this time. However some foreign authors already did not study imponderable fluids (neither did they use the term caloric to refer to heat), and their Spanish translations set an example for such fluids to be abandoned. This was the case with the textbook of Deguin, translated by Venancio González (Deguin 1845). The translator would write his own textbook later (González Valledor and Chávarri 1851), and despite going through numerous editions, would never abandon imponderable fluids. Another textbook of a French author is Pinaud (1847), translated by Florencio Martín Castro, although here imponderable fluids were still being studied in the original.

The handbook of Morquencho Palma (1845) presents physics as a science of Nature in general, including subjects such as geology and geography. This was the concept of physics that existed in Europe at the beginning of the century. On the positive side, the mechanical ideal which was at the base of the development of physics in the 19th-century did indeed have a reflection in Spanish textbooks. One reads in the prologue of the work of Ribero Serrano (1844):

> (. . .) Effectively, all the phenomena attributed to caloric, to light, and to the electric

TABLE I
Responses to the five questions posed in the text, according to the different works consulted

Textbook	1	2	3	4	5
(Ribero Serrano 1844)	Yes	Yes	No	No	No
(Deguin 1845), 2nd ed.	No	No	No	No	No
(Morquencho Palma 1845)	Yes	Yes	No	No	No
(Santos de Castro 1846)	Yes	Yes	No	No	No
(Pinaud 1847)	Yes	Yes	No	No	No
(González Valledor and Chávarri 1851), 2nd ed.	Yes	No	No	No	No
(González Valledor and Chávarri 1856), 4th ed.	Yes	No	No	No	No
(González Valledor and Chávarri 1857), 5th ed.	Yes	No	No	No	No
(Rodríguez 1858)	Yes	Yes	No	Yes	No
(Fernández de Figares 1861), 2nd ed.	Yes	Yes	No	No	No
(Santos de Castro 1865)	Yes	Yes	No	Yes	No
(Boutet de Monvel 1866)	No	No	No	Yes	No
(González Valledor and Chávarri 1868), 9th ed.	Yes	No	No	No	No
(Rico Sinobas and Santisteban 1869), 7th ed.	Yes	Yes	No	No	No
(González Valledor and Chávarri 1870), 10th ed.	Yes	No	No	No	No
(Feliú Pérez 1874), 2nd ed.	Yes	No	No	No	No
(Rico Sinobas and Santisteban 1875), 8th ed.	Yes	Yes	No	No	No
(Ganot 1876), 7th ed.	No	No	No	Yes	Yes
(Fuertes Acevedo 1879)	No	No	No	Yes	No
(Ramos Lafuente 1880), 6th ed.	Yes	Yes	No	Yes	No
(Fuertes Acevedo 1882), 2nd ed.	No	No	No	Yes	No
(Rico Sinobas and Santisteban 1882), 10th ed.	Yes	Yes	No	No	No
(Márquez Chaparro 1886)	No	No	Yes	Yes	No
(Pina Vidal 1887)	No	No	No	Yes	No
(Amigó Carruana 1889)	No	No	Yes	Yes	Yes
(Picatoste 1889)	No	No	No	No	No
(Feliú Pérez 1890), 7th ed.	No	No	Yes	Yes	No
(Escriche Mieg 1891)	No	No	Yes	Yes	No
(Paz Sabugo 1892)	No	No	Yes	Yes	Yes
(Garagarza Dujiols 1892)	No	Yes	Yes	No	No
(Lozano 1893), 3rd ed.	No	No	Yes	Yes	No
(Martín de Argenta and Martínez Pacheco 1893)	No	No	Yes	Yes	No
(Rodríguez Largo 1895), 2nd ed.	Yes	Yes	Yes	Yes	No
(Ribera et al. 1895)	No	Yes	Yes	Yes	No
(Feliú Pérez), 8th ed.	No	No	Yes	Yes	No
(Iglesias Ejarque 1897)	No	No	Yes	Yes	Yes
(Solar Sánchez 1900), 2nd ed.	No	No	Yes	Yes	Yes
(Lozano 1900)	No	No	Yes	Yes	No

> fluid are mensurable and calculable effects; all are attributed to forces, all consist of movements, and constitute, in sum, mechanics. (Ribero Serrano 1844, p. i)[3]

The texts that we were able to consult from the 1850s are mainly editions of the work of González Valledor & Chávarri (González Valledor and Chávarri 1851, 1856, 1857). The principal characteristic of this text was its immutability, edition after edition. Although it studied imponderable fluids, the term caloric was not used, and neither energy, nor the mechanical theory of heat, nor the kinetics of gases appear in the text. The

other textbook that we consulted is that of Rodríguez (1858). Although imponderable fluids are studied and the term caloric is used, the author briefly explains the theory of ondulations[4] (as the mechanical theory of heat was first known), and says of that theory that 'it is the one which today seems more correct' (p. 173). This work was awarded a prize in a public competition under the auspices of the Real Academia de Ciencias (Gaceta de Madrid, 9 September 1854). Neither the concept of energy in a general form nor the kinetic theory of gases appear in Rodríguez's text. It is interesting too that in this decade there appeared a physics textbook written in Latin which followed the scholastic tradition (Sant 1857).

The textbooks of Spanish authors of the 1860s were still studying imponderable fluids. They were also still using the term caloric to refer to heat, except for the editions of González Valledor and Chávarri (1868, 1879), as we noted before. One French-authored textbook, Boutet de Monvel (1866), did not study imponderable fluids or use the term caloric, but then neither did it use the energy concept or the theories we are looking for. The same was the case with the textbook of Deguin (1845), commented on above. A possible reason for these to be missing is that the translator, Ramón de la Sagra, used the 7th French edition.

The note of modernity is found in the textbook of Santos de Castro (1865), in which there appears an idea concerning the mechanical theory of heat, namely the hypothesis of ondulations, although for didactic purposes the theory of emissions (caloric) was preferred. Thus, one reads:

> The system of ondulations is the most scientific, and the most admitted in modern physics; but that of emission lends itself more to demonstrations, for which reason it is generally preferred for the explanation of the phenomena of the caloric. (Santos de Castro 1865, p. 204)[5]

The textbooks of the 1870s begin to abandon the traditional theses, and show signs of modernity. The most traditional are Rico Sinobas and Santisteban (1875), an 8th edition, and Feliú Pérez (1874). The latter already does not use the term caloric, and later editions were progressively modernized.

The textbook of Ramos Lafuente (1880) studies imponderable fluids, and uses the term caloric. In its treatment of radiant heat, however, the work seems very modern. As noted above for Santos de Castro (1865), the author prefers the caloric hypothesis for its simplicity in teaching:

> The admissible hypothesis is at present that of ondulations, in the light of the advances in modern physics; but as it simplifies the demonstrations, many physicists prefer the hypothesis of emission to explain the phenomena of heat. (Ramos Lafuente 1880, p. 148)[6]

The textbooks with a more modern spirit are those of Fuertes Acevedo (1879) and Ganot (1876). Máximo Fuertes Acevedo's work neither studies imponderable fluids nor uses the term caloric. But energy does not appear as a general concept either, despite the mechanical theory of heat being explained. Adolphe Ganot's textbook was much used in Europe. The first

Spanish edition is of the year 1853. We consulted the 7th Spanish edition (Ganot 1876). It contains a paragraph explaining the dynamic theory of gases: gases are described as formed by elastic molecules in motion, and the elasticity of a gas at a given volume is proportional to the *vis viva* (total mass of the molecules multiplied by the square of their speed). While making use of such concepts as this (today, of course, replaced by kinetic energy), the text does not deal with energy in a general form. As is to be expected with this perspective, imponderable fluids and the term caloric have been forgotten, and the mechanical theory of heat is studied.

All the textbooks of the 1880s that we consulted have abandoned imponderable fluids, with the exception of the handbook of Rico Sinobas and Santisteban (1882) which is already in its 10th edition. Of the other works, the most traditional is that of Picatoste (1889), since it neither deals with energy in a general way nor introduces the theories we are looking for. We then have the 2nd edition of the work of Fuertes Acevedo (1882), with no substantial changes from the 1st edition. We also consulted a Portuguese secondary education textbook, Pina Vidal (1887), which has a similar perspective to those of Fuertes Acevedo (1879, 1882). The textbook of Márquez Chaparro (1886) is the first of the series of books that we consulted in which energy is dealt with in a general fashion. The mechanical theory of heat is studied, but the kinetic theory of gases has still not appeared. The 7th edition of the work of Feliú Pérez (1890) has almost nothing to do with the 2nd edition that we commented on above (Feliú Pérez 1874). Now, energy and the mechanical theory of heat are presented. In the prologue to the 6th edition, also included in the 7th, one reads:

> With great insistence I have attempted in the treatment of heat to relate together all the phenomena of thermo-dynamic theory. (Feliú Pérez 1890, p. v)[7]

The outstanding textbook of this decade is that written by Amigó Carruana (1889), published in Tarragona. The author held the chair of physics and chemistry in the Instituto Provincial of Tarragona. This is a modern text which includes the kinetic theory of gases, and in general explains physical phenomena mechanistically. In the work's prologue, the author speaks about a book of his on mechanics published in 1885, and gives great importance to this branch of physics:

> The criterion that has inspired this treatise responds to the necessity already recognized by all to explain the subject of Physics in a single course, always preceded by a short course of Mechanics as foundation and basis of the former (. . .). (Amigó Carruana 1889, p. 3)[8]

As a continuation of thermodynamics, Amigó Carruana describes the kinetic theory of gases by following the ideas of Clausius and introducing the definition of free path of a molecule as the distance travelled between two consecutive collisions. He deduces Mariotte's Law, obtaining the formula $pV = \frac{1}{3}nmv^2$, where p is the pressure of the gas, V its volume, n

the number of molecules, v the mean velocity, and m the mass of a molecule. He also deduces Avogadro's hypothesis from the kinetic theory of gases (Vaquero 1998). As an indication of the little that this personality and his work have been studied, there only appears one book of Amigó Carruana in the *Collected Catalogue of Spain's Bibliographic Heritage: 19th Century* (Biblioteca Nacional 1889). This is a textbook on elementary chemistry (Amigó Carruana 1892).

The main characteristic of the books of the 1890s is that they all now treat energy in a general form, as well as the mechanical theory of heat. The textbook of Rodríguez Largo (1895) simultaneously uses imponderable fluids and the term caloric, but only as additional information. A more curious case is that of Ribera et al. (1895) whose textbook uses the term caloric without studying imponderable fluids.

The work of Escriche Mieg (1891) has the interest of studying heat and light side by side,[9] to bring out their relationship as vibratory phenomena:

> (. . .) The molecular vibrations of the bodies, transmitted by the aether, produce the feelings of HEAT in the touch and of LIGHT in the sight. (Escriche Mieg 1891, p. 496)[10]

Other modern textbooks are those of Lozano (1893), the pharmacist Garagarza Dijiols (1892), Martín de Argenta and Martínez Pacheco (1893), and Feliú Pérez (1896).

The small book of Paz Sabugo (1892) contains only definitions and principles. At no time is any idea developed, since the book's object is to serve as a collection of phrases for students to learn in preparation for their examinations. As part of these examination aids, the author prepared two plates which accompany the text, one on units and abbreviations of the decimal metric system, and another on physical units. The kinetic theory of gases does not appear explicitly, but some of its results do. For instance, one can read Maxwell's Law:

> The viscosity of a gas measured by the coefficient of friction is independent of the density. (Paz Sabugo 1892, p. 60)[11]

Another modern work is that of Iglesias Ejarque (1897). The author indicates on the first page in a footnote that the works that had been consulted were 'Spanish: Escriche, Feliú, Muñoz, Rojas, and Rodríguez Largo. Foreign: Ganot, Jamin, Joubert, Maxwell, and Tyndall'. The text contains a short paragraph on the Theory of Gases, in which Bernouilli, Clausius, and Maxwell are cited. A kinetic interpretation of pressure is also given, but neither is the concept of mean free path introduced nor estimates of molecular speeds given.

The textbook of Soler Sánchez (1900), another modern work, has in the book dedicated to heat an article on the *Thermal Constitution of Gases*, in which the kinetic theory is described. A kinetic interpretation of pressure is given, together with an explanation of high molecular velocities, including numerical estimates. A short section is dedicated to the *Height of the Atmosphere*, and another to the *Mean Free Path*, in which

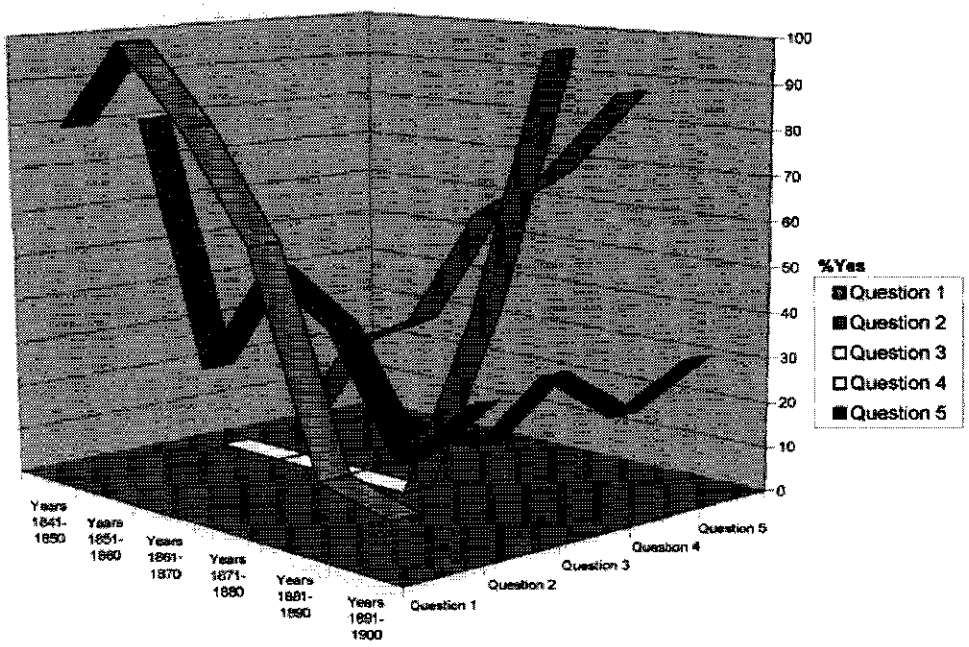

Figure 1. The evolution of textbook contents with respect to the abandoning of imponderable fluids and the introduction of the concept of energy, the mechanical theory of heat, and the kinetic theory of gases. The figure has been constructed by calculating for each decade the percentage of affirmative responses to the questions formulated in the text. The intention of these results is not to provide full statistical certainty, but to present qualitatively the findings of this investigation. One clearly appreciates the decline in the use of imponderable fluids and the rise of content related to an atomic view of matter.

one reads that 'Crookes calls mean free path the space travelled by the molecule between two of those collisions'. On the other hand, the kinetic theory of gases is not mentioned by Lozano (1900).

We also consulted some 20th-century books. They all had a modern perspective. The textbooks of Carrasco Garrorena (1925) and Monzón González (1928) did not include the kinetic theory of gases. The 6th and 8th editions of Iglesias Ejarque (1915, 1925) present improvements over the 1st edition. With respect to the kinetic theory of gases, a new paragraph is included to explain molecular velocities. The textbook of González Martí (1904) explains van der Waals's equation of state.

The last textbook that we wish to comment on is a translation of an Italian book. It is the work of Castelfranchi (1932), a university textbook of modern physics where the kinetic theory of gases is developed completely. The topics in the book are surprising in their breadth and modernity.

As a qualitative summary, Figure 1 shows the evolution of the responses to the questions that we formulated, according to the data listed in Table I.

3. CONCLUSIONS

Spain's educational policies in the 19th century encouraged a great similarity between the general physics textbooks of different authors, although there were voices such as that of Eduardo Lozano y Ponce de León, in discord with this policy. This situation led to the differences between the successive editions of a textbook being minimal, and as a result, the effective lifetime of these textbooks was extremely long. A noteworthy example is the Spanish translation of the work of A. Ganot – the 1st edition was published in 1853 and the last we know of was 1945.

Likewise, there were difficulties in rooting out the antiquated content of physics textbooks. In many of them, modern and old theories shared the pages. A significant example was the case of Eduardo Sánchez Pardo, who amplified his translation (Ganot 1876) with elements of old editions that had been discarded from consideration in new foreign editions. The result was to help make the recovery of Spanish physics was a very slow process.

With respect to the term caloric, it was used in the Spain of this period with different acceptations: as an imponderable fluid responsible for thermal phenomena (its original meaning), as a synonym for heat (the latter being understood according to the mechanical theory of heat), and as the cause of the phenomena of heat, whatever their nature.

Also, during the analysis of the sources that were available, we found the orientation towards examination preparation to be excessive in the textbooks that we consulted. Some are a simple cookbook of laws and physical phenomena that the students would have to learn if they were to pass their examination. Hence, no interest was aroused in reflecting on content or in carrying out experiments in practical classes. Certain textbooks shamelessly encouraged totally memoristic learning, so that content was not applied to new situations and was readily forgotten.

Another fact revealed by the analysis of the textbooks was the speed with which the mechanical theory of heat gained acceptance. This theory had become quite usual in many of the Spanish physics textbooks well before the concept of energy had begun to be treated in a general form. While this fact seems disconcerting from today's viewpoint, it must be pointed out that both the mechanical theory of heat and the second law of thermodynamics had been proposed before the law of conservation of energy was generally accepted.

The introduction of the kinetic theory into 19th-century Spain occurred from approximately the 1870s onwards. In the 1880s, the theory already appears more developed in one of the textbooks that we consulted. This was the work of Amigó Carruana (1889), which stands out for its mechanistic deductions of Mariotte's Law and Avogadro's Law. The topics dealt with concerning the kinetic theory in the textbooks that we consulted were: generalities of the theory, kinetic interpretation of pressure, molecular velocities, mean free path, height of the atmosphere, and the

van der Waals equation. Lastly it should be remarked that we found no original contribution to kinetic theory in these Spanish works of the end of the 19th century.

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NOTES

[1] The original text is: 'Deseoso por su parte el editor D. Cárlos Bailly-Baillière de que nuestro público en general, y particularmente los alumnos de nuestros Institutos y Facultades sigan á la ciencia en sus últimos adelantos, nos encomendó la traduccion de la última edicion del citado Tratado de Física. Mas al encargarnos de este cometido, con objeto de que la edicion española fuera mas completa, juzgamos conveniente, correspondiendo por otra parte así á los deseos del editor, conservar algunas teorías, la exposicion de varios experimentos y la descripcion de algunos instrumentos ó aparatos que en ediciones anteriores de la mencionada obra figuraban, y en la última hánse total ó parcialmente suprimido'.

[2] Among the old material that was revived one can find, for instance, sections on Animal Electricity, Perreaux's dynamometer, Alvergnat's barometer, Carré's device for making ice or Sturm's vision theory.

[3] The original text is: '(. . .) Efectivamente, todos los fenómenos atribuidos al calórico, á la luz y al fluido eléctrico, son efectos mensurables y calculables; todos se atribuyen á fuerzas, consisten todos en movimientos, y constituyen en fin la mecánica'.

[4] According to the hypothesis of ondulations, as defined in the 19th-century Spanish books we have consulted, heat is caused by the rapid motion of the molecules and is transmitted through the aether by ondulations.Thus, all the heat phenomena are referred to a unique cause, motion, in contrast to the heat understood as a substance (caloric). The hypothesis of ondulations is not exactly the same as the wave theory of heat (Brush 1986), according to which heat is the vibrations of aether itself.

[5] The original text is: 'El sistema de las ondulaciones es el mas científico, y el mas admitido en la física moderna; pero el de la emisión se presta más a las demostraciones, por lo que se prefiere generalmente para la esplicacion de los fenómenos del calórico'.

[6] The original text is: 'La hipótesis de las ondulaciones es la admisible en la actualidad, atendidos los progresos de la física moderna; pero simplificándose las demostraciones por la hipótesis de la emisión, muchos físicos la prefieren para esplicar los fenómenos del calor'.

[7] The original text is: 'Con insistencia grande he procurado en el tratado del calor hacer relacionar todos los fenómenos con la teoría termo-dinámica'.

[8] The original text is: 'El criterio que ha inspirado este tratado, responde á la necesidad ya reconocida por todos, de explicar en un sólo curso la asignatura de Física, precedida siempre de un cursillo de Mecánica como fundamento y base de aquella (. . .)'.

[9] On the other hand, Escriche Mieg does not distinguish radiant heat from heat as energy of molecular motion.

[10] The original text is: '(. . .) Las vibraciones moleculares de los cuerpos, transmitidas por el éter, producen en el tacto la sensación de CALOR y en la vista de LUZ'.

[11] The original text is: 'La viscosidad de un gas medida por el coeficiente de frotamiento es independiente de la densidad'.

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