Giacomo Ciamician and His Chemistry Courses in Bologna Over the Years 1889 to 1921

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Received January 9, 2012. Accepted May 16, 2012.

Abstract: Giacomo Ciamician, an Italian chemist of distant Armenian ancestry, was born in Trieste in 1857 and died in Bologna in 1922. Often referred to as the "father of organic photochemistry", he also made important contributions to the chemistry of pyrrole and of selected vegetal compounds. In appreciation of his achievements he was nominated nine times for the Nobel prize, not only by his Italian colleagues but also by foreign scientists, such as Emil Fisher (1852–1919). He became professor of General Chemistry at the University of Padua in 1887 and two years later was appointed to the chair of that title at the University of Bologna, where he remained for the rest of his life. Unfortunately, no matter how profound his dedication to teaching, he never wrote any textbook. The only remaining evidence of his lectures are the students' notes and a book edited by one of his pupils. To mark the centenary of "The Photochemistry of the Future", a famous address delivered by him on the occasion of the Eighth International Congress of Applied Chemistry (New York City, 1912), the above-mentioned documents were investigated in the historical perspective for chemical teaching across the nineteenth to twentieth century passage.

Introduction

Giacomo Ciamician became professor of chemistry at the University of Bologna in 1889 (Figure 1). This goal achievement made him especially happy because, as he later told one of his collaborators, there was plenty of chance in the city to listen to good music [1]. He then moved to Bologna from Padua, a location where he had lived for two years only, enjoying his first tenured professorship and launching a program of chemical research of international level, but where perhaps he did not feel completely at home. He continued to pursue his valuable research projects in Bologna as well, backed by what he had learned during a stay in Wien and a period of training in Rome, at the Cannizzaro School, considered at the time the best school in Italy for Chemistry scholars [2–4].

On the occasion of the 150th anniversary of the birth of Giacomo Ciamician, the career of this scientist was described in detail, with emphasis on his work on organic chemistry, solar energy, green chemistry and politics [2–4]. Besides being a very productive investigator and one covering a wide range of interests, he was also a very good teacher. The collections of notes, taken by students during his lectures, dealing with general & inorganic chemistry and organic chemistry, which were carefully preserved in the Department Library dedicated to him, while a few ended up in private hands, represent a direct testimony of the teaching of an outstanding scientist. Even though they were exhibited on many occasions and examined with great curiosity and admiration, they do not appear to have ever been subject to a critical historically minded review.

An Eminent Chemist

Ciamician's papers were published in the Monatshefte für Chemie, Berichte der Deutschen Chemischen Gesellschaft, Gazzetta Chimica Italiana (founded in 1870) and Rendiconti dell'Accademia dei Lincei. Although his greatest contribution to science probably lies in the field of organic chemistry, the spectroscopic research carried out by him as a student, in Wien, was important enough to deserve a citation by Dmitri Ivanovich Mendeleev (1834–1907) [5]. His scientific work may be broadly divided into four research themes: (1) elemental spectroscopy; (2) the chemistry of pyrrole; (3) the chemical action of light on organic compounds; (4) the chemistry of plants products. The success in these investigations lies at the basis of the nine nominations for the Nobel prize he received both from Italian and foreign scientists, including Emil Fisher (1852–1919) [6]. He was granted many academic honors, became a member of scientific academies in Italy and abroad and was nominated Senator of the Kingdom of Italy in 1910 [2–4]. He was therefore a celebrity and his pupils used to work very hard so as to obtain top grades because this entitled them to receive an autographed photo of their teacher, (an honor nowadays associated with pop singers). His scientific work took place in a small humble laboratory located in the proximity of the 1803 established seat of the University. Despite this, he liked Bologna enough to turn down more comfortable and prestigious offers made to him by foreign institutions. When Hugo Weidel (1849–1899) died, he was the one asked by Professor Adolf Lieben (1836–1914) to accept the chair of General Chemistry at the University of Wien and to preside over the first Wiener Chemical Institute, but he refused, and was consequently granted a wage increase and an honour was conferred upon him by the Italian Government. He stayed on and continued his

Figure 1. The young Giacomo Ciamician (approximately 1890).

investigations while the century ended, the WW1 took place, the peace returned, and so on. During the last few years of his busy life he finally devoted himself to promoting the building of new premises for the classrooms and chemistry laboratories of the University. However, even though he took active part in their design and witnessed the start of the work, he was unfortunately not fated to see its completion.

No graphic documentation exists on the small and badly-equipped chemical laboratory nor on the place where Professor Ciamician held his lectures. In this respect, nothing remains except the fleeting view by Antonio Basoli of an area close to the present intersection of Via Belmeloro with Via S. Sigismondo [7]. Looking at this picture (Figure 2), one may perhaps imagine where Ciamician may have staged his lessons. Thus, the only surviving evidence of his lectures are the notes, and a book edited by one of his pupils. But to better understand the university lectures of Giacomo Ciamician it should be remembered that he was not only a scientist of center-European culture, with numerous international relations, but also a brilliant popularizer, convinced that science knows neither insurmountable barriers within, nor any boundaries "on the outer side". In his attempt to put science at the service of society, he was attracted by a multidisciplinary approach and became actively engaged on different fronts [3], starting with that of energy. In the first decade of the 20th century, coal-dust pollution was more or less everywhere, as has been shown by recent surveys carried out on the ice deposits of Greenland [8–9]. Today, many people speculate on how to reduce our dependence on precious but finite energy resources like fossil fuels, how to curb damage and how to switch to renewable energy sources. Almost one hundred years ago the scientist Ciamician denounced the "growing greediness and thoughtless prodigality" associated with coal exploitation at international level. The year was 1912 and the 8th International Congress of Applied Chemistry was being held in New York. The four official languages were French, German, English and Italian, and Giacomo Ciamician belonged to a small group of speakers sent to represent the countries where the four languages were spoken. The others were Gabriel Bertrand (France), Carl Duisberg (Germany) and William Henry Perkin (Great Britain). Ciamician spoke in Italian in the afternoon of Wednesday, September 11. During his conference: "The photochemistry of the future" he put forward some bold ideas, announcing future developments which looked like dreams. He pointed out that coal deposits were not endless and that people should ask themselves whether coal was the only energy source that could favor modern civilization. The answer was to be found in the fact that most of the energy which the earth receives from the sun is wasted. Among other possibilities, one might envisage how to fix solar energy with suitable photochemical reactions, imitating the assimilation process of plants and viewing batteries as the basis of photochemical processes. Ciamician's paper was translated into various languages and immediately published (27 September) by the leading journal, *Science* [10] .When the *New York Times* wrote about the Congress under the title "Gives out secrets of making ammonia", referring to Heinrich August Bernthsen (1855–1931), it did not fail to add the sub-title "Italian scientist predicts that *black and nervous civilization* will yield to quiet one" [11]. Few years later, *The Popular Science Monthly*'s account of the speech started with this question: "Will the Sahara Furnish Power When Coal Gives Out ?" [12]. Giacomo Ciamician was not considered a mere dreamer because he spoke with the authority deriving from years of brilliant laboratory research in the field of organic chemistry, photochemistry and chemistry of natural products. During his career, he published about eighty papers on pyrrole and derivatives and a monographic one containing the results of his own research and that of others. His name is still associated with the reaction through which pyrrole is converted to pyridine, achieved (1882) in collaboration with Maximilian Dennstedt (1852–1931) [13]. Another of Ciamician's group of investigations concerns the chemical composition of substances of vegetable origin. Finally, during the first fifteen years of the 20th century, together with Paul Silber (1851–1932), Ciamician investigated thoroughly the chemical action of light on organic substances. He published about forty articles on oxide-reductions, polymerizations, condensations and autoxidations of various organic compounds caused by sunlight. His photochemical research was followed by other studies on the chemistry of vegetables. The Bologna chair, established in 1737 for Jacopo Bartolomeo Beccari (1682–1766), was therefore a post worthy of the value of this scientist.

A Successful Teacher

Professor Ciamician was considered a first class lecturer and listening to him must have been quite an intellectual treat since his classroom is said to have been full not only of students but also of scholars or experts in other subjects, sometimes high-ranking scientists and former pupils of the University. According to Luigi Mascarelli (1877–1941), author of the organic chemistry notes, Ciamician's lectures were clear and concise even when the topic was particularly complex [14]. Their elegance was consistent with his artistic spirit, and they were always backed by highly-accurate experimental preparations. His pupils were not only chemistry students, but, in view of the regulations of the time, also future engineers, physicians, naturalists and pharmacists. All of them would flock into Ciamician's classroom. It would not be wrong to speak about a real "Ciamician School", which helped refresh Italian chemistry. A round of welcome applause would greet Ciamician as he entered the classroom and paid tribute to him at the end of the lesson. He continued teaching until shortly before his death, despite being undermined by his illness and old age. However, no matter how prolific an author of research

Figure 2. Bologna, S. Sigismondo Alley (University Quarter). Engraving by Antonio Basoli (1774–1848).

articles, of which he wrote nearly four hundred, and despite his dedication to teaching, Ciamician never produced printed teaching support material. Nevertheless, his approach to lecturing, his didactic-exhibitive style and the way his lessons were organised, were analysed in depth by all those who officially commemorated him after his death, especially in order to explain the interest, or rather the enthusiasm which his teaching aroused. But apart from style, what we want to try and do here is underscore the constant updating of a teacher who was, at the same time, a scientist of European renown. According to Luigi Mascarelli, those highly popular lessons "were always a faithful mirror of the state of science in that period"[14] because Ciamician was a formidable reader and assimilator, who followed the scientific works of chemists the world over, step by step. He was so keen on bringing his lectures up to date that it was not unusual for him to convene his assistants late in the evening to prepare an experiment just read in the literature so it could be shown to his students the day after. Enlightened by these analyses, the students' notes acquire not only the value of historical documents throwing a light on chemistry teaching, but also on worldwide chemical endeavor. They illustrate how new discoveries of a chemical culture of European standing, scrupulously in step with the times, were transmitted in the early 20th century. The lively sentiment which this inspired teacher put into his lectures, though conducted with a sober and incisive style, devoid of artifices, explains why he was so much liked by his students, cherished by his assistants and held in high esteem by the people of Bologna who, it should be recalled, had elected him as their representative in the City Council. For example, according to the chronicles of the time, when Professor Ciamician (born in Trieste, at the time under Hapsburg rule, into a family of Armenian origin in 1857) died in Bologna on January 2nd 1922 after a long and painful illness, he was accompanied to the cemetery by his pupils, who organized the funeral and carried the coffin along the entire route, and by a large crowd of silent mourners [1]. The death did not pass unnoticed abroad either. His eulogies were published, for example, in the Proceedings of the American Chemical Society – 1922 [15], and in the Journal of the Chemical Society – 1926 [16]. Later on, his work was the subject of valuable historical studies in France as well [17].

The Students's Notes

The notes on which this paper is based are the work of a number of students who attended Ciamician's lectures. These were duplicated, bound and must have had a market among the students since the stamp or the signature of the owner sometimes appears on the cover. Some are written clearly by hand, while others are typed. In some cases, the name of the copying office, located in the vicinity of the University, appears on the front cover. Here is the list:

- General and inorganic chemistry/notes taken during the lectures of professor Giacomo Ciamician/by Dr. Adolfo Baschieri. (At top of front cover: R. University of Bologna, 1899–1900)
- Organic chemistry/notes taken during the lectures of professor Giacomo Ciamician/by Dr. Luigi Mascarelli. (At top of front cover: R. University of Bologna, 1901–1902)

Signed by owner, G. Bruni

- Notes of general and inorganic chemistry: taken during the lectures of professor Giacomo Ciamician/by the students Bruno Maggesi, Andrea Stagni. – 2. Reviewed corrected and supplemented edition. No date (19…)
- Notes of general and inorganic chemistry: taken during the lectures of professor Giacomo Ciamician/by the students Bruno Maggesi, Andrea Stagni. – 4. Reviewed, corrected and supplemented edition. No date (19…)
- Notes of organic chemistry: taken during the lectures of professor G. Ciamician (At top of front cover: R. University of Bologna; at bottom of front cover: handwritten 1920–1921)

In view of the large amount of material at disposal, this paper will ignore, except for a number of crucial references, the notes on organic chemistry, postponing their detailed analysis to some future occasion if it were to prove necessary.

The notes on General and Inorganic Chemistry taken by Adolfo Baschieri and dated 1899–900 (Figure 3), are the oldest of the group at disposal. Adolfo Baschieri (Bologna, 1874–1913) was a son of Settimio who manufactured, in collaboration with the chemist Guido Pellagri, the first smokeless gunpowder in 1885 and founded Baschieri & Pellagri in 1890. Adolfo graduated from Bologna University in Medicine (01/07/1899) and Chemistry (02/07/1900) [18]. Baschieri's notes differ considerably from all the others in terms of the extension of the historical part and in terms of quotations and classic experiments. The graphics and sketches of appliances are clear, elegant and carefully designed. Considering that chemical science began with the study of gaseous bodies, the lectures follow the historical and logical development of chemistry, and therefore start with the study of gases. So we are given the crucial information, about the gases, such as the characteristics of the major ones, their preparation and their storage, general properties, liquefaction. We then go on to the phlogiston theory developed by George Stahl (1659–1734), to the Lavoisier reform, to oxygen, hydrogen (Figure 4), explosive gases, water and ozone. The next section considers halogens, sulphur and carbon.The second part deals with the distinction between physical and chemical phenomena.

Figure 3. Front cover Baschieri's notes.

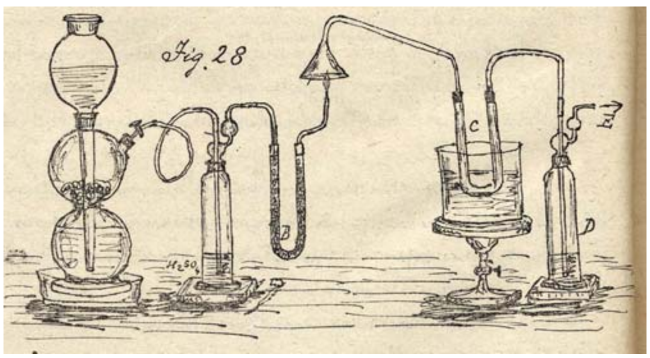

Figure 4. Apparatus for Nascent Hydrogen Production, Baschieri's notes.

According to the lecturer, *Chemistry* is subdivided into *general chemistry* and *special chemistry*. The first, which also comprises *physical chemistry*, studies the chemical properties of bodies in general, without any special reference to any one, and is made of two parts: *stoichiometry* and *theory of affinity*. The second part is split into *inorganic* and *organic*. Inorganic deals with all elements and their compounds except those of carbon. The study of general chemistry (about 228 pages) therefore starts with stoichiometry and the demonstration of the law of Lavoisier by Jean-Servais Stas (1813–1891). This is followed by the law of definite proportions and of reciprocal proportions by Jeremias Richter (1762–1807). Next we have the atomic hypothesis in its relations with stoichiometry (15 pages, full of experimental data), the problem of anomalous densities and the methods for determining the density of vapors. From gases we pass on to liquids, with the so-called *stoichiometry of liquids* and the laws of diluted solutions. Next come isomorphism and polymorphism, with the question of atomic and molecular heats, followed by the formation of compounds, the dualistic theory of Berzelius and Liebig's so-called *unitary system*. Finally comes the concept of valence and the periodic system of elements according to Mendeleev, which integrates stoichiometry. The second part starts with the law of *conservation of energy* and the description of the various forms in which the law presents itself. Next is thermochemistry and the law of Hess, with numerous numerical examples and the calorimetric measurements leading to its demonstration. This is followed by Berthelot's principle of maximum work and the principle of mobile equilibrium, confined to half a page. The final part, dedicated to electrochemistry, starts with considerations on electric units, continues with electrolysis and the laws of Faraday and Hittorf and finally goes on to address conductivity, by means of Kohlrausch's law. With regard to Friedrich Kolrausch (1840–1910), it must be said that the notes (page 206) contain a brand new quotation of his measurement of resistance taken (1890) by means of a Wheatstone bridge, with alternate current, to prevent polarisation. Next comes the electrolytes, with the brand new quotation and explanation (1887) of the theory of Svante Arrhenius (1859–1927) and that of Nernst (called of "solution-tension"). The dissociation theory is then applied to acids and bases, indicators, hydrolysis and electrolysis. In the inorganic chemistry section (246 pages) the elements are studied in groups, in the same order in which they are presented in the periodic system, but for each group considerations of a general nature are made. First mentioned are alkalis, split up into the two rows (Li, K, Rb, Cs) and (Na, Cu, Ag, Au), with indication that the last three will be discussed again together with transition metals. In the treatment of their compounds, the following are studied: halides, carbonates, nitrates and insoluble salts of various types. Plenty of room is dedicated to industrial preparations. For the second, third, fourth and fifth groups as well, the lecturer proceed according to the two halves of the system. The sixth starts from the second half (S, Se, Te) because oxygen had already been discussed (first half). Next comes the seventh, starting with (F,Cl,Br,I) and going on to deal with manganese. The transition metals follow (Group VIII), with Cu, Co, Au etc. and, finally, those of the platinum group.

The notes of students Maggesi-Stagni, following shortly after Baschieri's, show a substantial change in course content.Few biographical details are available about the two authors. Bruno Maggesi was born in Bologna on February 6th, 1892. He obtained his *Laurea* in Medicine on May 28th, 1915. Andrea Stagni was born in Bologna on June 19th, 1890 and obtained a *Diploma* in Engineering in 1914 [18]. Since the long historical introductory section is eliminated, the notes begin with stoichiometry, its laws, and then, explicitly, the atomic theory. Mention is made of the search for atomic weight, Avogadro's hypothesis is dealt with in detail, as are anomalous densities and the determination of vapor density. Next come liquids and the properties of solutions. After the liquids, we find the *stoichiometry* of solids. A new feature is the emphasis given to *Systematics*, i.e., in what way the formation of bodies can be envisaged when the different elements react with one another. This is followed by the dualistic theory, the unitary system and, with greater emphasis, Mendeleev's periodic system.Like in Baschieri's notes, we then have energetics, thermochemistry and electrochemistry. *Stoichiometry* ends with the part on chemical affinity. New here is the appearance of kinetics. An elaborate treatment of mathematics appears, with use of integrals, applied to reaction kinetics referred to Ludwig Wilhelmy (1812–1864) who, in 1850, studied the inversion of cane sugar in the presence of different acids,The second part of the notes deals with special chemistry, i.e., the systematics of elements and their compounds, according to Mendeleev's periodic system. Before proceeding by groups however, hydrogen and oxygen are dealt with because the former is taken as a term of comparison for

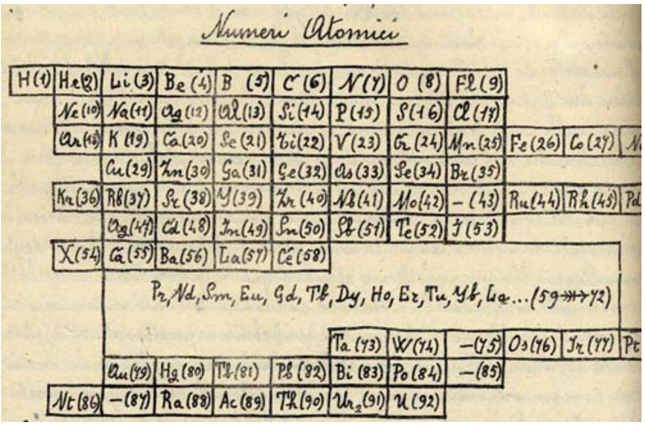

Figure 5. The periodic system sorted by the atomic numbers (Maggesi-Stagni).

the atomic weights and the latter is used to determine the maximum valence by means of the limit oxides.

In the so-called fourth edition (1920–21) of the Maggesi and Stagni notes (Figure 5), a special enphasis, in systematic, is devoted to Radium (isolated by Mme. Marie Curie in 1911), radiations and radioactive bodies (about 10 pages) and, in the general section, widely extended, to the periodic system and its evolution. The idea that the elements might be ordered according to atomic numbers (Figure 5), and the stratagem proposed to find a suitable place for the rare gases and the probability of the transformation of matter into energy are mentioned. Whenever equilibria are referred to, the fundamental contribution is indicated of Faustino Malaguti (1802–1878), who had found exile in France after the Bologna uprising of 1831 and became a professor and rector at Rennes [19]. It was Malaguti, according to Ciamician,who demonstrated the law of chemical equilibria with the reaction between calcium carbonate and potassium sulphate. The quotations of subsequent contributions go from Guldberg and Waage (1867) to Robert Henry Thurson (1869), and Berthelot and Pean de Saint Gilles (1873) and end with Ostwald (1876). Plenty of space is also dedicated to the osmotic theory of electrochemical cells (Nernst's law, 1889). The systematic part is developed using the same criteria seen previously. Other differences between the two editions include: the rounding off of atomic weights and molecular weights, sketches of appliances omitted and replaced by the description, more historical details.

It may also be interesting to compare the above notes with Ciamician's "Lessons of General Chemistry" reconstructed by Dr. Bruno Ghetti, pupil of Ciamician, from Bagnacavallo (Ravenna), graduated July 7, 1922; the book was published by Zanichelli in Bologna in 1924, with the authoritative introduction of Nasini and Padoa [20]. The content comprises twenty lectures, each one dated, and covers the period from November 9 to 1 March 1, 1921. They are more concise than the notes, but almost fully reflect the latter's contents. The first note should be recalled at the foot of the page, where Ghetti points out that professor Ciamician, in the introductory lecture to his last course, announced as theorem the atomic constitution of matter, drawing from this the laws of combinations. He did in fact believe that atomic reality had by then been demonstrated by the experiences of Laue and Bragg. Other problems, as can be read in the last lesson, remained open, including that of affinity. It must be said however that the studies on radioactive bodies, which demonstrated that atoms could be split and that they had an internal structure, made it possible to hope that one day, after becoming better acquainted with this, a solution would be found. This is what Ciamician said in his lecture dated March 1, 1921. Soon, very soon, his efforts to keep in touch, as Nasini wrote, "with all new thoughts and writings", would no longer be necessary[20].

Acknowledgments. A shortened version of this paper was read at the Symposium of the Commission on the History of Modern Chemistry (Paris 21–24 June 2011) and appeared in Italian in "*La Chimica e l'Industria*", the official organ of Italian Chemical Society in April 2012. I get permission to reproduce part of published material from the Editor in Chief (Prof. Ferruccio Trifirò) and Managing Editor (Dr. Anna Simonini). Basoli's view of Bologna (Figure 2) belongs to the collection of Dr. Tiziano Costa.

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