

procede na base da Análise e da Síntese, decompondo os corpos em seus princípios, e tentando reproduzi-los a partir dos princípios encontrados na decomposição, natural lhe parecia que também a linguagem adoptada nesta ciência se acomodasse com a mesma metodologia, de tal modo que a simples pronúncia do nome indicasse as componentes do composto: "os Saes compostos, ou neutros tem os seus nomes geraes terminados em *atos*, ou em *itos*, como *nitratos*, e *nitritos*; no primeiro caso quando a base do accido he saturada de oxyginio; e no segundo quando a mesma base não he saturada. A especie do Sal he determinada pelo nome da base, que se lhe ajunta, como por exemplo *nitrato de potassa*, *de soda*, *calcareo*, etc., ou *nitrito de potassa*, *de soda*, *calcareo*, etc., conforme o acido he, ou não, saturado de oxyginio. A respeito do mais não he preciso advertência alguma; o próprio nome diz tudo"³⁰. E diz tudo precisamente por tentar reproduzir directamente os resultados da observação.

Também no carácter experimental da química, fundamenta Vicente de Seabra as duas Classes de corpos que considera na descrição das propriedades dos mesmos, pondo de lado "a tradicional divisão do Imperio da Natureza considerada pela Historia Natural". Afastando-se do esquema geral do *Tratado Elementar de Química* de Lavoisier³¹ (que ainda não fora publicado quando Seabra apresentou o primeiro volume do seu próprio Tratado, em que a adopção da referida divisão é apresentada e justificada), Seabra não analisa as propriedades dos corpos distribuindo-os pelos três Reinos *Mineral* (desorganizado), *Vegetal* (organizado, insensível e sem movimento livre) e *Animal* (organizado, sensível e com movimento livre), pois "nos tres Reinos se achão substancias dotadas das mesmas propriedades", mas distribuindo-os antes por duas Classes dicitómicas, a dos *Corpos Incombustíveis* e a dos *Corpos Combustíveis*, compreendendo a primeira três Ordens, a saber, a *Terra*, *Substancias Salino-térras* e *Saes*; e a segunda, apenas duas

Ordens, a dos *Corpos Combustíveis por si mesmos* e a dos *Corpos Combustíveis não por si*³².

No exame prático que apresenta compreendendo os diversos corpos de qualquer das duas Classes que adoptou, a metodologia é sempre a mesma: (i) descrição das suas propriedades características decorrentes duma observação directa de laboratório; (ii) descrição do seu comportamento reactivo na presença de outros corpos ou sob a acção de quaisquer agentes químicos, também ela decorrente duma observação directa de laboratório; (iii) a racionalização do comportamento observado, em termos dos princípios químicos então aceites, nomeadamente em termos das afinidades químicas determinantes do diferente estado de equilíbrio entre corpos capazes de se combinarem entre si; e em termos dos princípios fundamentais a que Lavoisier recorreu para explicar os diversos fenómenos de calcinação, combustão e redução.

Numas e noutros se consubstancia "a tendência à combinação com o princípio que lhes falta"³³. Umas e outros, são as duas grandes traves mestras em que se alicerça toda a teoria que enforma o seu Tratado, ambas suportadas pelas propriedades observadas para que se procura uma explicação racional generalizante, e para a mesma substancialmente orientadas.

4. CONCLUSÃO

Dissemos que, em termos do empirismo racional de Francisco Bacon "toda a ciência se constroí sobre os resultados da experiência"; e mostrámos que os *Elementos de Química* de Vicente Coelho de Seabra, no século XVIII, se conformam com este princípio. Dissemos ainda que neste trabalho não era nossa intenção entrar nos pormenores da problemática filosófica da interrelação da prática com a teoria na construção das ciências ditas experimentais.

Apontando a consistência filosófica dos *Elementos de Química* de Vicente de Seabra com a metodologia científica do seu tempo, gostaríamos

de salientar, todavia, em termos de conclusão, que muito embora as leis naturais na sua formulação geral não sejam meramente os resultados observados directamente, pois que generalizando os ultrapassam, o referencial do conhecimento sistemático das ciências da natureza é sempre a experiência, não importa se como fonte em que foi bebido, architectado e construído, se como teste em que foi creditado.

Permitimo-nos, pois, concluir com uma citação de De Broglie salientando isso mesmo: "si tranchée que paraisse à première vue la distinction entre la découverte expérimentale et l'invention théorique, une étude plus attentive ne tarde pas à atténuer considérablement, car elle montre que la découverte des faits expérimentaux, du moins dans la science actuelle, est à bien des égards une invention, tandis que l'invention théorique est en quelque mesure une découverte"³⁴.

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NOTAS

¹ J. R. d'Alembert, *Encyclopédie ou Dictionnaire Raisonné des Sciences, des Arts, des Métiers* (Lucques, Paris, 1758-1776).

² Este empirismo nasceu duma oposição frontal ao dedutivismo aristotélico. O seu lugar de destaque no desenvolvimento da ciência moderna não significa, todavia, que a atitude aristotélica tenha sido posta de parte, por completo, ou tenha perdido de todo o seu sentido. Recorde-se, a título de exemplo, a polémica de que se fez eco, já no nosso século, a revista *Nature* a propósito de *Modern Aristotelianism* (*Nature*, vol. 139 (1937), pp. 997-1021), ou então, as palavras do consagrado cientista que foi A. Eddington: "não há nada em todo o sistema das leis da Física que não possa ser deduzido sem qualquer ambiguidade a partir de considerações epistemológicas (...) Uma inteligência familiarizada com o nosso Universo deveria ser capaz de conseguir todo o conhecimento da Física que nós atingimos por experimentação" (A. Eddington, *Relativity Theory of Protons and Electrons*, 1936, p. 327).

³ A. M. Amorim da Costa, *Química, Uma ciência experimental? Aspectos históricos do Empirismo Racional in Problemas da Filosofia Química Contemporânea* (Coimbra, Coimbra Editora, 1988), pp. 103-115.

⁴ *Estatutos Pombalinos da Universidade de Coimbra*, Liv. III, Pt.III, Tit.II, cp. II, 6

⁵ *Idem*, Liv.III, Pt.III, Tit. III, cp. IV, 1-13.

⁶ Joan. Ant. Scopoli, *Fundamenta Chemiae - Praelectionibus Publicis Accomodata* (Praga, Apud Wolggangum Gerlb, 1777).

⁷ Jac. Reinboldi Spielmann, *Institutiones Chemiae - Praelectionibus Academicis Adcommodatae* (Argentorati, Ed. Joannem Godofredum Bauerum, 1766).

⁸ Carta de 12 de Fevereiro de 1773 do Marquês de Pombal ao reitor-reformador in *Colecção Geral das Ordens*, fl. 92.

⁹ J. A. Simões de Carvalho, *Memória da Faculdade de Filosofia* (Coimbra, Imprensa da Universidade, 1872), pg. 282.

¹⁰ *Idem*, pg. 285.

¹¹ Heinrich Friedrich Link, *Voyage en Portugal depuis 1797 jusqu'en 1799* (Paris, Levraut, Schoell et C.ie Lib.), Tom. I, pg. 393.

¹² Morveau, *Tractado das Affinidades Chimicas* (Coimbra, Real Imprensa da Universidade, 1793).

¹³ *Idem*, pg. V.

¹⁴ Thomé Rodrigues Sobral, *Jornal de Coimbra*, Vol. VII (1814), Part. I, pg. 286; *idem*, Vol. IX (1816), Part. I, pg. 305.

¹⁵ Vicente Coelho da Silva Seabra e Telles, *Dissertação sobre a Fermentação em Geral e suas Espécies* (Coimbra, Real Imprensa da Universidade, 1787).

¹⁶ Vicente Coelho da Silva e Seabra, *Dissertação sobre o Calor* (Coimbra, Imprensa Real da Universidade, 1788).

¹⁷ Vicente Coelho de Seabra, *Elementos de Chimica* (Coimbra, Real Officina da Universidade, Part.I - 1788; Part. II - 1790).

¹⁸ Vicente Coelho de Seabra, *Memória sobre os Prejuizos causados pelas sepulturas dos cadáveres nos templos e métodos de os prevenir* (Lisboa, José Mariano Velloso, 1800).

¹⁹ Vicente Coelho de Seabra, *Nomenclatura Chimica Portuguesa, Franceza e Latina* (Lisboa, Off. da Casa Literária do Arco do Cego, 1801).

²⁰ Vicente Coelho de Seabra, *Elementos de Chimica, Part.I*, pp. 2-9.

²¹ *Idem*, Part. I., pp. 9-10.

²² *Idem*, Part I, p. VI.

²³ *Idem*, Part.I, p.VII.

²⁴ *Idem*, Part.I, p.VI.

²⁵ *Idem*, Part. I, p.VIII.

²⁶ *Idem*, Part. I, p. IX.

²⁷ *Idem*, Part. I, p.9.

²⁸ *Idem*, Part. I, p. 10.

²⁹ *Idem*, Part. I, pp. 55-56.

³⁰ *Idem*, Part.I, pp. 56-57.

³¹ A. L. Lavoisier, *Traité Élémentaire de Chimie* (Paris, 1789).

³² Vicente Coelho de Seabra, *Elementos de Chimica, Part. I*, p. 57.

³³ *Idem*, Part. I, p. 52.

³⁴ Cit. in H. Margeneau, *The Nature of Physical Reality - A Philosophy of Modern Physics* (N. Y., McGrawHill Book C.ie, 1950), p. 99.



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University Education of Chemists in Portugal

I. EDUCATION AND TRAINING

1.1. Access to Higher Education (University and Polytechnic)

Eligibility to apply for a place at an establishment of higher education depends on students having completed 12 years schooling (in principle from the ages of 6 to 18 years).

Access to higher education is limited, being conditioned by the existence of a *numerus clausus*, proposed annually by individual higher education establishments, for each of the degree courses administered by them. This proposal has to be approved afterwards by the Ministry of Education.

The candidate can indicate, by order of preference, up to a maximum of 6 combinations of higher education institutions and courses. Selection is centralised by the Ministry of Education, using a judicious formula, which takes into account the following parameters:

i) the marks of the last two years of secondary schooling.

ii) the marks of national entrance exams taken in one or two disciplines, which aim at correcting the divergencies in standards of the classifications given by the different secondary schools.

iii) the marks of yet another national entrance exam in two disciplines chosen by each establishment of higher education for admittance to each course. In the case of Chemistry, one of these disciplines is Mathematics and the other is, in general, Chemistry, although, in some exceptional cases it can be Physics.

The classifications obtained in the exams referred to in i) and ii) do not eliminate candidates, serving only to order them. Thus a student with good marks in i) who in ii) and iii) receives 0, or thereabouts (on a scale of 0 to 20, the same scale that is used for classification in the first degree both of the universities and polytechnics), still has a chance of entering higher education.

This system of access has the following consequences:

i) Only about 50% of candidates succeed in getting a place in one of the 13 state universities - including the Open University. (It should be emphasized that, in the last few years, there has been a great explosion of private universities, where, however, courses which involve an experimental component - like Chemistry - are virtually non-existent).

ii) In the case of combinations of degree course/higher education establishment which enjoy great national prestige, the majority of students admitted are those that chose such a combination as their first option.

iii) In the case of less prestigious combinations it is common to find that a percentage of the students admitted put that combination in 2nd, 3rd, 4th, 5th or 6th option. For example, a student who put as his or her 1st option, the degree course in Medicine at Coimbra university, putting as 2nd option, Chemical Engineering at Oporto, could end up by being placed in the Chemistry degree course at the University of Lisbon. As is evident, such a student would not feel very motivated.

iv) Since the polytechnics enjoy much less social prestige than the universities, it is a general rule that students who are placed in the polytechnics are those who did not succeed in getting a sufficiently high classification to enter university.

1.2. The Teaching of Chemistry at University Level

1.2.1. General Education (undergraduate level)

Degree courses in Chemistry exist in 9 of the 13 Portuguese state universities (see annex 1). Typically, these universities organize three kinds of Chemistry courses:

i) Chemistry courses in which Chemistry as science is the central objective. In some universities this course is referred to as "Chemistry -

scientific branch".

ii) Chemistry courses which include pedagogical content, intended to train teachers for secondary schools. In some universities this kind of Chemistry course is given together with a Physics course, and can include some specialisation in the final years of the course. In general, these courses are known as the "educational branch" of the Chemistry course, or Physics and Chemistry course.

iii) Chemistry courses with some industrial component, which, in general, are designated as Applied Chemistry, or Technological Chemistry.

Some universities only give one of these three variations (in general, the "educational branch") and some universities administer all of them.

An analysis of the teaching of Chemical Engineering in Portugal falls outside the scope of this report. In most Portuguese universities the teaching of Chemical Engineering is done according to what is customarily referred to as the "anglo-saxon" system. It should however be emphasized that the Chemical Engineering course administered by the Instituto Superior Técnico of the Universidade Técnica de Lisboa includes, for historical reasons, a variation called Chemical Engineering/Applied Chemistry, in which the Chemistry component is similar to that of the various degree courses in Chemistry in type iii), mentioned above.

The Portuguese education system grants wide liberty to the universities in organising degree courses (especially after the approval of a new law of University Autonomy in 1988). Consequently, existing university courses are far from uniform, in relation both to their curricula and duration - which can be 4 or 5 years (although the majority of students take longer to finish). The organization of the academic year also varies, although the semester system predominates. While some courses include industrial training, which can take up to a year, others do not. The "educational

branch" normally includes a 5th year in which the student begins to teach in a secondary school, supervised by the university teaching staff responsible for the course. As for systems of assessment, the diversity is total, not only among, but even within, different universities. Apart from some very general indications drawn up by a Pedagogical Council (on which students are represented), each member of the teaching staff is more or less free to establish the model of assessment in his or her discipline. Statistically, the written exam predominates, with some teachers demanding, in addition, an oral exam in order to clarify the mark in borderline cases. Some teachers also use the system of continuous evaluation, sometimes accompanied by a written final exam.

The diversity noted above prevents the presentation of a uniform curriculum for the teaching of Chemistry at university level. We therefore present, as an example, the structure of the Chemistry degree at the university of Coimbra, one of the universities which administers all of the three course variations noted above.

a. *Licenciatura* in Chemistry - Scientific branch

Duration: 4 years

Number of credit units required: 120

Distribution of credit units by scientific area:

Mathematics	16
Physical Chemistry	12
Physics	12
Others	5
Chemistry	75

The 75 credit units of Chemistry include 20 in disciplines chosen by the student, 12 in practical scientific training and 43 in fixed, obligatory disciplines covering fundamental areas of Chemistry.

b. *Licenciatura* in Chemistry - Education branch

Duration: 5 years

Number of required credits: 120

The 5th year is dedicated to professional pedagogical practice and training.

Distribution of credit units:

Mathematics	16
Physical Chemistry	9
Physics	16
Education Science	30
Chemistry	49

c. *Licenciatura* in Industrial Chemistry

Duration: 4 years

Number of credits required: 121

Distribution of credit units by scientific area:

Mathematics	16
Physical Chemistry	6
Physics	9
Chemical Technology	25
Chemistry	63
Economics	2

Merely in order to give an example of the aforementioned lack of uniformity, the *Licenciatura* in Technological Chemistry at Lisbon University lasts for 5 years, the final year comprising a period of practical training in Industry.

(see annex 2)

1.3. The Teaching of Chemistry at Polytechnic Level

Polytechnic education represents one of two sides of Portuguese higher education and has been declared a priority by the Portuguese government. Characteristically, it has a strong regional component. There are about 20 Polytechnic Institutes in Portugal. They confer the degree of Bachelor after a course lasting three years, although the law allows them to prolong their programmes of study for two further years, in order to confer a diploma of more advanced studies, corresponding, for

practical purposes, to the *licenciatura* conferred by the universities. It is curious to note that within the 300 combinations of course/teaching establishment offered by higher polytechnic education, only one is explicitly referred to as Chemistry (Industrial Ceramics), administered by the university of Aveiro, and three as Chemical Engineering.

Despite the official political discourse concerning the necessity of and support for higher polytechnic education, it continues to be a fact that, for traditional cultural reasons, this kind of course carries little prestige and, in general, recruits as students those candidates who failed to obtain a place at university.

1.4. Graduate Studies

1.4.1 M.Sc Degree

The degree of Master was created in Portugal by the Ministry of Education in 1980, the legislation being revised in 1992. In accordance with the 1980 legislation, the maximum duration of a Master's degree was 4 years. The Master's degrees in the area of Chemistry were typically 3 years: a year of lectures and a maximum of 2 years to complete the research work and write a thesis. The year of lectures was, in general, divided into 2 semestres and the various disciplines were given in parallel in each semestre. In some cases, disciplines were given in blocks of lectures, especially when delivered by foreign professors invited to come to Portugal for that purpose. The assessment of this so-called "school part" of the Master's degree was done through exams which took place at the end of each semestre or at the end of each lecture block, according to the respective organization. Approval in all the exams was an indispensable condition of beginning research work. The thesis presented at the end was examined publicly by a jury and the final classification, if the thesis was approved, was "Good" or "Very Good".

The legislation of 1992 introdu-

ced some important alterations in this regime. One very significant change was the reduction of the maximum duration of the Master's degree (including "school part", research and thesis) to 2 years. The other important change was that this legislation emanating from the Ministry of Education only established very general principles regulating the Master's degree, leaving more detailed regulation to the universities, which, in turn, leave more detailed definition to the competence of each faculty within the same university.

The acceptance of a candidate for a Master's degree course is conditioned, in principle, by the obtention of minimum final classification of 14 marks (on a scale of 0 to 20) in the licenciatura. It is however possible to accept candidates with an inferior classification on the basis of a favourable report by those responsible for organising the course.

(see annex 3)

1.4.2. Ph.D. (Doctorate)

The following can be accepted as students for doctorates:

- i) university graduates with a minimum final classification of 16
- ii) university graduates with a minimum final classification of 14, who have already obtained a Master's degree
- iii) university graduates with other final classifications whose intellectual capacity is guaranteed by their *curriculum vitae*

Work for the doctorate is based essentially on the elaboration of a thesis based on original research, only very rarely including the obligatory attendance of lectures. When completed, the thesis is examined publicly by a jury appointed for the purpose. If the candidate is approved the final classification has two grades "Distinction" (Distinção) and "Distinction Cum Laude" (Distinção e Louvor). In principle there is no maximum time limit for comple-

tion of the doctorate. This is, rather, conditioned by the length of time during which financial support is available. Until a few years ago the overwhelming majority of doctoral students already had contracts as teaching assistants at university. In such cases, the continuation of the contract depends on defending the thesis within six years of obtaining the contract, a period which can be extended by two years, habitually granted. The percentage of doctoral students without a university job, whose doctoral research was subsidised by a student grant used to be very small. This percentage has substantially risen in the last four years, mainly due to a policy directed at the formation of human resources financed by programmes involving a strong co-participation of funds from the European Community. The length of these student grants is 3 years, with the possibility of being prolonged for a further year.

As was already mentioned in the case of the Master's degree, the new legislation issued by the Ministry of Education in 1992, besides establishing very general principles for the doctorate, leaves the universities and, in the second instance, the various faculties within each university, free to regulate the process of admission and organization of the examination of the thesis. For instance, some universities opted for just one grade instead of the previous two.

The Portuguese system incorporates two, relatively specific situations, which perhaps deserve reference here:

- i) Once a teaching assistant in a given faculty has successfully defended his doctoral thesis within the period of time defined above he/she has the right to be automatically re-contracted as assistant professor in that faculty.
- ii) Although the first doctorates obtained on the basis of student grants (i.e. by people who do not have contracts as teaching assistants) are only now starting appearing and

although, also, this number is still relatively small, there is no evident inclination, on the part of the Portuguese Chemical Industry, to recruit professionals with this qualification. The same is actually true for people with M.Sc. degrees.

(see annex 4)

1.4.3 Other Studies

Four years ago, a programme was initiated, also with the strong co-participation of funds from the European Community, to develop Portuguese Industry (PEDIP). In the area of this programme there exists the possibility - which has been much taken advantage of - to finance the work of young graduates in a university research group during a period of 2 years (without writing a final thesis), with the intention of preparing them to work in Industry. In the new version of PEDIP, which has just been approved, the involvement of Industry in this process has to be greater than it has hitherto been. It is now necessary for the candidate to have been working in Industry and a letter from Industry manifesting, in principle, an interest in the kind of formation proposed is considered insufficient to obtain finance for research.

1.5. Acceptance by the profession

In Portugal there is no professional association which registers Chemists, at any level of study (*bacharelato*, *licenciatura*, Master's degree or doctorate). The national scientific association (Sociedade Portuguesa de Química) has always been a scientific society and has no powers in any professional area. Under these conditions, all Chemists with the same academic qualification are subject to the same market conditions, the choice being that of the employer. As was already mentioned, employers in Chemical and other related industries show little willingness to recruit people with either Master's