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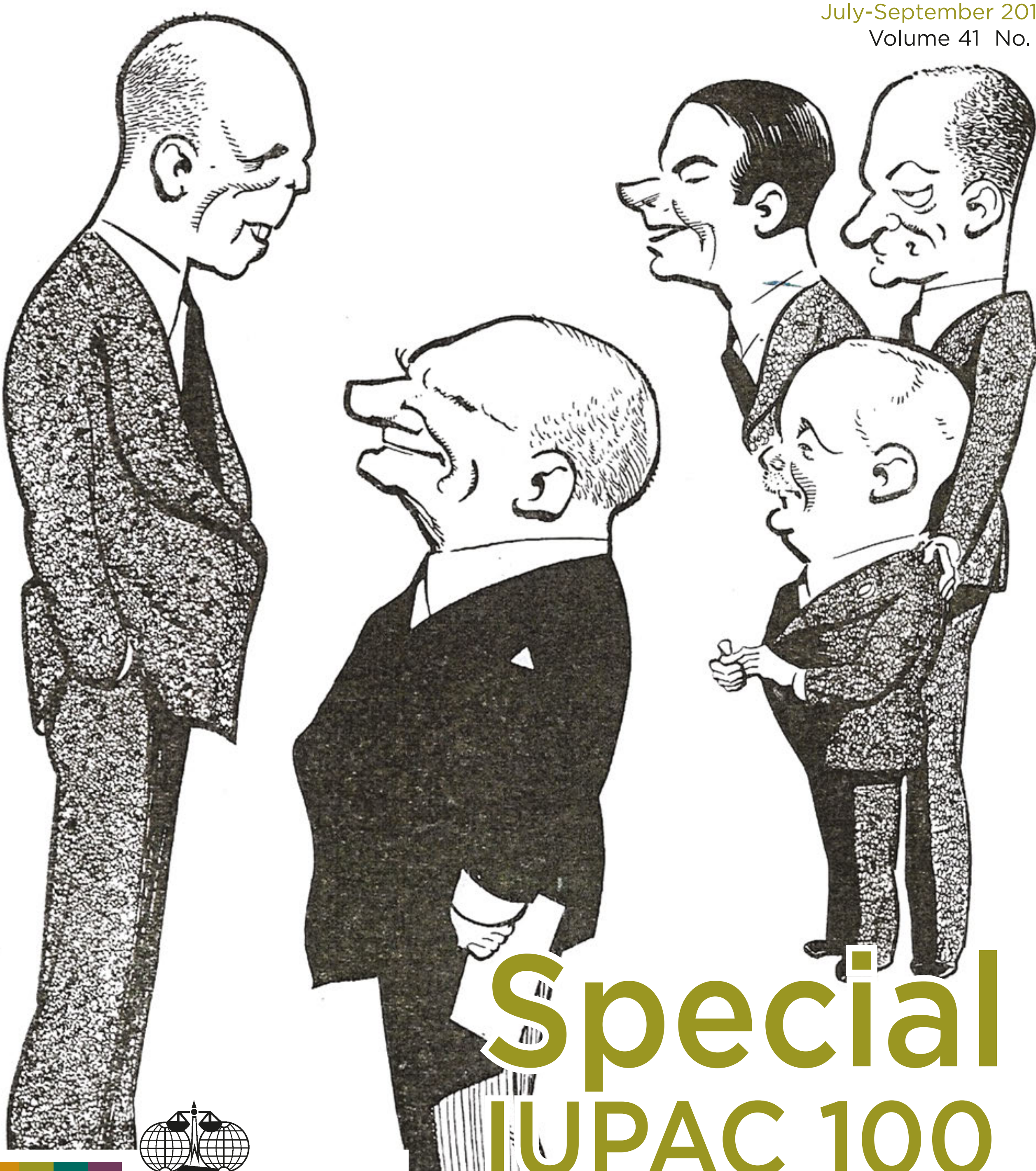

Special IUPAC 100

A Glance at The Union History

INTERNATIONAL UNION OF
PURE AND APPLIED CHEMISTRY

CHEMISTRY International

The News Magazine of the International Union of Pure and Applied Chemistry (IUPAC)

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Front Cover: **Luncheon by The Society of Chemical Industry to the XIth International Congress of Pure and Applied Chemistry at the Mayfair Hotel, London, July 18, 1947. Some impressions by Fred May. See more on page 20.**

Special IUPAC100

We embarked on the adventure of researching IUPAC's history a few years ago, inspired by the looming IUPAC 100 anniversary in 2019 and the desire of the French National Committee to host that year's Congress and General Assembly in Paris. The proposal to host the fiftieth IUPAC General Assembly and forty-seventh Congress in Paris was received and approved by IUPAC Council during its assembly in 2013. Soon after, Jean-Pierre Vairon, a member of the organizing committee of the IUPAC 2019 Congress, contacted Danielle Fauque, and together we started to think about special symposia devoted to the history of IUPAC. At the Congress in 2015 in Busan, Korea, the idea was met with enthusiasm and interest from Natalia Tarasova, then president of the Union, and the project of this special issue was formed with Fabienne Meyers, Chemistry International editor. We also met with Christopher Brett later that year to speak about this project.

The well-known *History of IUPAC* by Roger Fennell and its sequel by Stanley Brown sketch the inner workings of IUPAC's structure, and provide a first basis for historical exploration. IUPAC also published many printed documents over its years of existence as "color books," articles in *Pure and Applied Chemistry*, and diverse reports and proceedings including *CI*. Amazingly, it's hard to get a hold of complete sets of these kinds of publications, even though they were printed and distributed in large numbers. This "grey literature" had to be assembled piece by piece. The IUPAC archives kept at the Science History Institute were crucial to getting closer to decision processes and to the core of the discussions involved.

What we discovered through the process is the difficulty in approaching the history of such a delocalized, multinational, and multilayered organization, which is in itself a world with many inhabitants and cultures. As such, and with the present knowledge of the historical documentation at hand, it's a challenge to speak of IUPAC as a cohesive body and to describe its actions and impact. At the core, these actions are, of course, made by men—and more recently also a few women—but while a narrative centered on individuals provides trajectories and explains the fine structure of negotiations before decisions and recommendations, such a narrative is not enough. Another approach would be to simply list the decisions, but then one misses the mediation and the interplay inside and outside of IUPAC—outside because IUPAC is far from alone on the international playground. As working groups, the commissions could also provide coherent objects for a series of dedicated histories, and we hope that someone will take on such research.

As to the present publication, we have chosen a mixed approach, giving a survey that includes persons, topics, and achievements, and putting them in the context of the challenges of the times in which they existed. The results shared in this special issue are but a milestone in a longer research described in the epilogue (p. 58).

As we were working on the history of IUPAC through several workshops and panels over the last two years, we were fortunate to find historians whose interest and research crossed paths with

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the international organization of scientific work. Some of them have authored a piece in this issue. At the workshop held in Paris in November 2018, the time was ripe to share perspectives with actors who witnessed and participated in IUPAC's actions over the last decades. We want to acknowledge Maurice Chastrette, Yves Jeannin, Jeff Leigh, Roberto Marquardt, and Nicole Moreau, as well as others who could not be present in person but shared their experiences and memories with us by other means: Ted Becker, James Bull, Michael Freemantle, and John Malin.

A special thanks to Yves Jeannin, who dug into his photo albums and helped us to identify people in several older photographs. Last but not least, we want to express our thanks to Fabienne Meyers, who has accompanied us since the project of this special issue to celebrate the 100th anniversary of IUPAC emerged. Over the last year, we have benefitted from her advice and thoughtful remarks, and she was also of crucial help connecting us with many present and former IUPAC active officers and members. She has shepherded the special issue with care, creativity, and imagination.

Brigitte Van Tiggelen, Special issue editor

1919-1939: The First Life of the Union

by Danielle Fauque

In April 1919, delegates of five allied nations gathered in Paris, at the initiative of *the Société de Chimie Industrielle* (SCI-F) and the French Federation of Chemical Associations (FNAC) to decide on the creation of an interallied confederation for pure and applied chemistry. The delegates were following up on a proposal made by the Interallied Conference of Scientific Academies that had met in London and Paris in 1918. Each country was asked to create a national body in each discipline, and these entities would be united into a Union, at first an interallied then international union when the wounds of war healed. The whole structure was to be headed by an International Research Council (IRC) [1].

An international organization devoted to pure chemistry had been created before the First World War, the International Association of Chemical Societies (IACS) [2]. Nothing of this kind existed for applied chemistry [3]. The Society of Chemical Industry (SCI-UK) and its French counterpart, *the Société de chimie industrielle* (SCI-F) both supported an endeavor that would coordinate all aspects of chemistry. Indeed, this had been the topic of informal discussions, during a SCI meeting held in London in November 1918 attended by Paul Kestner (1864-1936), the founding president of the SCI-F. He was an assiduous member of the SCI-UK, and a close friend of its president Henry Louis (c.1856-1939) [4].

The two men were eager to continue into peacetime the fruitful exchanges between the sister societies that had been initiated during the war. The SCI-UK had also fostered the creation of the British Federal Council for Chemistry chaired by Sir William J. Pope. The example of these two societies was followed by American chemists affiliated with the American Chemical Society (ACS). By March, a Belgian national committee had been created and the founding of an Italian committee was underway.

In Paris, on 14 April 1919, 49 chemists coming from these five countries approved the creation of an interallied confederation for pure and applied chemistry [5]. They stated the principles for the statutes, and a special commission chaired by Charles Moureu (1863-1929), was set-up to write them. The morning after, the statutes were discussed and approved. Moureu, president of the FNAC, was elected president of the confederation, on the proposal of William J. Pope (1870-1939). Pope was at that time vice-president of the SCI-UK and president of the Chemical Society—he was later to play an important role in the Union.

The second interallied conference was hosted by the SCI-UK in London, during the SCI-UK annual meeting from July 14 to 18. The statutes were once again discussed, taking into account several proposals made by American chemists. A delegation led by Moureu travelled from London to Brussels on 18 July to submit the application of the chemistry confederation to the IRC [5, p. 128, n. 60].

The third interallied conference of scientific academies took place between 18 and 28 July in the *Palais des Académies* in Brussels that had been restored after the depredation incurred during the war. The

Attendees of the 1st Interallied conference held in Paris on 14 April 1919 *(reprint from Chimie & Industrie, Vol. 2, No. 5, p. 501, May 1919).* ***Pope and Moureu are 3rd and 4th sitting from the left; standing on the far left is Jean Gérard.***

dissolution of all international organizations existing before the war was confirmed, and all the new unions established without the Central Powers would be put under the IRC authority.

On 22 July, the confederation became a Union. After having pronounced the termination of the IACS by a majority of societies from allied and neutral countries, its president Albin Haller (1849-1925) gave its seat to Charles Moureu, signifying that the Union was to replace the IACS, even though structure and aims were different as noted above [5, p. 129-130]. Two days after, the executive committee of the IRC agreed on the statutes, and on 28 July, the International Union of Pure and Applied Chemistry was accepted as a member of the IRC, along with the International Astronomical Union (IAU), the International Union of Geodesy and Geophysics (IUGG) and the International Union of Radio Science (URSI).

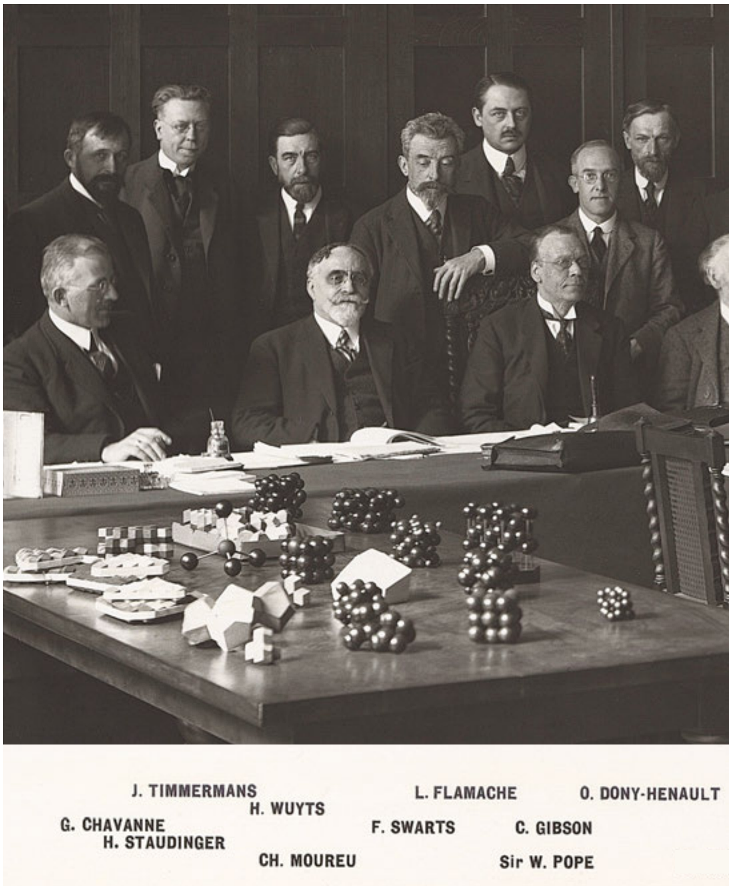
Created on paper on 28 July 1919, IUPAC needed to materialize. The first years were devoted to defining the international perspective and the next courses of action. All the while, difficulties emerged due both to individual trajectories and geopolitical evolution.

Finding its feet: The Union between 1919 and 1925

While the founders themselves refer to the International Association of Chemical Societies (IACS) as the Union forerunner [2], IUPAC was in fact an entirely new entity, in its conception and extent. In particular, the IACS was a federation of chemical societies, chosen as national representatives of the respective communities, whereas the Union is constituted of national adhering organisms, represented by a national committee, a science academy, a national federation, or even sometimes the government. Furthermore, the IACS focused on pure chemistry while the Union aimed at representing chemistry in all its dimensions.

Chemists, either academic or industrial, had united in the war effort and discovered the mutual benefit their collaboration could bring in times of peace. The necessity of a rational, scientific, and technical reorganization of the afterwar world became a discussion to which governments lent a watchful ear. More than ever, chemistry presented itself as unique, being both a science and an industry, pure and applied. It was thus pressing to establish the regulation of the Union, and install the first commissions for the most urgent questions.

Apart from the successive presidents in the first 20 years of the Union, all deeply involved in the development of IUPAC, one man was key: the young secretary general, Jean Gérard (1891-1956) who was



Eminent chemists -some closely related to IUPAC- meeting in Brussels in April 1925 for the 2nd 'conseil de Chimie' of the Solvay International Institute.

Source: La Digithèque <http://ladigitheque.ulb.ac.be/items/show/999>.

only 28 as he started his term. He proved to be an exceptional organizer and administrator. The Union was physically based in a business district of Paris, in the headquarters of the *Société de Chimie Industrielle* and the French national federation adhering to the Union, both of which Jean Gérard was also secretary general. These circumstances offered a permanent secretariat to the new Union that allowed it to function as a corporate enterprise in the interwar period.

The other members of this first Bureau consisted of the president, Charles Moureu (France), and the vice-presidents representing the founding nations, among which Sir William J. Pope (UK) who would become the second president. According to the statutes, the Union was to act through a Council supported by an administrative secretariat and the *Office international de Chimie* (a kind of international agency for chemistry) (art.3). In addition to the Council, which consisted of the Bureau and the delegates of the

Moureu
1st ICC,
Rome

2nd ICC, Brussels

3rd ICC, Lyon

Pope
4th ICC,
Cambrigde

5th ICC, Copenhagen

1920 1921 1922 1923 1924

adhering nations (art. 6), an Advisory Council was instituted, gathering representatives from each branch of pure and applied chemistry (art. 11). French was the official language (art. 18) and the Council, the commissions and the delegates met during an annual conference, each year in a different country (art. 8).

In 1920, at the first international conference of chemistry (ICC, or CIC in French, equivalent to today's general assembly) in Rome, a proposal for a regulation was discussed, amended, and eventually adopted. This regulation clarified the management and operating of the *Office International de Chimie*, the permanent commissions, the Advisory Council and the conference. The *Office* would be in charge of organizing international congresses, as well as a basis for international chemical documentation (directories or important textbooks). The *Office* would be financed by national contributions independent from the Union's and prearranged by international convention [6, 7].

Once the regulation was established, a report on the former state of the Union was made to the assembly. It included the goal of standardizing chemical analysis; the creation of an Institute of chemical standards in Brussels (*Bureau des étalons chimiques*); the recapitulation of the International congresses of applied chemistry before the war; the issue of the use of sealed envelopes for patents; and last but not least, a report of the *International Commission on Atomic Weights*.

The next year in Brussels, the Union had progressed considerably on nomenclature and publication standards for chemical abstracts. The applied aspect of chemistry was also dealt with dynamically by the Union's activities: at the ICC in Lyon in 1922, technical commissions focused on food (bromatology), ceramic products, and combustibles, as well as industrial hygiene, and all remained active in the following years. But the autonomy in the composition and the management of commissions created instability, and for some of them, unproductivity. A stricter frame of reference was instituted in 1925 with the introduction of titular members, and each commission president was accountable to the Bureau. A better result would soon follow.

Through tensions and reforms: 1925-1930

Pope succeeded Moureu, but other founding nations had to wait longer to be represented in the presidency of the Union (Italy in 1934, USA in 1938, and Belgium in 1977). This was linked to tensions that forced the Union to evolve beyond the principles that formed the basis of its creation. Hereafter we detail what appeared to be the two most important issues: the German question and the holding of Congress.

The German Question

The embarrassing but haunting question was that of the return of Germany among the represented nations [1]. The question was discussed in all scientific unions; inside IUPAC, it was raised in particular by Dutch colleagues as early as 1922. Some days before the third ICC in Lyon in June, Ernst Cohen (1869-1944) invited the German chemists at Utrecht who were clearly contemplating joining the Union. At that time vice-president, Cohen's involvement became key as he was elected president in absentia at the sixth ICC in Bucharest in 1925; he initiated internal discussions on the German question as well as informal contacts with German chemists [8]. The last step was to convince the IRC to modify its statutes [1].

From then on, the Union established a more open correspondence with the German chemists, and the international celebration surrounding Marcellin Berthelot's centennial provided the opportunity for France to officially invite German and Austrian delegations to Paris in 1927 [9]. Exchange between chemical societies from France and Germany started again as if they had never been interrupted. At the ninth ICC in The Hague, in 1928, German chemists participated actively in the discussions.

The necessity of reforming the statutes had been put forward in Copenhagen in 1924, and the changes were accepted in The Hague in 1928. The conferences would from then on be biennial, and commissions that had accomplished their tasks were terminated. The regulation was deeply modified. The Advisory Council disappeared, and its job transferred to the future IX congress. With the Council, several technical commissions dealing with industrial products, including patents and industrial ceramics, also disappeared, as well as two commissions on combustible products. The commission for documentation had been ended in 1927; the *Office International de Chimie,* finally created in 1927, would continue its work [7].

The Union thus had a completely new face at the conference in Liège in 1930. The German delegation received a standing ovation from all the delegates. The session also started with a simple, yet significant, modification: a change of name [10]. The Union was now the International Union of Chemistry (IUC). At the core of its activities were nomenclature, atomic weights, radioactive constants, and thermochemical data. The *Bureau des étalons physico-chimiques* (Bureau for Physico-Chemical Standards) was confirmed and the affiliated commission

6th ICC, Bucharest
1925

Cohen
7th ICC,
Washington
1926

8th ICC, Warsaw
1927

9th ICC, The Hague
(change to biannual)
1928

Biilmann
10th ICC,
Liege
1930

of the *Tables of constants* remained attached to the Union. The "applied" component had disappeared from the structure though, and it was left to the Congress to carry that dimension of chemistry.

The problem with the Congress

According to Cohen, while the commissions were working productively, the dust was accumulating on their publications. It was thus necessary to reflect on connecting to the world at large, and revising the workings of the Union, which had been achieved with the reform of the statutes. The next issue was the holding of a congress. The Advisory Council had been asked to provide a recommendation, but in 1926, nothing had yet been decided, two years after this Advisory Council was terminated. Several groups demanded insistently that the IX congress be held as soon as possible (the XIII and former Congress took place in Washington in 1912). In Cohen's opinion, the prestige of the Union depended on it: *"*Coming events cast their shadows before them!" he said at the ICC meeting [11, p.11]

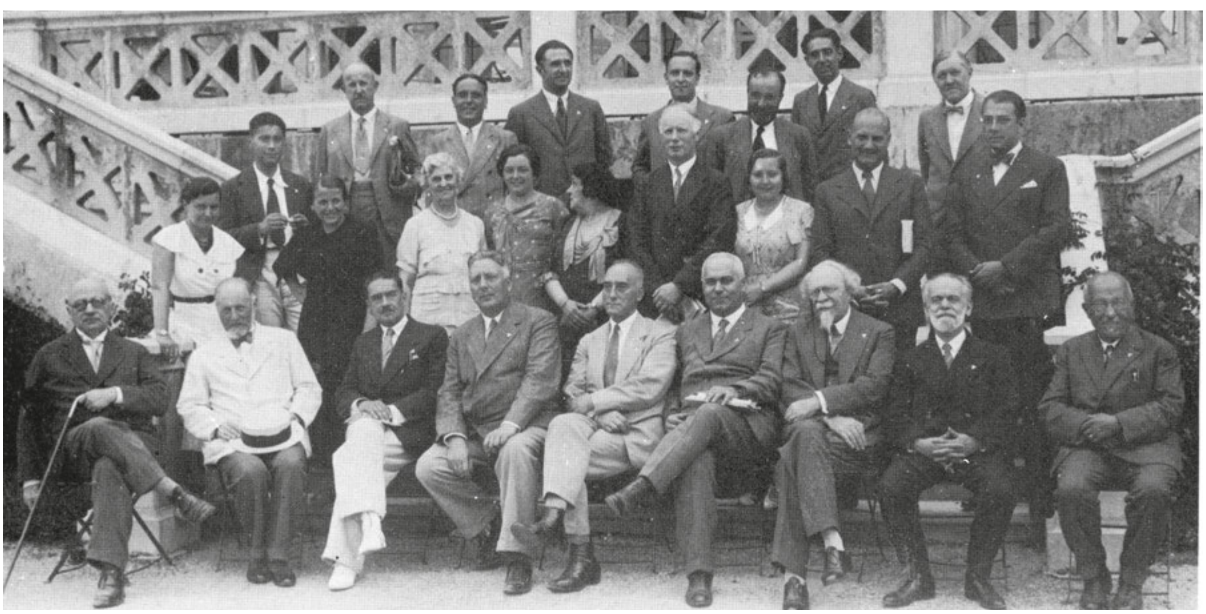
The Spanish proposal for hosting the 1932 Congress in Madrid was thus enthusiastically accepted. The minutes of the Liège ICC reveal a feeling of hope, and a breath of fresh air. Reconciled at last, all chemists were fully members of a truly international community. The nomination of Fritz Haber as vice-president was the most visible symbol of this new momentum.

Working through financial and political challenges 1930-1938

The 1930s are affected by the impact of the 1929 crash, and the competition of the Union with the International Institute for Intellectual Cooperation (IIIC) projects, but all the while, the commissions demonstrated a burst of productive activities.

The financial crisis

The 1929 financial crisis and its economical aftermaths reached Europe in the following years. Until mid-December 1931, the holding of a congress in 1932 seemed assured, but then the financial situation deteriorated in several countries. It became hard to acquire foreign currencies, and thus to travel, and the governments were no longer securing funding. Correspondence exchanged between members of the Bureau and Spanish colleagues display the worries of holding



During eleven days (from Wednesday 9th to Sunday 20th August 1933) a meeting to prepare the eleventh ICC (or General assembly) and the IX IUPAC Congress (Madrid, 5-11 April 1934) took place in the "Universidad Internacional de verano de Santander". The participants pictured in the front of The Magdalena were: (from left to right), seated: Fritz Haber (NP 1918), Richard Willstätter (NP 1915), Hans von Euler-Chelpin (NP 1929), Einar Biilmann (IUPAC President), E. Cohen, Nicola Parravano, Camille Matignon, E. Hauser, Fritz Fichter; first row: Mrs Cohen, Mrs Ribas, Mrs Seidel, Mrs del Campo, Mrs Calvet, George Barger, Mrs del Fesno, Jean Gérard (IUPAC Secretary General), Paulo E. de Berrédo Carneiro; second row: Fernando Calvet, Angel del Campo Cerdán, Augusto Pérez Vitoria, Enrique Moles, Carlos del Fresno, Antonio Madinaveitia, Ignacio Ribas, and Atherton Seidell. *(reproduced from Chem Int Nov-Dec 2008, ref. 13)*

a meeting to which few chemists had registered. At an extraordinary meeting of the Bureau and Spanish organizers, held in Paris on 22 January 1932, it was decided to adjourn the congress and the conference, and to ask for the full power of the Council to be transferred to the Bureau until the situation would allow for a plenary meeting of the Union [12, p. 11-12].

In summer 1933, the Spanish committee was allowed to commit to 1934, and a meeting was held in Santander (Spain) in August to prepare the congress [13]. Commissions were moving slowly, some of them even encountered problems. For instance the Commission for the Nomenclature of Biological Chemistry was in conflict with the Commission of Organic Chemistry. And the Inorganic Chemistry Commission had not been able to meet in Berlin as planned.

In fear of a massive devaluation, financial decisions were made to secure the Union's reserves [12, p. 19]. In April 1934 in Madrid, the Italian Nicola Parravano (1883-1938) succeeded the Dane Einar Biilmann (1873-1946), president since 1928. Switzerland hosted the conference in 1936, and while dues were still payed with delay, the financial situation was improving.

The question of scientific terminologies

A new tension had appeared as early as 1932 on the subject of scientific terminology. The IIIC connected to the International Committee for Intellectual Cooperation (ICIC), and thus to the League of Nations, insisted on taking charge of scientific terminology, its underlying methodology, and the accommodation to different languages. The Bureau of the Union sent observers to the meetings, but remained skeptical, and even opposed to the project of the IIIC. How would an international general organization pretend to achieve a consensus whereas specialists in each discipline had difficulty to reach an agreement? Also this incursion in what the Union considered to be its purview raised concerns in the Union, despite the necessity to adapt. A mode of collaboration was established in 1936, that protected the Union's authority, and the merging of the two commissions of physico-chemical symbols and terminology reinforced the liaison with IIIC [12, p. 14 and 14, p. 20].

The successes of the Union: the productive years 1930-1938

The scientific commissions—which had been reduced to 5 or 6 since the Liège Conference—worked more effectively. Publications followed at a regular pace between 1931 and 1938: *Tables annuelles des poids atomiques* (on annual tables of atomic weights), *Rapports sur les isotopes stables* (Report on the stable isotopes), *Etalons physico-chimiques organiques* (on organic physico-chemical standards), *Tableaux des réactifs pour l'analyse minérale* (on tables of reactants for mineral analysis). The latter publication, in three languages, was the first report of a new commission, created in 1934, *Réactions et réactifs analytiques nouveaux* (Reactions and new analytical reactants), a wish that the analytical section had expressed at the Madrid Congress.

This wasn't the only innovation elicited by the Congress, and it demonstrated that limiting the Union's activities to the scientific commissions was untenable. Several international organizations representing applied chemical activities requested the Union's approval of analytical methods, or specific nomenclature, and the Union could not refuse. This is how other commissions were created and international commissions affiliated, among others, one devoted to fats. Gathering a meeting under the auspices of the Union was a way to secure international authority.

The 1938 activity report appeared very encouraging, showcasing the achievements of a very successfully operating Union. In between conferences, commissions met, often at the new head office of the Union, located at the *Maison de la Chimie* managed by Jean Gérard, in Paris, since 1934 [7].

But shadows were on the horizon. In 1936, Austria had committed to host the fourteenth conference in 1940 [14, p. 30]. But in Rome, in May 1938, it became clear this was out of the question, after Austria had been annexed by Germany in March of that year. Both Germany and Great Britain volunteered, and the diplomatic resolution was to approve both invitations, with two successive meetings; one in London in spring 1941 and one in Berlin in the fall of 1942 [15]. During the Rome meeting, the Bureau elected its first American president, Marsten Taylor Bogert (1868-1954) for a 1938-1942 term. But his task was to be eventually achieved in the difficult time of the political turmoil that culminated with the outbreak of the Second World War.

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The International Research Council and Its Unions: 1919-1931

by Robert Fox

IUPAC was a product of a restructuring of world science that took place immediately after the Great War. In a series of three conferences in London, Paris, and Brussels between October 1918 and July 1919, delegations from twelve allied nations established a new body, the International Research Council (IRC), that was to control international relations in science through subsidiary unions for the various scientific disciplines until a review of the statutes planned for 1931. Four of these unions were established at the Brussels conference, among them IUPAC.

Both the IRC and the unions were profoundly marked by the guiding principle that the defeated Central Powers—Germany, Austria, Bulgaria, and what remained of the former Ottoman Empire—should have no place in the new structures. Scientists from those countries would be excluded from congresses, and even the use of the German language was to be forbidden. The exclusionist principle had its roots in early discussions in which the French, represented by the mathematician and secretary of the Académie des Sciences Emile Picard, had an especially powerful voice.

The solidarity that characterized the inter-allied conferences of 1918-19 came under strain from the moment the IRC cautiously opened its doors to countries that had taken no part, on either side, in the war. The Netherlands was one such country that joined the IRC and several of its unions, despite unease about the exclusion of colleagues from Germany and Austria with whom the Dutch had strong traditional links. The case of the Utrecht chemist Ernst Cohen brings out the dilemma of someone who served IUPAC loyally while also working for a relaxation of the IRC's ban on the former Central Powers, especially in his years as IUPAC president (1925-28) [1].

By 1923, cracks were showing even among those who had supported the decisions made in Brussels four years earlier. William Albert Noyes, a powerful figure in the American Chemical Society and a committed internationalist, represented a widely held American opinion that the time had come to admit German chemists to the IRC and IUPAC. The divisions put the IRC under intense pressure. Political pressures too played their part. Once the Locarno agreements of 1925 had opened the way to Franco-German reconciliation and the opening of the League of Nations to all countries, including the former Central Powers, the IRC had no choice but to review its statutes, as it did at a specially summoned general assembly in 1926. While membership of the IRC remained formally a condition for membership of a union, any nation that belonged to the League of Nations was now eligible for admission to the IRC and thereby to the unions.

CENTENAIRE DE L'INDÉPENDANCE DE LA BELGIQUE

PALAIS DE LA CHIMIE — EXPOSITION DE LIÉGE 1930

The question that remained was whether the newly eligible nations would choose to join the IRC. Germany did not. Nevertheless, through the later 1920s German scientists regularly attended congresses, despite the irregularity of their position. In IUPAC, as in other unions, the German presence grew, culminating in 1930, when Germany sent a large delegation to the IUPAC general assembly in Liège (Belgium). There, as had happened at the 1928 congress of the International Mathematical Union (IMU) in Bologna, the German delegation received a standing ovation. Even more pointedly, the assembly elected Fritz Haber, the pioneer of gas warfare, to a four-year term as vice-president, in the expectation that he would probably in due course become president (though, in the event, he died before such a term might have begun) [2].

In July 1930, with its authority terminally undermined, the IRC began the procedures that led, a year later, to its demise and replacement with a new International Council of Scientific Unions, ICSU. The transition was far more than an administrative adjustment. It marked the end of a venture in the centralized organization of scientific research and a decisive move towards a federation of autonomous disciplinary unions, the status that ICSU (now the International Science Council) retains in our own day.

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Ernst Cohen and the Challenge of a Truly International Union

by Jorrit P. Smit

In 1925, the Dutchman Ernst Julius Cohen (1869-1944) was unanimously elected president of the IUPAC (in absence) at the annual meeting in Bucharest. Although quite well known as able linguist, physical chemist and student of J.H. van 't Hoff, no one could have suspected this turn of events three years earlier. On 21 June 1922, Cohen had organized an informal, purely scientific meeting in Utrecht— the International Chemical Reunion Utrecht (ICRU)—to restore friendly relations between scientists from all previously warring nations. However, Belgian and French chemists, headed by Jean Timmermans and Charles Moureu, boycotted this meeting as they had not yet forgotten the atrocities of the 'chemists' war.' At the subsequent IUPAC meeting in Lyon (27 June - 1 July), Cohen, together with Hugo Kruyt, had to fend off harsh criticisms by their international colleagues [1].

Even though the ICRU was first perceived as a challenge to IUPAC, by 1925 Cohen presented the Utrecht reunion as stepping-stone towards his now established presidency [2]. The theme of reconstructing international relations in science ran through both activities: "Union is the strength of our Union," he exclaimed in his last presidential address. In this "swan song," as he named it, Cohen touched upon all the issues he pushed for during his three years of presidency [3]. Speaking for the general assembly gathered in the Dutch parliament in The Hague in 1928, he first recalled the three "weak points" of the organization that he aimed to ameliorate through statutory alterations. First, he suggested to meet less frequently—once every two years instead of annually. Second, he hoped to reduce the amount of pages of reports drafted every year. Perhaps he was too pessimistic, but he feared that most of those reports were destined for oblivion. Both these points connected with his desire for an efficient organization, a preference already visible in the modern and practically equipped Van 't Hoff laboratory in Utrecht that he had designed himself at the beginning of the century [4].

Third, he pushed for the organization of a scientific chemical congress—as had always been stated in the statutes [5]. He echoed the words of his hero Michael Faraday, that such gatherings can have importance in "our lives and in the life of all the world, because they are festivals of fraternization of all natural philosophers." This connected to his attempts at reconciliation with German, Austrian, and Hungarian chemists. But as these nations had not yet joined the International Research Council —whose initial boycott was followed by their counter-boycott—Cohen could not officially invite them to The Hague [6]. However, by scheduling the 25th anniversary of the Dutch Chemical Society (NCV) right before the IUPAC assembly, he found, with sufficient political cunning, an elegant manner to invite these ostracized chemists.

On July 21st the delegates and their spouses first visited the Peace Palace, and were then convened to a garden party hosted by Mr and Mrs Samuel van den Bergh, one of Unilever founders, at their country estate Wiltzangk, below Wassenaar. Cohen thanked them in English, French and German for their generous reception [7]. A remarkable photo of that 'tuinfeest' is preserved in Cohen photoalbum at the Universiteitsmuseum Utrecht (inv.nr 0285-25630).

At the 1928 meeting altered statutes were

IUPAC Conference in the 'old chamber' of the 'Tweede Kamer' (House of Representatives)" in The Hague in July 1928. Ernst Cohen sits in the presidential chair and directly at his left is Secretary General Jean Gérard. Image from photoalbum of professor dr. E.J. Cohen, 1928-1933, Universiteitsmuseum Utrecht, inv.nr 0285-25630. Reprinted with permission.

Gathering of the 9th IUPAC Conference in front of the Ridderzaal (Hall of Knights), the main building of the 13th century 'Binnenhof' in The Hague. Image from photoalbum of professor dr. E.J. Cohen, 1928-1933, Universiteitsmuseum Utrecht, inv.nr 0285-25630. Reprinted with permission.

endorsed, which made official inclusion of all chemists possible. But one more step was required to take "the strangeness" away, as Fritz Haber wrote to Cohen—a special informal meeting in Scheveningen in 1929. There, Kruyt chaired a meeting with twenty chemists, who finally agreed on the Scheveningen Protocol that invited Central Power chemists in a cordial way back into the international chemical community [8]. During his years as IUPAC president, Cohen had combined his skills as organizer with his ideal of internationalism, to achieve, belatedly, a truly international Union.

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IUPAC in Brussels in 1921: A Historical Photo

Ernst Homburg, Danielle Fauque, Peter J. T. Morris, Franco Calascibetta, and Santiago Alvarez

During a search of photographs and documentation on the Belgian photographer Benjamin Couprie, who took the well-known pictures of the Solvay Conferences during the first half of the twentieth century, Santiago Alvarez [1] came across an image in "La Digithèque des Bibliothèques de l'Université Libre de Bruxelles" with the title "Réception de l'Union Internationale de Chimie Pure et Appliquée, photographie de groupe" (Figure 1) [2]. It is a high-resolution copy of a very sharp photograph of a group of 86 people. On the frame of that photo one can read two inscriptions noted in pencil above and below the photograph, respectively: "Union Internationale de la Chimie pure et appliquée," and "Reception au chateau de La Hulpe le 29 Juin 1921." Moreover, just under the photograph there are two inscriptions in smaller letters: "Bruxelles 1913," on the left, and the signature of "Benj. Couprie" on the right, both in the same handwriting. Two questions arise: (1) Which is the correct date for that photograph? (2) Who are the persons that appear in the photo?

1913 was indeed the year in which the International Association of Chemical Societies (a forerunner of IUPAC) met in Brussels [3,4], a meeting that was arranged to coincide with the 50th anniversary of Solvay & Cie, and with the creation of the International Solvay Institute of Chemistry. The meeting, supported by Solvay, took place from 19-23 September, when a group picture might have been taken. The meeting must not be confused with the second Conseil Solvay de Physique, that also took place in Brussels from 27-31 October of the same year. In the picture under consideration (Figure 1), however, only a handful of the scientists present in

Figure 1. *Participants at a reception given at the Château de La Hulpe, Brussels, on 29 June 1921. Photo: Benjamin Couprie.*

Key	Name	Country	Key	Name	Country
1	Edmund Trepka	Poland	39	Marcel Delépine	France
2	Angel Goslino	Uruguay	40	James Conant	USA
3	Maurice Huybrechts	Belgium	41	unidentified	
5	Kai Warming	Denmark	56	Charles Marie	France
6	Emil Votoček	Czechoslovakia	57	Gustave André	France
7	Marcel Guichard	France	58	André Kling	France
8	Gabriel Bertrand	France	59	Georges Urbain	France
10	René Etienne	France	60	Gerrit Hondius Boldingh	Netherlands
12	Piero Ginori Conti	Italy	61	Raymond Marquis	France
13	Raffaello Nasini	Italy	62	Jacobus Petrus Treub	Netherlands
14	Victor Grignard	France	63	Edmond Blaise	France
15	Birger F. Halvorsen	Norway	64	Frederick Cottrell	USA
16	Charles Moureu	France	65	Thomas Martin Lowry	UK
17	Fernand Bordas	France	66	Paul Pascal	France
18	Ernest Solvay	Belgium	67	Constantine Zenghelis	Greece
19	Camille Matignon	France	68	René Lucion	Belgium
20	William Pope	UK	69	Paul Nicolardot	France
21	Philippe A. Guye	Switzerland	70	Hugo R. Kruyt	Netherlands
22	Auguste Béhal	France	71	Nicola Parravano	Italy
23	Stephen Miall	UK	72	Enrique Moles	Spain
24	Frédéric Swarts	Belgium	73	Léon Crismer	Belgium
25	Armand Solvay	Belgium	74	Paul Cazeneuve	France
26	Amé Pictet	Switzerland	75	Einar Biilmann	Denmark
27	Edouard Bourgeois	Belgium	76	Oscar Scarpa	Italy
28	Adolphe Lecrenier	Belgium	77	Felice Garelli	Italy
29	unidentified		78	Umberto Pomilio	Italy
30	Octave Dony-Hénault	Belgium	79	Paul Kestner	France
31	José Rodríguez Mourelo	Spain	80	Francesco Giordani	Italy
32	Paul Dutoit	Switzerland	81	Francisco Pastori	Uruguay
34	Julien Bergé	Belgium	83	Domenico Marotta	Italy
35	Henri Wuyts	Belgium	84	Jean Voisin	France
36	Jean Timmermans	Belgium	85	Martiniano Leguizamón Pondal	Argentina
37	Stefan Minovici	Roumania	86	Mario G. Levi	Italy
38	Emil Bosshard	Switzerland			

Table 1. *Identification of the scientists present in the group photograph (Figure 1), using the numbering of the attendees shown in Figure 2.*

the photograph of the 1913 chemistry meeting can be identified: Auguste Béhal, Einar Biilmann, Léon Crismer, Thomas Martin Lowry, Charles Marie, José Rodríguez Mourelo, and Phillippe A. Guye, which clearly tells us that those are images of two different groups taken at two different occasions.

The second date written on the frame is close to, but earlier than, that of the First Solvay Conference on Chemistry (1922). In fact, this photograph may have been taken at Château La Hulpe (Belgium), Ernest Solvay's summer mansion, on Wednesday, 29 June 1921, as written below the picture, during a reception given by Solvay to the attendees of the 2nd International Conference on Pure and Applied Chemistry, or as it is called today "General Assembly." This Conference was held at the Palais des Académies in Brussels from 25-30 June 1921. The local organisation of the conference was the responsibility of Prof. Octave Dony-Hénault and the social programme was organised and sponsored by the Belgian government and local industrialists.

The programme of the Brussels conference for Monday evening included a reception by the Belgian Minister of Science and the Arts, Jules Destrée. On Tuesday afternoon, a convoy of motor cars took the participants to Tirlemont, where they saw the ruined buildings left by the Germans after the war, and

Figure 2. *Key for the identification of the attendees to the 1921 IUPAC conference present in the reception offered by Ernest Solvay at Chateau La Hulpe. (***a***) Back rows, (***b***) front rows.*

the large sugar refinery where they admired how the equipment and organisation were up-to-date. They then went to Lubeck, to Lucien Beauduin's estate where they were received by the industrialist and his family for lunch [5-8]. On Wednesday, the participants were taken by motor cars to the mansion of La Hulpe. Solvay and his family received the participants for lunch and the children had the opportunity to stroll around the park. On Thursday evening, participants and their wives enjoyed a conference banquet offered by the Belgian National Committee of Chemistry at the Taverne Royale in Brussels. Frédéric Swarts, president of the Committee, chaired the banquet flanked by Jules Destrée and Charles Moureu, President of IUPAC, while Joseph Wauters, Minister of Industry, Labour and Food Supplies sat next to Moureu. Toasts were given in French by Swarts, Moureu, Destrée, and William Pope, IUPAC's Vice president.

It is no coincidence that Ernest Solvay is standing in the La Hulpe picture in between IUPAC president Charles Moureu, who would also become a regular attendee of the prestigious Solvay Chemistry Councils, and Pope, who would become the next IUPAC president. At that time Solvay would have been working on the preparation of the first Solvay Chemistry Council, which would take place in 1922 [10,15]. The dates and programme for the 1922 Solvay Chemistry Council were discussed and approved in a meeting of the organising committee held in the private laboratories of Ernest Solvay on 24 June 1921 [10], just before the IUPAC meeting. This committee was chaired by Pope and the other participants were Paul Hegel, Émile Tassel, Georges Chavanne, Jean Perrin, Phillippe A. Guye, André Job, and Dony-Hénault. Ernest Solvay himself did not participate in this committee, as there is a decision mentioned in the minutes to send him a telegram of recognition.

The list of participants [7,8] includes 82 scientists from 18 different countries.1 With the help of that list, we compared other photographic sources in which the same chemists are unequivocally identified [11-14] with the faces in Couprie's photograph, and could identify a number of them. A few more were identified with the

1The chemists from Germany and the other Central Powers were excluded from the IUPAC conferences by the statutes approved in 1919, a situation that lasted formally until 1931, although some chemists from those countries were personally invited to the Hague (1928) and Liège (1930) IUPAC conferences. For other political reasons chemists from the Soviet Union did not participate either.

Year	Location and Conference	Participants also listed in the 1921 IUPAC Conference	Reference
1913	Brussels Int. Assoc. of Chemical Societies	Béhal, Biilmann, Crismer, Guye, Lowry, Marie, Rodríguez Mourelo, Paternò, Wauters	3
1920	Rome 1st IUPAC Conference	Bertrand, Biilmann, Bordas, Crespi, Garelli, Gérard, Kestner, Kruyt, Lindet, Lucion, Marie, Marotta, Matignon, Moureu, Nasini, Nicolardot, Paternò, Pope, Swarts, Votoček, Warming, Zenghelis	16
1922	Brussels 1st Solvay Chemistry Council	Biilmann, Chavanne, Delépine, Dony-Hénault, Lowry, Moureu, Pope, E. Solvay, Swarts, Urbain, Wuyts	15, 17
1923	Cambridge 4th IUPAC Conference	Béhal, Bertrand, Biilmann, Bordas, Bourgeois, Crespi, Delépine, Dutoit, Étienne, Gérard, Ginori Conti, Giordani, Holleman, Huybrechts, Kestner, Kling, Kruyt, Lecrenier, Lindet, Lowry, Marie, Marquis, Miall, Minovici, Moles, Moureu, Nasini, Parravano, Paternò, Pictet, Pomilio, Pondal, Pope, Swarts, Warming, Zenghelis	18,19
1924	Copenhagen 5th IUPAC Conference	Bertrand, Biilmann, Crespi, Gérard, Marie, Matignon, Moureu, Nasini, Pope, Scarpa, Votoček, Warming	20
1925	Bucharest 6th IUPAC Conference	Bourgeois, Étienne, Gérard, Ginori Conti, Giordani, Kling, Parravano, Pope, Swarts, Votoček	21
1925	Brussels 2nd Solvay Chemistry Council	Chavanne, Dony-Hénault, Job, Lowry, Moureu, Pope, Swarts, Timmermans, Wuyts	22
1926	Washington 7th IUPAC Conference	Bertrand, Crespi, Ginori Conti, Giordani, Holleman, Minovici, Moles, Parravano, Pomilio, Swarts, Voisin	23, 24

Participants identified in group photographs of Chemistry conferences contemporary to the IUPAC 1921, and who participated at the 1921 IUPAC Conference (which does not necessarily imply that they are on the 1921 picture).

help of an international team of historians of chemistry, familiar with several of the chemists on the picture. The identification of most of the participants (all men) is summarised in Table 1, using the numbering shown in Figure 2. As a final step, we systematically studied pictures of other chemistry conferences from that period (Table 2), in conjunction with the lists of participants of those conferences, helped by keys to those pictures. There are also several women in the picture, but none of them participated in the Conference, and it was impossible to identify them with any degree of certainty.

We have not been able to reasonably identify the faces of the following people that appear in the list of participants: Victor Cambon (France), Giuseppe Paternò (Italy) and J. F. Schmitz (Roumania). There were also participants whose images we had at hand and who were almost certainly not in the group picture taken at La Hulpe: Georges H. Baril (Canada), Daniel Berthelot (France), Pierre Bruylants (Belgium), Georges Chavanne (Belgium), Emilio Crespi (Italy), Jean Gérard (France), Arnold Frederik Holleman (Netherlands), André Job (France), Edgar de Laire (France), Léon Lindet (France), Colin M. Mackall (USA), Emanuele Paternò (Italy), Georges Peny (Belgium) and Jules Wauters (Belgium).

Leaving aside one child and 18 women who are not listed as participants of the conference, there are a total of 67 males in the photograph, 65 of which have been confidently identified. This leaves us with only two unidentified scientists in the picture (numbers 29 and 41 in Figure 2). Taking into account that Ernest Solvay was not on the list of 82 participants, we may conclude that 15 persons in that list did not attend the Solvay reception or were not in the group when the picture was taken, as was the case of Lindet and E. Paternò, whom we know that were present at the conference on the 27th. In the case of Gérard, he was present at the beginning of the conference, but left in the morning of 29 June because he was ill, and was substituted by Voisin. The almost complete match between the list of participants at the 1921 IUPAC conference and the faces found in the group photograph leaves no doubt that it was taken during that conference, and that the annotation of the date of 1913 by Couprie was probably made at a later stage, and he probably mistook it for another photograph taken earlier on the occasion of the International Association of Chemical Societies and the creation of the International Solvay Institute of Chemistry.

In the year that marks the centennial of IUPAC, we find it appropriate to publicly document a photograph of such a historically important event, especially given the scarcity of individual portraits of scientists of that time.

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Pioneers of Japanese Participation in IUPAC

by Yoshiyuki Kikuchi

East Asia occupies a substantial position in IUPAC today. The incumbent president for 2018-2019, Qi-Feng Zhou, is from China/Beijing, and three out of ten elected members of the Bureau are from East Asia: Mei-Hung Chiu from China/Taipei, Kew-Ho Lee from Korea, and Ken Sakai from Japan. This region is thus well-represented in the IUPAC leadership. However, this is not how this now global institution looked in the past. Its first president from East Asia was Saburo Nagakura (b. 1920) from Japan who assumed this office from 1981-1982, more than 60 years after the IUPAC was established in 1919. He was followed by Jung-Il Jing from Korea (2008-2009), Kazuyuki Tatsumi (2012-2013) from Japan, and Zhou. In terms of national adhering organizations (NAOs), Japan was the first East Asian nation admitted to IUPAC in 1921, but we had to wait until the late 1970s for all other national chemical communities in East Asia to be officially admitted to the IUPAC: The Chemical Society Located in Taipei in 1959, the Korean Chemical Society in 1963, and the Chinese Chemical Society in 1979. East Asia's position in the IUPAC is the outcome of a rather long historical process.

The above paragraph is simply not enough to understand how and why East Asia has risen to its current position in IUPAC. But it does point to Japan's exceptionally early and still current role in this process [1]. In this short article I shall focus on the development of international careers of two pioneering Japanese chemists working for the IUPAC whose paths Nagakura followed: Joji Sakurai (1858-1939) who served as a Vice-president of the IUPAC in the 1920s; and San-ichiro Mizushima (1899-1983) who served IUPAC as a bureau member between 1955 and 1967. Sakurai, Mizushima, and Nagakura shared research interests in physical chemistry, and this is not a coincidence. One of Sakurai's students at Tokyo Imperial University (today's University of Tokyo) was physical chemist Masao Katayama (1877-1961) who taught Mizushima at the same institution. Mizushima was then the teacher of Nagakura at Tokyo. Sakurai, Mizushima, and Nagakura were connected with each other by a strong academic lineage.

Sakurai and the Early Years of the IUPAC

Joji Sakurai started studying chemistry at one of the antecedent institutions of Tokyo Imperial University in the early 1870s. But Sakurai moved to Britain in 1876 and finished his study at University College London with renowned organic chemist Alexander W.

Joji Sakurai (b. 1858) in his advanced age.
Courtesy of the Ishikawa Prefecture Museum of History, Kanazawa, Japan.

Williamson (1824-1904) in 1881. Sakurai was immediately appointed lecturer in chemistry at his alma mater and promoted to professor a year later. Sakurai was one of the first native Japanese chemistry professors in Japan.

Sakurai inherited Williamson's penchant for a theoretical approach to chemistry, including research interests in reaction mechanism and three-dimensional thinking, and became the main advocate of physical chemistry in Japan in the 1880s, though he had been originally trained as organic chemist. Equally important was what Sakurai called "cultural training" during his study in London, which made him a confirmed anglophile. He polished his English, gained fluency in German and French, and eagerly assimilated British and European culture through his personal acquaintances beyond scientific circles. These were all essential skills to survive in the international chemical community, but very few Japanese scientists actually had them in the late nineteenth and early twentieth century [2]. That is why Sakurai could make his mark as a representative Japanese "scientific diplomat" later in his career from the 1900s as the Japanese delegate of the International Commission on Atomic Weights, International Convention of the International Scientific Catalogue, and then of the International Association of Chemical Societies [3].

IUPAC was created in 1919 to reconstruct the international chemical community torn apart by the outbreak of the First World War. The starting point of the postwar reconstruction of international science was the establishment of the International Research Council (IRC) in the same year by scientists from allied countries [4]. Japan embraced the IRC as part of the war-winning *entente*, with Sakurai as its champion in spite of strong oppositions from his Japanese peers with German connections. Largely through his strenuous effort, Japan was admitted to IUPAC in 1921 through the Division of Chemistry at the National Research Council of Japan, created in 1920 to be a national member of the IRC. Sakurai became Vice-President of IUPAC twice, from 1923-1924 and 1928-1930 [5]. Simultaneously he cultivated connections with scientists in Pacific Rim countries such as Australia, the United States, and New Zealand through his Anglo-American connections, and successfully organized the Third Pan-Pacific Science Congress in Tokyo in 1926 [6]. He was active in international science until the very end of his life, as is shown by his vice-presidency of the International Council of Scientific Unions (ICSU), the successor institution of the IRC, for 1937-1940.

In summary, Sakurai was well-suited for the role of navigating the Japanese scientific community into a post-First World War international science dominated by allied scientists. Sakurai's efforts towards international cooperation in science and chemistry described above was also aided from the 1900s by his former student and successor at Tokyo, organic chemist Koichi Matsubara (1872-1955) [7]. He studied overseas with William H. Perkin Jr. (1860-1929), at Owens College Manchester and also with Emil Fischer (1852-1919) at the University of Berlin. Like Sakurai two years later, Matsubara represented the Japanese government at the Second International Convention of the International Scientific Catalogue held in London in 1905. For IUPAC, he attended the 1925 Conference in Bucharest, Rumania, as the Japanese representative to the International Committee of Documentation for 1925-8 and also was present at the 1926 Conference in Washington, DC [8]. His election as a vice-president of IUPAC for 1934-1938 would be best interpreted as the recognition of his work as the supporter and successor of Sakurai and as the reflection of the situation of the IUPAC in the 1930s in which Germany was granted its full membership.

Joji Sakurai (JS) attended the 9th IUPAC Conference in The Hague in 1928, with at least two other Japanese colleagues, Yukichi Osaka (YO), professor emeritus of Kyoto Imperial University and Keita Shibata (KS), professor of Tokyo Imperial University. In this close-up of the group, Sakurai (JS) stands three raws behind Moureu (CM), IUPAC first President; nearby on the back are Osaka (YO) and Shibata (KS), and toward the front is Fritz Haber (FH). Also on the front raw, is Ernst Cohen (EC), IUPAC President, and Jean Gerard (JG), Secretary General. See Jorrit P. Smit, this issue page 10 for full picture. Image from photoalbum of professor dr. E.J. Cohen, 1928-1933, Universiteitsmuseum Utrecht, inv.nr 0285-25630.

Mizushima with Debye around 1930. Courtesy of the Mizushima family.

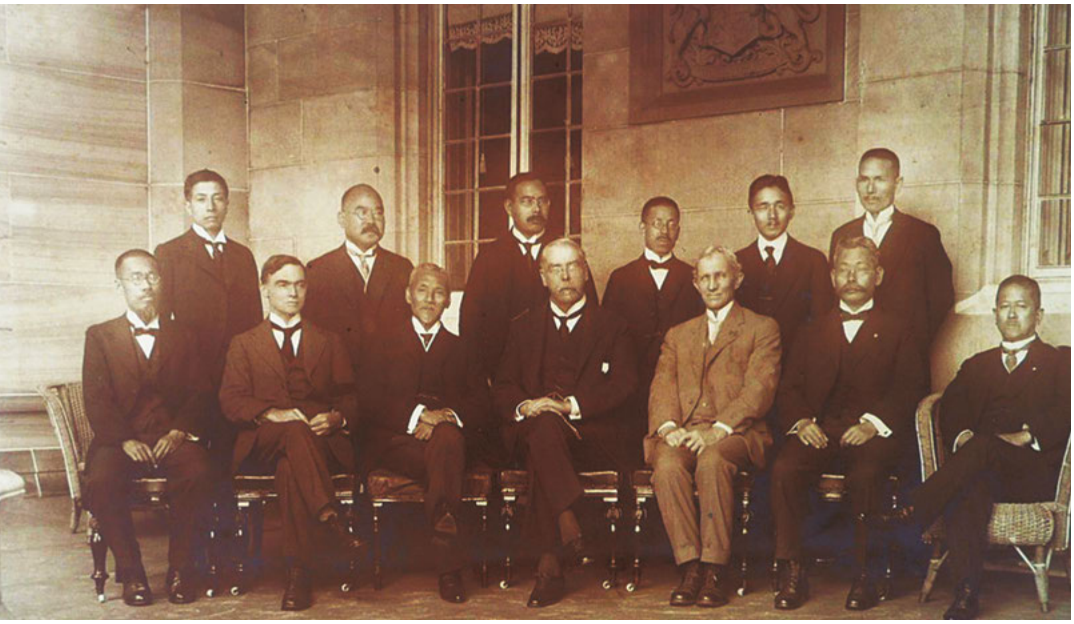
Mizushima and Japan's readmission to the IUPAC

In 1951 Japan was readmitted unanimously to IUPAC after six years of suspension of its membership following the end of the Second World War. Japan regained independence as a country in the same year, so it was a surprisingly smooth process in comparison with what happened after the First World War. San-ichiro Mizushima, who studied first at Tokyo with Katayama, the student of Sakurai, and then with Dutch-born physicist Peter Debye (1884-1966) at the University of Leipzig in the 1930s, was the main participant to the 1951 General Assembly of IUPAC held in New York City and became a bureau member four years after that in 1955. The reason for his quick promotion in IUPAC partly lies in Mizushima's effort to cultivate international connections since the 1930s and growing reputation, especially in the United States, based on his path-breaking research in conformational analysis. He coined the "gauche" form around 1940 for a conformation where two vicinal groups are separated by a 60-degree torsion angle. Linus Pauling (1901-1994) was one of the first American scientists who corresponded with Mizushima in the 1930s. Debye immigrated to the United States in 1940, took up a professorship at Cornell University and became a strong supporter of Mizushima's international career. The invitation from American physical chemist George Glockler (1890-1969) to Mizushima for an American Chemical Society symposium enabled his trip to New York City in 1951. Mizushima's international career therefore reflects the importance of American-Japanese relations in science and indeed in chemistry specifically after the Second World War. The first Japanese president of the IUPAC, Saburo Nagakura, who studied with both Mizushima and American chemist Robert S. Mulliken (1896-1986), underscores this trend.

Conclusions

Japan's early role in IUPAC was the outcome of a variety of scientific, cultural and political factors. The quick learning of Western science, culture, and languages and the gradual recognition of research done by Japanese chemists are certainly important, but also were politico-historical factors such as the two world wars, growing presence of the United States (in addition to Europe) on a global scale, and regional alliance in Asia and the Pacific Rim. Japanese chemists' positions in IUPAC and other international scientific organizations in turn helped them cultivate connections with first-class scientists around the world. This obviously facilitated the flow of scholarly information across national borders and the successful organizing of international conferences: the essential factors in

Linus Pauling, Ava Helen Pauling, and Mizushima standing in front of the Great Buddha in Kamakura, Japan, 1955. Courtesy of the Oregon State University Special Collections and Archives Research Center, Corvallis, Ore., USA.



Sir Walter E. Davidson (Governor of New South Wales: front row, sitting, at the center) and Joji Sakurai (front row, third from the left) during the Second Pan-Pacific Science Congress held in Sydney and Melbourne, Australia, 1923. Courtesy of the Ishikawa Prefectural Museum of History.

the development of chemistry in twentieth-century Japan [9]. We have no reason to doubt the importance of IUPAC in East Asia in later periods and that the above scientific, cultural, and political issues would play a substantial role in this region's continuing rise in IUPAC to this present day.

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London 1947: A Caricature

by Brigitte Van Tiggelen, Danielle Fauque and Fabienne Meyers

The caricature published in *Chemistry and Industry,* 2 August 1947, is Fred May's impressions of the luncheon offered to the XIth International Congress of Pure and Applied Chemistry at the May Fair Hotel, London, 18 July 1947 by the Society of Chemical Industry to distinguished chemists on the occasion of its centennial [1]. Fred May (1891-1976) was a caricaturist and painter, who sent his first cartoons from the front in 1917. May insists on the strenuous time the toastmaster had during the dinner that welcomed many prominent British and international figures in the chemical sciences and industry. Dr Leslie H. Lampitt, president of the SCI, chairman of the Congress and treasurer of IUPAC (1947-1957) "expressed that welcome in a very homely way" [1]. William Hulme Lever, 2nd Viscount Leverhulme (1888-1949), cofounder of Unilever, a past president of the SCI, acted as president of the Congress [2].

In 1947, the IUPAC was in the midst of a recovery, in the aftermath of World War II that interrupted chemical cooperation. IUPAC President, Colonel Marston-Taylor Bogert (USA, 1938-1947—the President who stood in office for the longest period of time) had written to all nations members in January 1940: "*... The Union, as its name signifies, is an organization of scientists banded together for the good, not of any one country, but of all. Its aims are the welfare and happiness of all mankind, through the advancement of civilization by the triumphs of chemistry...*" [3]. As the war became global, Bogert's hope were reduced to naught. Nevertheless, thanks to his determination and the resilience of many chemists, this was not the end of the Union and in Spring 1945 there was enough will to revive the Union and rebuild the Bureau and organize a "*Reprise de contact*" meeting in London in 1946 [4]. And so it went, the XIth International Congress of Pure and Applied Chemistry and the 14th *Conférence Internationale de Chimie* (equivalent of today's General Assembly) were to be held simultaneously in London, in July 1947 [5].

Besides Bogert, the cartoon shows Sir Robert Robinson (UK), president of the Royal Society, and IUPAC Vice President 1938-1947, who would continue as Bureau Member from 1947-1951. Robinson was already a scientist of high repute, and was awarded Nobel Prize in Chemistry later that same year, in 1947. Others acquired executive positions during that meeting in London, including Arne Tiselius (Sweden), who became IUPAC Vice President from 1947-1951 and would continue as President from 1951-1955; and he too would be awarded a Nobel Prize in Chemistry in 1948. Paul Karrer (Switzerland), winner of a Nobel Prize in Chemistry in 1937, was invited to deliver a lecture during the congress, and became Vice-President for the period 1947-1955.

Also depicted in the cartoon is Linus Pauling (USA, Nobel Prize in Chemistry in 1954 and Peace in 1962) who presided over section II of the Congress on 17 July and delivered a lecture titled "Molecular Structure and Biological Specificity" [6]. Both Karrer and Pauling were conferred *honoris causa* degrees by the University of London along with Johannes Nicolaus Brönsted (1879-1947—he died in December that same year) and Cyril Norman Hinshelwood (1897-1967), who are not pictured in this cartoon. The presence of Sir Wallace Akers (1888-1954) is related to his service during wartime and his career in Imperial Chemical Industries. The French Robert Bienaimé (1876-1960) was at that time president of the *Société de Chimie Industrielle*, sister society of the *Society of Chemical Industry*. Lesser known figures but nevertheless renowned chemists and highly productive IUPAC members also present in the cartoon are the Belgian Jean Timmermans (1882-1971), director of the *Bureau international des Etalons physico-chimiques;* the Dutch Barend Jansen (1884-1962), specialist of nutrition who together with his colleague Willem F. Donath (1889-1957) was the first to isolate a vitamin in pure (crystalline) form (the anti-beriberi vitamin which they named thiamine)); and the Czechoslovakian Vítězslav Veselý (1877-1964), an organic chemist member of the Commission on oils, fats and derivatives that became an IUPAC commission in 1938 (Veselý was chair in 1937-1938, and the main promotor of this affiliation).

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4. For more details, see "Rebuilding IUPAC after WWII," infra p. 22
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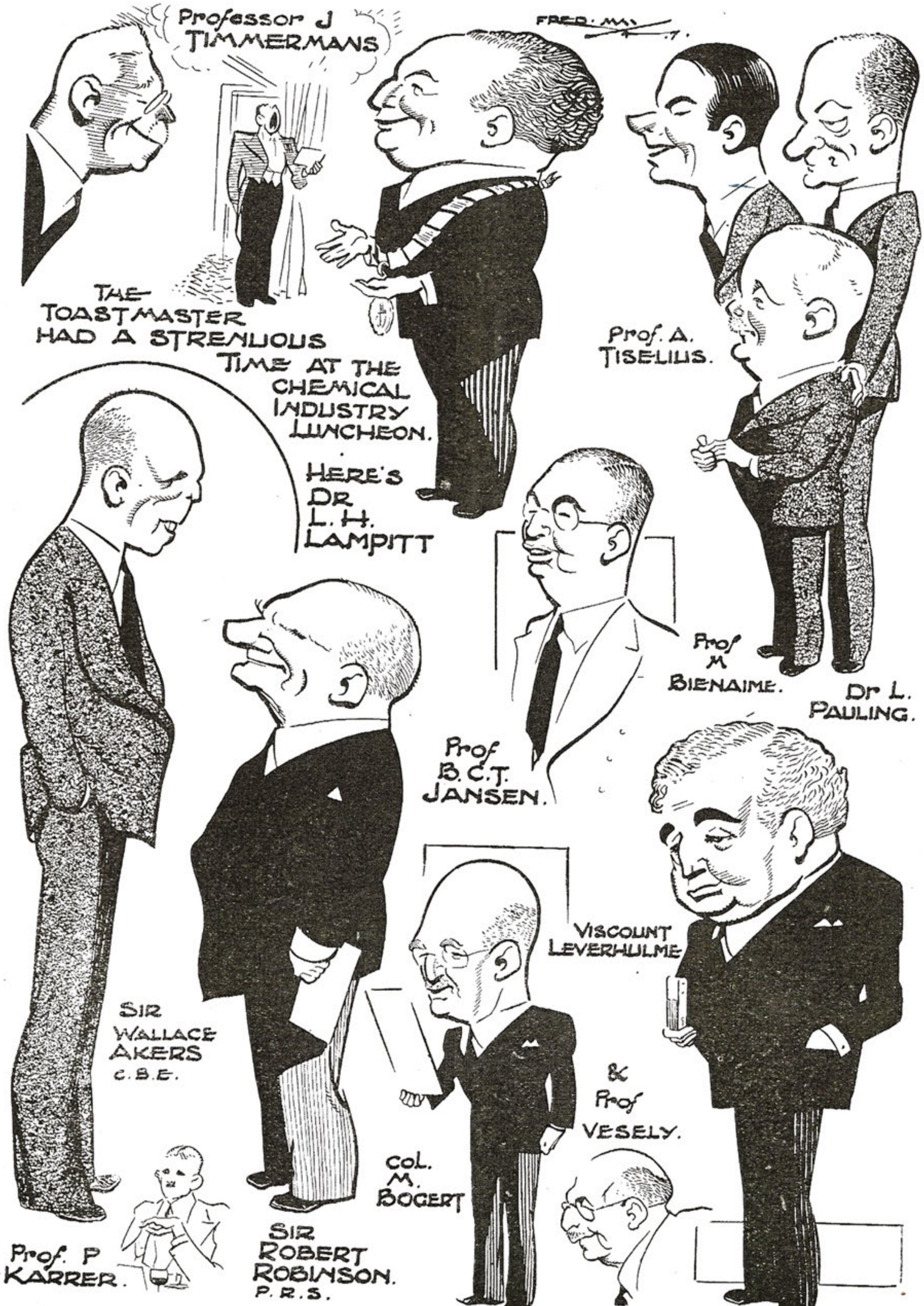


The cartoon was published by the journal of the Society of Chemical Industry, Chemistry and Industry, August 2, 1947, p. 473 [ref. 1]. It is also available online as part of "It's in the Blood! A documentary History of Linus Pauling", from the Special Collections & Archives Research Center, Oregon State University Libraries, http://scarc.library.oregonstate.edu/coll/pauling/blood/pictures/1947i.11.html

Rebuilding IUPAC after WWII

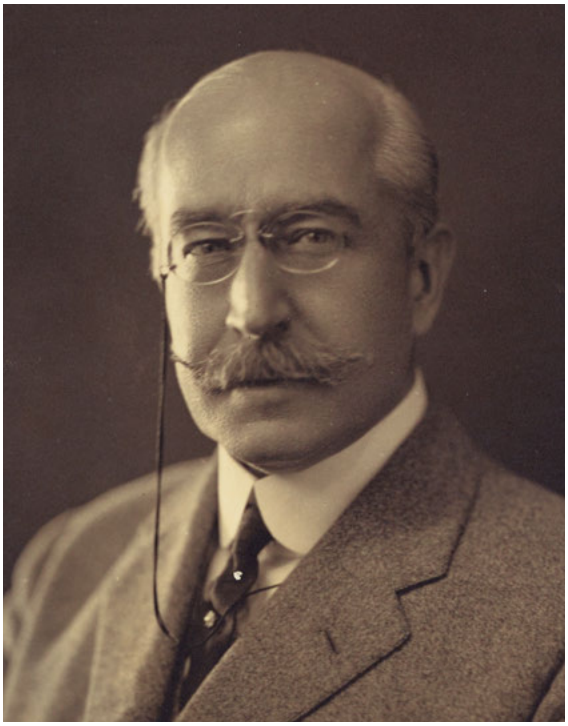
by Danielle Fauque and Brigitte Van Tiggelen

The League of Nations' failure to ensure global peace by solving conflicts through diplomatic and peaceful means prompted Franklin Roosevelt and Winston Churchill to discuss the creation of a more efficient international organization as soon as the Second World War erupted. These preliminary efforts led to the signing of the Charter of the United Nations (UN) in San Francisco in 1945. In January 1946, the first general UN assembly took place, along with the Security Council and the Economic and Social Council. The latter created several international bodies, among them UNESCO. At first, UNESCO seemed to be the continuation of the International Institute for the Intellectual Cooperation (IIIC) coupled with the International Commission for the Intellectual Cooperation (ICIC), but was actually based on new rules [1].

In this new international framework, what would become of ICSU, which had gathered the scientific unions since 1931? There were three possibilities: 1) disband ICSU, and with it all the unions, 2) adapt ICSU to the new framework and continue to exist or 3) become completely independent of any umbrella organization, taking the risk of seeing parallel unions created inside UNESCO on different grounds and principles. During a meeting in London in July 1946, pragmatism prevailed and ICSU decided to cooperate with UNESCO. The main concern was the potential scattering of traditional disciplines into specialized unions that were already emerging.

From London (1946) to Amsterdam (1949), from the *"Reprise de contact"* to new Statutes

At the ICSU meeting in London in 1946, the Unions presented their activities during the war. As for the International Union of Chemistry (its name was *Union internationale de chimie*, UIC, since 1930), Marsten T. Bogert (USA, 1868-1954), who had been elected president back in 1938, had written in 1940 to all members urging them to keep the Union going as much as possible, and encouraging the chemical societies of nations at war to remain active [2]. As a result, in 1946, the UIC was able to announce that the *Annual Tables of Physical Constants* had been published for the period 1931-36 and that a US group at Princeton, under the direction of Hugh S. Taylor (1890-1974), had prepared the table for 1941-1942, with the support of Jean Timmermans (1882-1971), director of the *Institut international des étalons physico-chimiques* in Brussels, who had taken refuge in London [3]. The Commission on New Analytical Reactions and Reagents (CNARR) had also kept close contact with its members located in Delft, Ghent, and Geneva, and published its works in Basel, situated in neutral Switzerland, in 1945.



Marsten T. Bogert, USA, elected President in 1938 (Portrait collection, Science History Institute, Philadelphia; https://digital.sciencehistory.org/works/z029p478k)

A delicate matter was preoccupying the Council though. Jean Gérard (1890-1956), who had served as a most efficient secretary general since 1919, was accused of collaboration with the German occupying authority that had been hosted at the *Maison de la Chimie* (Paris), the Union headquarters. Frédéric Joliot-Curie (1900-1958), director of the Centre national de la recherche scientifique (CNRS) and a figure of the Resistance, had already demanded his exclusion in 1944. In 1945, Bogert received Gérard's resignation and designated Raymond Delaby (France, 1891-1958), as provisional secretary general, on the recommendation of Joseph Bougault (France, 1870-1955), vice-chair of the Union. Delaby was member of the CNARR that had so diligently worked during wartime.

At the "*Reprise de contact*" [4] meeting in London, in July 1946 the new secretary general listed all the ongoing projects since the last conference in Rome, in 1938. The first step was to resume contacts with all the adhering bodies of the Union and suggest new commissions (macromolecular chemistry, glassware standardization, purity of chemical substances, and traces of toxic substances in the atmosphere). Also, the cooperation with UNESCO presented itself well, since the headquarter would also be located in Paris.

During the summer of 1947, three events occurred in London. Between 14-17 July, the Chemical Society (London) celebrated its centennial with more luster than it had in 1941. This was immediately followed by the XIth International Congress of Chemistry (17-24 July), simultaneously with the 14th International Conference of Chemistry.

The Dutch Hugo Kruyt (1882-1959), who had just finished his term as chair of ICSU, succeeded Bogert as the UIC chair. Delaby was confirmed in his role as secretary general, and the Union headquarters remained at the *Maison de la Chimie*, in Paris. French persisted as the official language of the Union for the time being. A financial agreement was met between ICSU and UNESCO to support most of the travel expenses for the Bureau and commission members. The Union for chemistry was counting 24 national adhering organizations, and many other countries were aspiring to adhere.

"O people of the world,
Ye are all branches of one tree,
The leaves of one branch,
The drops of one sea."
-Baha U'llah

Quote reprinted on Bogert's address of 24 July 1946 [4, p.15].

From Amsterdam (1949) to Paris (1957): Restructuration

All the while, the issue of new specialized unions was corroborated by the facts. A new International Union of Crystallography (IUCr), presided by Sir Lawrence Bragg (1890-1971), had just been accepted by ICSU in 1947, followed by an International Union for History of Science in 1948. Also, the analytical chemists were organizing an international conference apart from the International Congress. Not to mention the coming creation of an International Union of Biochemistry that will be dealt with in the next section.

To avoid a dismantling of the Union, Delaby suggested a structure based on autonomous disciplinary sections that would oversee the related commissions. The new statutes discussed in 1947 were submitted and approved at the Amsterdam Conference in 1949 [6, p. 47]. A resolution, adopted by the Council, instituted six sections (Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Biological Chemistry, Analytical Chemistry, and Applied Chemistry) whose presidents would *de facto* become members of the Bureau. The Union president was now elected for four years, the 16 members of the Bureau delegated the ordinary administrative management of the Union between two conferences to an Executive Committee (EC) of five members, and a *Circulaire d'information*, initiated by Delaby in 1947 kept everyone informed. At the same time, the Union was going back to its initial name of pure and applied chemistry, insisting on the fact that the chemical industry could no longer be ignored [6].

The 16th Conference in Washington DC – New York City in 1951 took place during the XIIth Congress of Pure and Applied Chemistry. The 75th anniversary of the American Chemical Society (ACS, founded in 1876) was also celebrated, as well as the 50th anniversary of the National Bureau of Standards. Among the members of the Bureau (1951-1955), under the presidency of Arne Tiselius (Sweden, 1902-1971, Nobel Prize in 1948), many new faces, who would become chairs of the Union later, are to be spotted: Arthur Stoll (Switzerland, 1887-1971), William A. Noyes Jr. (USA, 1898-1980), Jacques Bénard (France, 1912-1987), and Alexander R. Todd (UK, 1907-1997). A new generation is in place, one that will get deeply acquainted with the life of the Union before taking its reins [7].

The meeting in Stockholm (17th ICC, 1953) unfolded very much in the same manner as it was conceived in 1919, with the many traditional meetings of sections. The sections established internal rules, in line with the Union statutes, consolidating both their relationship with the Union and their qualified autonomy. In his report on the state of the Union, Tiselius praised the new structure and its workings, underlining how much "our new method of approach seems perfectly adapted to the incessant developments within our vast field" [8, p. 39].

Some tensions clearly persisted: the National Research Council (NRC, USA, Division of chemistry and chemical technology) insisted on the creation of specialized unions; the Union denied the creation of a division for chemical engineering. In general, the Union did

Conference of the International Union of Chemists in Amsterdam in September 1949 (photo on the front steps of the Indisch Museum). First raw in the middle with a black suit is IUPAC President (1947-51) Hugo R. Kruyt (Netherlands); Also, Secretary General Delaby stands on the 3rd step on the far right.

not contemplate the creation of commissions on new topics that were already the concern of other organizations, in which case the creation of a temporary *ad hoc* commission was usually preferred [8, p. 44].

Tiselius concluded his president report with a clear request to the sections: They should publish their results swiftly, before others would do it outside of the Union. The reports should be published as textbooks or monographs; that is to say in a more accessible format that would allow for more details [8, pp. 44-45].

The 18th conference in Zurich in 1955 was the last one in which Delaby participated as secretary general. Since 1951, the management of the new structure, though efficient, had created more work. One has to remember that Delaby was carrying the duty alone, assisted by one secretary and...an old type machine, relying on the section secretaries. His request for additional assistance was denied. The task had become much too absorbing, and he wanted to devote himself solely to the organization of the Paris congress in 1957, hosted by the *Société chimique de France* of which he became president for the second time. The SCF was to celebrate its centennial in 1957. In Zürich, Delaby concluded his last address as secretary general underlining the crucial role of the many meetings triggered by the Union in promoting and keeping the peace every man aspires to [9, p. 6].

Delaby, who had volunteered for service in WWI in 1914, suffered all his life from the after effects of gas attacks and understood what he was talking about in his flesh. As a pharmacist and professor of chemical pharmacy, he had lived through two world wars, and experienced the geopolitical tensions firsthand while managing the Union. There were the diplomatic difficulties of gathering scientists from different geopolitical blocks, and the endless paperwork required to get them to work together and share their knowledge. Indeed, the Soviet Union was a member since 1931 and former foes, Japan and the Federal Republic of Germany, joined the Union in 1951.

Structure versus interdisciplinarity: the issues of Biochemistry and Radioactivity

Among the unresolved affairs Delaby left behind, was the question of biochemistry. A successful meeting of biochemistry in Cambridge in 1949 brought to light the intent of creating an International Union of Biochemistry. And since a similar meeting in Copenhagen in 1950, an international committee for biochemistry was knocking at ICSU's doors. The Union of chemistry opposed the project, arguing it was contrary to the ICSU statutes and would diffuse the resources.

The delegates of International Committee of Biochemistry and the IUPAC section Committee met

twice, in 1951 and 1953, without finding an agreement. The most pressing impediment related to the mode of representation: The International Committee of Biochemistry preferred representation through learned societies, in the manner of the International Association of Chemical Societies (IACS) in 1911; they argued that in some countries the national representation would not make the effort to reallocate space enough for the biochemists. This demand was contrary to the statutes of the Union, thus problematic.

But in 1955, the International Union of Biochemistry (IUB) was admitted to ICSU. Sir Edward Ch. Dodds (1899-1973), who as Union Section chair for biological chemistry had been in charge of the relationships with the Biochemists, was at the end of his mandate. He reiterated that he had accepted his chairmanship in New York in 1951 "provided that it was clearly understood that he supported the idea of an independent International Union of Biochemistry working alongside this section" [9, p. 74]. The Section had supported this opinion for four years, and created a coordination committee with the UIB to avoid overlap. Obviously, the Section had not followed the Bureau, and in particular the Executive Committee, who opposed the establishment of the UIB.

Since the end of the war, the Union comprised inter-union, mixed commission, as a "mother union," directly under the supervision of ICSU. Transdisciplinary work had indeed become necessary, inevitable, and more with IUPAP in matters of radioactivity or with the *Commission mixte des données et des étalons physico-chimiques.* The Union also worked with IUPAP, IUBS, and IUCr on macromolecular chemistry within the ICSU mixed commission on rheology [6, p. 15; 7, p. 11]. To be in line with the ICSU statutes however, mixed commissions were approved for a limited time of three years, renewable once with the adjunction of new members, which gave rise to heated debates. For instance, the sudden termination of the Joint Commission on radioactivity by ICSU, in 1955, followed the assessment of its lack of progress since 1946, (due to the tensions between old and new members on the question of the radium standard.) As a consequence, none of its members were kept for the newly established Joint Commission on Applied Radioactivity (founded in 1955, effective in 1957).

Conclusion

The eight years period that stretches from the Amsterdam Conference (1949) to the Paris Conference (1957) witnesses the establishment of a structure, the skeleton of which would be basically kept until the end of the 20th century. There would be some adjustments. The exponential evolution of chemistry in its theoretical aspects as well as in its industrial, social and legal applications, continued in a world undergoing geopolitical tensions (Cold War, strategic use of nuclear power and colonial wars). Other developments would be necessary, in particular with regard to publications. A new generation was taking charge, and the next ten years would witness great changes inside the Union. The UNESCO subsidy was declining year after year, as a consequence of the growing number of organizations to be supported. The Union had to find other sources of funding that only the industry would be able to provide.

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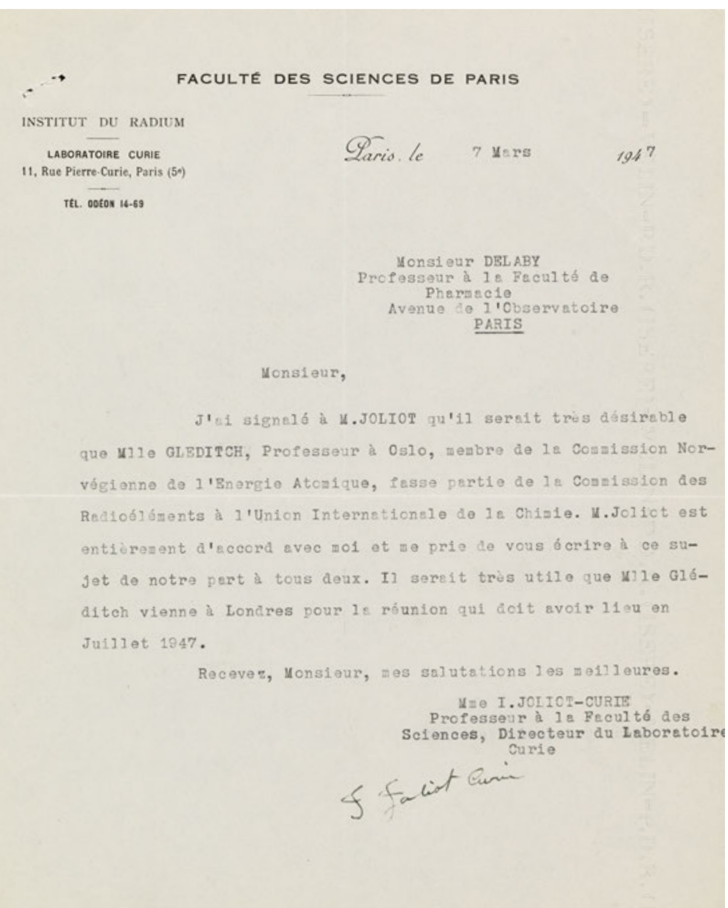
Ellen Gleditsch: Woman Chemist in IUPAC's Early History

by Annette Lykknes

Ellen Gleditsch in 1927, two years before she was appointed professor of inorganic chemistry at the University of Oslo. Courtesy of Chris Koch.

In 1907, a 28-year-old Norwegian pharmacist-chemist arrived in Paris to work with Marie Curie at the Radium Institute. Like many women at the time, Ellen Gleditsch was attracted to the newly discovered phenomenon of radioactivity and wished take part in exciting scientific endeavour. Working with the Nobel Laureate Marie Curie was a unique opportunity for the ambitious young chemist, whose skills in mineral analyses led to her being accepted into the otherwise fully staffed laboratory. By all accounts, Ellen Gleditsch appears to have been one of the first women associated with IUPAC. In 1921 she was the Norwegian representative of the committee working on the *Tables Annuelles de Constantes et Données Numériques de Chimie, de Physique et de Technologie* [1], published under the auspices of IUPAC with the agreement of the International Research Council. In the following year she was a member of the Commission on Nomenclature of Inorganic Chemistry during its meeting in Lyon [2]. In 1947 Gleditsch became a full member of the Joint Commission of Standards and Units of Radioactivity, joining her friends Frédéric and Irène Joliot-Curie in this capacity, and all three continued to be members until the Commission's dissolution in 1955 [3]. IUPAC was the mother union of this Joint Commission, and directly linked with International Council of Scientific Unions (ICSU).

Gleditsch worked in Curie's laboratory for five years, and was promoted to Marie Curie's personal assistant soon after her arrival, to take care of fractional crystallizations. During this time Gleditsch also conducted research, publishing (with Curie) on an alleged transmutation of copper into lithium, which they disproved, and by herself on the uranium-radium ratio in minerals, thus contributing to the knowledge of radium's place in the radioactive series. In 1911 she won a scholarship to research at the Royal Frederick University in Kristiania (now the University of Oslo), and in 1916 she was appointed associate professor of radiochemistry. Gleditsch spent extended periods at Yale University and at the Radium Institute in Vienna, but most of all she considered the Curie laboratory her scientific home, and returned there whenever she was on leave. In the autumn of 1916 she was even a substitute for Curie's chemist André Debierne while he was serving at the front. The radium factory provided space for the chemical work of the Curie laboratory, which was supervised by Debierne, and in return Curie tested and certified the radium salts that were produced at the factory [4].



FACULTÉ DES SCIENCES DE PARIS

INSTITUT DU RADIUM

LABORATOIRE CURIE
11, Rue Pierre-Curie, Paris (5e)

TÉL. ODÉON 14-69

Paris, le 7 Mars 1947

Monsieur DELABY
Professeur à la Faculté de Pharmacie
Avenue de l'Observatoire
PARIS

Monsieur,

J'ai signalé à M.JOLIOT qu'il serait très désirable que Mlle GLEDITCH, Professeur à Oslo, membre de la Commission Norvégienne de l'Energie Atomique, fasse partie de la Commission des Radioéléments à l'Union Internationale de la Chimie. M.Joliot est entièrement d'accord avec moi et me prie de vous écrire à ce sujet de notre part à tous deux. Il serait très utile que Mlle Glé-ditch vienne à Londres pour la réunion qui doit avoir lieu en Juillet 1947.

Recevez, Monsieur, mes salutations les meilleures.

Mme I.JOLIOT-CURIE
Professeur à la Faculté des Sciences, Directeur du Laboratoire Curie

I Joliot Curie

Irène Joliot-Curie (March 7, 1947) Letter to IUPAC Secretary General Mr. Delaby, in support of Miss Gleditsch participation in the Commission on radio element and her attendance to the upcoming conference in July 1947. Records of the Commission on Atomic Weights and Isotopic Abundances of IUPAC, Box 14, Folder 4. Science History Institute. Philadelphia. https://digital.sciencehistory.org/works/8c97kq448

Ellen Gleditsch with colleagues from the Joint Commission of Standards and Units of Radioactivity (short: Joint Commission on Radioactivity) in Stockholm at the IUPAC conference in 1953: the IUPAC secretary general Raymond Delaby (far left), the IUPAC past president Hugo R. Kruyt (fifth from the left, the tallest), the French chemist Irène Joliot-Curie (sixth from the left), Ellen Gleditsch (ninth from the left, the shortest), the president of the Joint Commission, Friedrich Paneth (tenth from the left), the Austrian physicist Berta Karlik (eleventh from the left, next to Gleditsch), and the Hungarian-born Swedish chemist George de Hevesy (twelfth from the left). National Library of Norway.

During her time in Paris, Gleditsch grew to know several other women working in radioactivity, and their group became the basis of a strong, supportive network to which she could turn when things became difficult at home. In the 1920s she became involved with the International Federation of University Women (IFUW), and through this channel established formal networks of women academics. From 1926 to 1929 Gleditsch was the president of the IFUW. During her term Gleditsch initiated the establishment of scholarships for university-educated women to go abroad. She spoke in support of the right for women to opportunities equal to those of their male colleagues.

In 1928 Gleditsch applied to become a full professor of inorganic chemistry at her home university. Some of her influential colleagues in Norway subverted her candidacy and did everything they could to steer the selection towards a promising young male candidate, but Gleditsch was the preferred candidate for the majority of the international experts, and she was appointed in 1929. In this application process she had turned to Marie Curie for support, who sent a letter of recommendation to the vice dean of the Faculty of Science and Mathematics, the female professor of zoology Kristine Bonnevie, who knew Gleditsch well and was one of the founders of the Norwegian branch of the IFUW [5]. It was, in fact, also Marie Curie's warm friendship and collegiality that in the early years secured an international role in the IUPAC affiliated committees for Gleditsch—the male-only group of the Norwegian Chemical Society did not make much room for her. While the national representative Birger Fjeld Halvorsen was elected with a majority of 42 votes, and his male colleagues received 34, 5 and 3 votes respectively, Gleditsch only received a single vote [6]. Indeed, it seems that she was appreciated abroad more than she was at home.

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IUPAC Expansion from 1957 to 1975

by Danielle Fauque and Brigitte Van Tiggelen

To chemists and chemical educators, there were two important events in the '60s and '70s. First, in 1961, the agreement between physicists and chemists on the choice of carbon 12 as unique element of reference in the atomic weights table and then in 1971, the definition of mole as the seventh unit of the international system [1]. In both of these issues the Union played its role as expert to the fullest, and established solid grounds for a common language of chemistry across the world. This role is also extended to other matters at a time marked by social changes. Technological progress improved quality of life like never before and the space conquest that opened new horizons, both scientific and technological, to explore. All the while, despite the Cold War, international and interdisciplinary projects are established, and new international organizations, such as UNESCO, appear to cope with the new challenges. Alongside these organizations, the longstanding ICSU and the Union adapt themselves.

With unprecedented demographic growth, food and public health had become challenges that were met through the development of industrial production and intensive farming, in which chemistry played a crucial role. However, this was not without any societal impact, and contributed to raise social awareness on chemistry's environmental impacts. Rachel Carson's book, *Silent Spring,* in 1962, accompanied the beginning of that movement, at the very time chemistry underwent new expansions and developed new interdisciplinary approaches.

The International Conferences of Chemistry (equivalent to nowadays General Assembly), which were privileged moments for Council, sections and commissions meetings, were in a productive rut. A report of the state of the Union was distributed in advance to all members, sharing the internal affairs of the Union. It was the opportunity to recollect deceased members, summarize the work of the executive committee based in the reports of the sections and commissions sent by their chairs, and share news on the collaboration with ICSU and UNESCO, to which the president of IUPAC would add his personal reflection on the general policy of the Union. The presidents between 1957 and 1975 were main movers in important changes, not so much in the structure of the Union than in a fresh way to relate to the non-chemical world, and the new adhering organizations [2].

The turn of the sixties: milestones in IUPAC history

Arthur Stoll (1887-1971) and William A. Noyes Jr. (1898-1980), respectively President from 1955 to 1959 and from 1959 to 1963, initiated these reforms. As early as 1957, and in the midst of his tenure, Stoll (Sandoz Ltd, Bâle) underlined two major concerns, stemming from the increasing level of activities of the members, which would later significantly impact the evolution of the Union. First, the question of financial resources needed for the Union to intensify its actions called for more support from the chemical industry. Second, there was the question of lack of diversity in the representation in the Council, the section committees, and the commissions. Western Europe and North America were indeed largely dominant, and some adhering countries didn't even have any commission representative (see fig. 1), (cb2, p.49). In 1961, Noyes also insisted on the matter in an unusually long half term report. To him, the Union was facing the following difficulties, which we will elaborate on in the next pages: (a) The rapid evolution of chemistry; (b) The increase of direct exchanges between chemists as travels become more accessible; (c) The financial state of the Union, and (d) Awareness of IUPAC and publications.

The rapid evolution of chemistry

Faced with the challenges of interdisciplinarity and the changes in the boundaries between chemical specialities, IUPAC had to adapt. For instance, a new commission was established to spread the recent advances in the use of spectroscopy in chemical analysis: The Commission on Molecular Spectroscopy, founded in 1957 following Harold Thompson's suggestion, who was to be its chairman until 1963 [3]. The aim was here again to propose relevant methods and recommend standards. Thompson (1908-1983) also chaired the independent *Triple Commission for Spectroscopy* from 1965-1967, a joint commission linked to the three international Unions (Physics, Chemistry, Astronomy) under the aegis of ICSU. (Thompson will later serve as IUPAC President in 1973-1975.) Other specific topics required new international commissions: for example, catalysis was not represented in the Union at this time. Also, IUPAC had to be devoted to applied as much as pure objects of investigation; in particular, IUPAC had to be involved in topics more relevant to the global society such as atmospheric and water pollution, water wastes, industrial toxicology, and so on. Noyes added that several organizations needed expert and objective advice and IUPAC had to fill that role, going beyond scientific nationalism to benefit human kind: "A resurgence of scientific nationalism must not be tolerated" (cb4, p. 75). The modernization of commissions was urgent. In 1963, at the end of his term, Noyes insisted once more on the opening of IUPAC to new fields, stressing especially the duty to support ICSU's commitments and the proposal of UNESCO on science teaching.

The travel revolution and the acceleration of direct exchanges between chemists

Travelling was becoming easier and more accessible, which allowed the chemists to meet more regularly and discuss issues without waiting for the International Conferences or Congresses. For the Union, that meant a loss of control in the decision process. The travel revolution had another impact: easy travel also eased the circulation of chemists from developing countries. As mentioned earlier, both Noyes and Stoll were convinced that IUPAC had to open itself geographically. Noyes argued with data and repeatedly detailed how much IUPAC was mostly a North American and Western European organization. Office terms should also be shorter to include more diversity, and the statutes were reformed to that aim. Principally the president term was reduced to two years. Alexander R. Todd (1907-1997), who succeeded Noyes in 1963, was the first president with a two-year term, with the vice president considered president elect and the past president remaining in the Council also for two years. At the section level, a president now had to be chosen not only for his standing as a chemist but also his nationality. As a result of this policy, Victor N. Kondriatev (1902-1979), from the Soviet Academy of Science, was the first Russian president in 1967 [4]. At the time, the Bureau (1967-69), in addition to Kondriatev, was only composed of 5 non-European and non North-American members out of 23 (thus only 22 % of titular members) (cb7, p. 15). However, to avoid potential distorts,

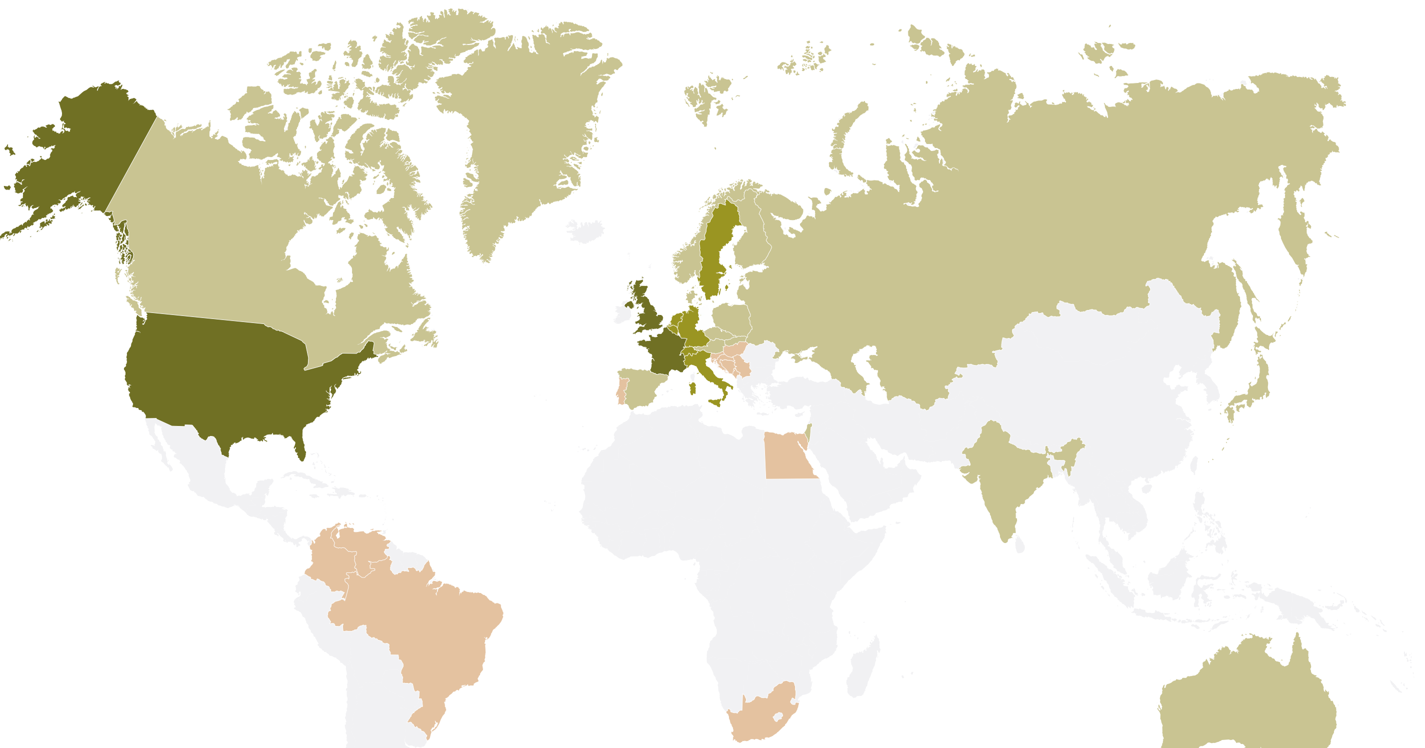
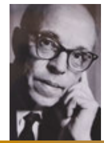


Fig. 1 : on the question of lack of diversity, data presented by Stoll in 1957(cb2, p.49).

USA	66	Spain	5	Poland	1
UK	53	Australia	4	USSR	1
France	47	Austria	4	Brazil	0
Germany	24	Czechoslovakia	4	Colombia	0
Netherlands	23	Canada	3	Egypt	0
Sweden	19	Finland	3	Hungary	0
Switzerland	16	Norway	3	Portugal	0
Italy	13	India	2	South Africa	0
Belgium	11	Japan	2	Venezuela	0
Denmark	8	Israel	1	Yugoslavia	0

Todd
23rd ICC, Paris
XX Congress, Moscow
1965

Klemm
24th ICC
XXI Congress
Prague
1967



Kondratiev
25th ICC, Cortina d'Ampezzo
XXII Congress, Sydney
1969

Kondratiev immediately underlined that the choice had to prioritize the scientific excellence, above geographic provenance.

The financial state of the Union

Up to 1955, the financial health of the Union had been excellent, allowing for a steady growth in the Union's activity and presence compared to the other Unions. In 1956 however a deficit was clearly emerging.

The recurrent financial struggles were due to the ever-increasing international involvement in scientific and technological questions. ICSU, at that time, was very committed to interdisciplinary operations, starting with the International Geographical Year (1957-1958), and continuing with the Committee on Space Research (COSPAR, established in 1958), the Special Committee on Oceanic Research (SCOR), and the Special Committee on Antarctic Research (SCAR, established in 1957). In parallel, ICSU was also collaborating with other international organizations such as FAO or ISO (particularly with the change of the international system of units from CGS to MKSA), all activities which included IUPAC. That required a reform of the statutes, which was agreed upon, to provide greater structural flexibility to the divisions (the new name of the sections), to allow them to send members in these new structures.

To solve the financial dead-end, Stoll recalled a proposal made in 1955 but not implemented: to ask for contributions from leading chemical companies. That was done in 1961. At this time, the secretary general Rudolf Morf (Switzerland) was based in Basel and benefited from the generosity of the Swiss Companies, notably of Sandoz where he worked, and later, of F. Hofmann-La Roche. Morf, an industrial engineer and secretary general since 1956, was not only honorary secretary but also executive secretary. Discussions with big chemical companies led to the creation of a new group of IUPAC adhering bodies: the *Company Associates Group* (CAG) that would have delegates at the Council without voting rights. In 1967, the CAG had 70 members.

IUPAC also benefited from advice from the Union Bank of Switzerland, which ensured a better management of the funds. During the '60s, the taxes on IUPAC funds kept in London increased significantly. On the advice of the Union Bank of Switzerland, they were sent to Zurich, where they were free of taxes. The headquarter, in Paris since the birth of IUPAC, followed, and was now located in Zurich Airport, along with the archives—In this way, IUPAC entered the Swiss legal system. The increasing activity of the Union also imposed new consideration on the secretariat work that had exceeded what the secretary general was able to handle. At last a permanent office was installed, not without difficulties, in Oxford in April 1968 (cb8, p. 13).

Spreading the word beyond the immediate circle

As Stoll stated in 1959, IUPAC was not well known beyond its immediate membership. More had to be done to raise IUPAC's profile in the wider community, as for instance growing a stronger presence through publications such as the Red Book [5]. With regard to other publications, the IUPAC journal *Pure and Applied Chemistry* (*PAC*) born in 1960 enjoyed increasing success, and a more ambitious version of the *Information Bulletin* was even suggested. This bulletin, a booklet really, was sent to Council members to inform them of decisions taken during the regular Council meetings. Raymond Delaby initiated this publication in 1948 as *Circulaire d'information*. The typescript *Bulletin d'information* managed by R. Morf turned into the *Information Bulletin* in the 1960s, underlining the role of English as the only vernacular language of IUPAC. It was presented at this time as a booklet, nicely printed by Butterworths, London, giving news on recent proposals in nomenclature to be discussed before they were published, or commissions or committees' reports, among them the Committee on Teaching Chemistry (CTC). In 1979, it became *Chemistry International*.

The '60s and '70s: Opening to the world and facing societal challenges

As stated earlier, the exponential growth of specialized fields of chemistry, often interdisciplinary, required adjustments in IUPAC's structure, and the time period 1965-1975 witnesses several modifications. Division IV (biological chemistry) disappeared in 1967, as the relationships with IUB pacified, and the corresponding nomenclature commission was moved to Division III (organic chemistry). The commission of clinical chemistry turned into a section attached to the Bureau (cb7, p. 26), before eventually becoming a division (Div. VII) in its own right in 1979. By contrast, in 1967 the commission on macromolecular chemistry rose to the level of a division: the Macromolecular Division (Div. IV) (without of the term 'chemistry'), later (in 2004) renamed the Polymer Division. A Joint commission IUB-IUPAC was linked to Divisions III (organic chemistry) and IV (macromolecular) for matters of nomenclature. The breadth of topics foreshadows other specialized commissions.

The Analytical Chemistry Division (Div. V) seems to remain unchanged through that period, but a closer look shows that, because of the increasing sensitivity of analytical instruments, its commissions adopted more contemporary topics especially in the field of trace analysis.

The Applied Chemistry Division (Div. VI), composed of several sections, each of them with several commissions, evolved substantially, demonstrating how much more engaged IUPAC was in interdisciplinary projects related to society. One good example of this is the Commission on Pesticides. The name of this Pesticides Section, early Crop Protection Products Division (1953) linked with an international body on agronomy, was changed in 1959. From 1965 onwards, in relation with the Codex Alimentarius Commission of the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) of the UN, the decision was taken to establish standardized analytical methods to measure the pesticides residues in foodstuffs. To that aim, two commissions were set up in 1967 (cb7, p. 165): Terminal Pesticides Residues and Pesticide Residue Analysis, which published long reports in the *Comptes rendus* the following years, notably in 1969 (cb8, p. 166-208). The 1975 reports of these commissions reveal the extent of the work accomplished.

In the same way, *Food Section* (VI.1) was replaced by its two commissions (Food Additives and Food Contaminants) and a Coordinating Committee in 1975 (cb11, p. 304), signalling the new perspectives and demands on food control by intergovernmental agencies. In a similar fashion, the *Water, Sewage and Industrial Wastes* commission became the *Commission on Water Quality* while a new *Commission on Air Quality* was formed. In the meantime, and under the pressure of several unions including IUPAC, ICSU creates SCOPE in 1969, one of the aims of which is the study of the social effects of man-made change in the environment. The IUPAC SCOPE Committee was linked to the IUPAC Executive Committee, and its members came from both the Analytical and Applied Chemistry Divisions. By skip stones, there was a shift in the topics discussed inside these divisions.

But three Interdivisional Committees (nomenclature, machine documentation and analytical methods) demonstrated the limits of the traditional structure of IUPAC; they were created outside of the divisional hierarchy to facilitate exchanges between their members and to avoid double studies and to represent IUPAC in other international organizations.

Even though IUPAC's structure as it stands in 1975 displays a distribution of topics and fields more in tune with the evolution of chemical sciences and technology, the structure was in fact still based on the

Puzzling logos and the story behind

In 1969, and likely to celebrate IUPAC 50th anniversary, the Union started to use the logo we are most familiar with today. Before, after, and in between, others appeared in various publications, and some are quite elusive. **Who can tell that story? If you are interested, please reach out** edit.ci@iupac.org.

Taking stock in 1973: Bénard's report on the state of the Union

In contrast with tradition, Jacques Bénard (1912-1987) addresses three major issues in his 1973 state of the Union, leaving aside all the routine questions of details. Interestingly, his approach anticipates the major organizational reform the structure of IUPAC will undergo a few years later (cb10).

The first point focuses on nomenclature. IUPAC's traditional role in nomenclature was now scattered in specialized commissions, to the point that an *Interdivisional Committee on Nomenclature and Symbols*, attached to the Executive Committee, had been created to coordinate these different commissions, on the suggestion of the CNIC in 1963. A task group was asked to investigate the possibility of regrouping all activities pertaining to nomenclature, and perhaps to symbols, in a particular division.

The second theme related to chemistry's applications. Since the merging of commissions in divisions in 1951, the place for applied chemistry was problematic, because of its swift expansion and flexible boundaries with established domains of chemistry. More crucial was the budding preoccupation of national governments with food quality, as well as the environmental and health impacts of chemistry. An interdivisional approach was necessary, and it was high time to give a statutory place to the Company Associates Group (CAG) that had played a crucial role. This CAG became the very active *International Company Associate Group* (ICAG) in 1973, and later the *Committee on Chemistry and Industry* (COCI) in 1977, definitively becoming an integral part of IUPAC structure.

ICAG promoted the interests of chemistry within civil society, and under its influence, a new Committee, *CHEMRAWN* (*Chemical Research Applied to World Needs*), totally different from the traditional commissions in its structure and working, was founded in 1975 and set directly under the Executive Committee's responsibility.

In his report, Bénard already advocated for a more flexible structure of the Union, based on operational projects with a clear delineation in terms of goals, duration and financial means. In his view only such a reform would allow the Union to follow closely and efficiently the course of development in applied chemistry.

The third point dealt with IUPAC's relations to other national and international institutions. A need for rationalization at the ICSU level was clear (SCOPE, CODATA, COSPAR, etc.). Under the aegis of UNESCO, IUPAC participated at a high level with the thriving joint actions for education: international meetings, but also publications, including the *International Newsletter on Chemical Education*. With this periodical, the Committee on Teaching Chemistry (CTC) was building on the success of the "New trends in chemistry teaching."[1] Notably, the establishment of the *Associated Organizations* membership had already secured steady liaisons with learned and technical societies related to chemistry.

Bénard concluded that the structure of the Union did not suit the present circumstances of chemistry and the wealth of its applications—he went as far as saying that if IUPAC was created in 1973, it would actually be on totally different fundamentals. To him, IUPAC ought to develop a way of adapting to the conjunctures of chemistry, creating new commissions if necessary, but also being able to accept the dissolution of the oldest or inefficient ones to leave the way to new commissions, otherwise the actions of the Union would soon become fruitless.

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1 E. Cartmell (ed.), *New trends in chemistry teaching / Tendances nouvelles de l'enseignement de la chimie*, vol. 1 (1964-1965) (UNESCO, 1967, 2nd ed. 1968), Foreword by R.S. Nyholm, chairman, CTC-IUPAC; Vol. II

principles of 1950. And as chemistry deployed in all its components and pervaded all aspects of life and society, the pace of IUPAC's structural adjustments proved too slow. It would be necessary to wait until the '90s to make a radical transformation of the Union.

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1. R. Marquardt. The mole and IUPAC: a brief history, infra p. 50
2. The IUPAC presidents between 1957 and 1975 were: Arthur Stoll (1955-1959), William A. Noyes Jr. (1959-1963), Alexander R. Todd (1963-1965), Wilhelm Klemm (1965-1967), Victor N. Kondratiev (1967-1969), A. Lloyd G. Rees (1969-1971), Jacques Bénard (1971-1973), and Harold W. Thompson (1973-1975).
3. C. Reinhardt. IUPAC: Engaged in the Instrumental Revolution, infra p. 35
4. E. Zaitseva-Baum**.** The First Russian President of IUPAC: Victor Kondratiev (1902-1979), infra, p. 33
5. G.J. Leigh. A History of the IUPAC Commission for the Nomenclature of Inorganic Chemistry (CNIC), infra p. 39

continued on page 34

The First Russian President of IUPAC: Victor Kondratiev

by Elena Zaitseva-Baum

Victor Nikolaevitch Kondratiev was elected a member of the Bureau, the Executive Committee and the Editorial Board of IUPAC at the beginning of the XXI[st] International Conference in Montreal, in August of 1961. He succeeded Boris A. Kazanski (1891-1973) who had resigned. At this time the Academy of Science of USSR was the national adhering body in IUPAC since 1930.

Kondratiev's portrait—date unknown. Photo from the archives of the Institute of Chemical Physics RAS.

As a full member of the USSR Academy of Science (1953) Kondratiev was indeed a world-renowned scientist at that time. He began his scientific work in Petrograd (known as Leningrad since 1924) in the Physical-Technical Radiological Institute where he designed the first spectrometer for research purposes in the USSR. In 1925 he was trained by James Franck at the Physical Institute of the University of Gottingen where he mastered the spectroscopic methods and studied photochemical reactions. Later, Kondratiev's main scientific activity was associated with the Institute of Chemical Physics of the Academy of Science of USSR (*Institut khimicheskoĭ fiziki*, Leningrad), located in Moscow after 1943 and established by the Nobel laureate Nikolaï N. Semenov (1896-1986) in 1931. As a corresponding member of Academy of Science of USSR (1943), Kondratiev held the position of the deputy director of this Institute beginning in 1948. His most famous works were devoted to the investigation of elementary processes during chemical transformations in the gaseous phase. Kondratiev's career and his international contacts explain why the scientist was immediately elected at the Bureau. He was also involved in the Commission on Molecular Structure and Spectroscopy (CMSS) as associate member from 1963 on.

In 1965, owing to Kondratiev's efforts, the 20th IUPAC Congress was held in the USSR (Moscow, 12-18 July) for the first time. Under his supervision as chairman of the Soviet Organizing Committee, 570 proposals were selected out of the 760 submitted. Kondratiev who was elected IUPAC vice-president some days before this congress at the IUPAC general assembly in Paris (2-9 July), was elected president in 1967 for a two year term. The scientist also took part in founding CODATA (1966) as an interdisciplinary Committee of ICSU. Notably, he participated in a special Task Group of this Committee, established in 1969, and his most important initiative was the foundation of the special kinetic section within the Task Group [1].

(from left to right) Nikolaï N. Semenov, Cyril N.Hinshelwood, Victor N. Kondratiev in 1956. Photo from the archives of the Institute of Chemical Physics RAS.

As president of the IUPAC, Kondratiev brought up the question about the composition of Division Committees and Commissions (memoranda 1967 and 1969). The Memorandum written in 1967 contained two main proposals: "(1) that each

Commission of a Division should be represented in the Division committee itself and (2) that National Bodies should be invited to send representatives to meetings of Commissions" [2]. These proposals, approved, would be applied at the next elections as a mean of "strengthening the responsibility of Presidents and Committees of IUPAC Divisions for the activities of their Commissions and Divisions" [3]. Among others the need to introduce procedure rules or regulation for the Divisions activities was felt, by analogy with the procedures existing in the Analytical Division.

Before leaving IUPAC, Kondratiev considered—as his last task—the necessity to include representatives of the Soviet chemical industry as participants of IUPAC. To that aim, he raised the issue in the late 1960s before the Presidium of the Soviet Academy of science about the creation of a special organization: the National Committee which would include representatives of the domestic chemical industry along with representatives of the Academy of Science and Ministry of Higher Education. Such an organization was founded in the USSR by the beginning of the 1970s. Kondratiev headed it until his withdrawal from IUPAC in 1971.

Postage stamp issued by the USSR on 15 June 1965 to publicize the 20th IUPAC Congress, held in Moscow a month later (12–18 July). See Daniel Rabinovich, Chem Int Jan-Feb 2009, 29(1), p. 3; https://doi.org/10.1515/ci.2007.29.1.3

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3. RAS Archives. Fund 579 (Foreign Relations Main Administration of the USSR Academy of Sciences). Schedule 4. File 848 (Materials on the participation of Soviet scientists in the activities of IUPAC). (Archives in Russian, quotes in this article translated by the author)

Dr. Elena Zaitseva(Baum), Senior Research Fellow and lecturer of history of chemistry at Moscow University, is the coauthor of several monographs on Russian scientists (e.g., Wladimir Fedorovich Louginine, Moscow, 2012) and a number of textbooks (e.g., Chemical discoveries and theories of the first half of the XIX century. The historical excursus. Baku, 2018). She is Russian representative in the EuCheMS Working Party on History of Chemistry.

IUPAC Expansion from 1957 to 1975 (cont. from p. 32)

Complementary bibliography (cb)

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IUPAC Engagement in the Instrumental Revolution

by Carsten Reinhardt

In the second half of the Twentieth Century, the chemical and molecular sciences experienced a deep transformation with regard to the types of research instruments used, and the associated methods involved. Historians have coined this development the *Instrumental Revolution,* and even described it as the Second Chemical Revolution [1]. With the latter notion, they referred to the First Chemical Revolution of the late eighteenth century, when Antoine Laurent Lavoisier and his allies transformed chemistry's theoretical framework along with its nomenclature, creating modern chemistry. The "second" chemical revolution of the twentieth century had an equally deep impact on chemistry's theoretical base, linking chemistry to quantum physics, and expanding its range into the life sciences and technologies, the material sciences, and engineering. However, the related changes in terminology and nomenclature have largely escaped the historian's attention, and this might explain why IUPAC's role in the Instrumental Revolution has not been investigated in any detail. In the following, I will first briefly describe the Instrumental Revolution, and its main impact on chemistry and related fields, before sketching IUPAC's role in facilitating and enhancing it [2].

Physical Methods Reach the Core of Chemistry

The key development of the Instrumental Revolution has been the introduction of techniques and methods that had mostly been developed in physics and were based on advanced electrical engineering as well as concepts of theoretical physics. Examples include Infrared and Ultraviolet Spectroscopy, Raman Spectroscopy, Mass Spectrometry, Nuclear Magnetic Resonance (NMR), Electron Spin Resonance (ESR), and many others. These spectroscopic methods were used for the identification of molecules and elements, and they often came hand in hand with chromatographic techniques applied for separating single compounds, or groups thereof, from mixtures, in this sense isolating them.

It is of course true that physical methods were applied in chemistry from very early on—Lavoisier's first chemical revolution being a famous case in point—but arguably the usage of such old physical methods was rather limited, both in scale and scope. Even in the late nineteenth century, when modern physical chemistry came into being with the "push" of concepts and techniques of physics, the "pull" of most chemical subdisciplines was rather slow in coming, and weak. Notably organic chemistry, chemistry's most dynamic and powerful subdiscipline in the late nineteenth and early twentieth centuries, only reluctantly applied methods that were not relying on wet chemistry. Still, infrared spectroscopy had its impact on organic chemistry even then, and ultraviolet was soon joining, but the bulk of the organic and inorganic chemists' benchwork was still done with test tubes and consisted mainly in carrying out chemical reactions. Analytical and synthetic chemistry still worked hand in glove sharing the same basics in methodology. The cornerstone of the feat of the elucidation of an unknown molecule's structure was its synthesis.

Much of this changed in the mid twentieth century, and it changed very rapidly so. The above-mentioned techniques, and others, took chemistry by storm. In the year of Sputnik (1957), elite US scientists assembled in the newly founded National Science Foundation (NSF), were drumming the news that "much can still be done with test tubes, slide rule, paper and pencil, but there is now convincing evidence that great scientific discoveries are to be expected through the development and use of the expensive new tools of scientific research [3]". In 1965, a detailed survey by the US National Academy of Science, aptly entitled *Chemistry: Opportunities and Needs*, brought up empirical evidence that the experimental practice of all chemists had deeply changed. A graph showed the seven most widely used new instruments in chemistry, based on their citation rate in articles of academic journals. Most of these techniques (Infrared, Ultraviolet, NMR, VPC (vapor-phase or gaz chromatography), Computer, Mass Spectrometry, and ESR) came into existence only after 1940. Their citation rate (which supplied a measure for actual use) in the early 1950s equaled only ca. 43 per 100 articles, thus less than a half of all relevant publications used one of these techniques. In 1964, about 120 citations per 100 articles made clear that the authors of the articles used on average 1.2 of these techniques in the work leading to a single publication. What was once unusual became routine, and a necessity, in roughly a decade and a half. See Figure 1.

What were the reasons for this rapid and wide-ranging transformation of chemical practice? How did it unfold? To answer the first question, historians have pointed to the impact of World War II. Armament research and development led to major advances in electrical engineering, and many appliances, for example those related to radar, found their way out of military establishments into the scientific laboratories. In addition, physical theory since the 1920s has brought about major shifts in chemistry as well. The theoretical

Walmer Studios. "Beckman Instruments International Touring Laboratory," 1964. Beckman Historical Collection, Box 57, Folder 24. Science History Institute. Philadelphia. https://digital.sciencehistory.org/works/ws859f652.

understanding of chemical bonds and molecular structure made such clear advances that all chemists had to take notice—mentioning the names of Linus Pauling (1901-1994) and Robert S. Mulliken (1896-1986) might suffice here. All of this was connected to the use of physical methods, and soon, all chemists had to apply them, because colleagues that had a tendency to "ride the waves" of new technologies used the generous funding available after the start of the Korean War to speed up their efforts. Thus, technology push and demand pull came together with the felicitous rise of governmental spending on science.

However, methods development is still seen today by many as a marginal affair, relegated to the methods sections in articles, and finding refuge only in the technical bulletins of industrial suppliers. In contrast to this neglect, the role of methods development loomed large in science: method makers developed and applied all kinds of research instrumentation, from big science to table-top instruments. They often worked in an interdisciplinary fashion, and played a major role in the tremendous expansion of the chemical sciences in the second half of the twentieth century. Arguably, without the inroads of physical methods into chemistry, many of the recent advancements in science and technology—from material science and nanotechnology through molecular biology and the life sciences to medicine—would not have been possible. Crucially, many activities of the method makers involve standardization, terminology and nomenclature. Thus, it does not come as a surprise that IUPAC and its commissions had a major role in the rise of physical methods in chemistry, and in the expansion of chemistry's reach into neighboring fields beyond chemistry's original turf. In the following, I will sketch briefly some of the major hubs of IUPAC's activities in this regard, with special attention to the strategies deployed, and the goals envisaged.

Facing new methods in chemistry

In 1960, early in the Instrumental Revolution, William Albert Noyes (1898-1980), then president of IUPAC, together with Harold Warris Thompson (1908-1983) gave methods center stage in a description of IUPAC's major functions. Referring to the longstanding goals of IUPAC to facilitate international agreement, and to bring about "uniform practice," they included "certain methods of analysis and assay." [4] In IUPAC's characteristic structure, commissions took over this task, notably those in the Analytical Chemistry Division (ACD), and especially the Commission on Molecular Structure and Spectroscopy (CMSS) of the Physical Chemistry Division.

Plans for including spectroscopic methods in IUPAC's portfolio reach back to the year 1951, when IUPAC's division structure was firmly in place. After some delays, the CMSS was founded in 1955 at the meeting in Zurich, with Thompson as president. This was done with the awareness that existing sub-commissions on absorption and emission spectroscopy of the Division of Analytical Chemistry were only focusing on procedures directly relevant for analysis. Moreover, it was felt that European and US activities needed more coordination. In taking up this task, the CMSS in the late 1950s focused on standardization and presentation issues, mainly of Infrared and NMR Spectroscopy, adding Optical Rotatory Dispersion, the latter a technique developed by Carl Djerassi (1923-2015) in the United States. In addition, activities unfolded to coordinate between IUPAC, the International Union of Pure and Applied Physics (IUPAP), and the International Astronomical Union (IAU), which later led to the creation of the Triple Commission on Spectroscopy—since 1966 under the aegis of ICSU. Inside IUPAC, in the Analytical Chemistry Division, a commission of optical data was formed in 1955, which in 1959 changed its name into Commission on Spectrochemical and Other Optical Procedures for Analysis [5].

Chemists in IUPAC were swift in their actions; most of them were crucially impacted by the Instrumental Revolution, and they were eager to develop guidelines and signposts. For example, a task force in the ACD focusing on gas chromatography formed in 1959, less than ten years after this technique had been invented. Among their aims was "to recognize and encourage existing, well established conventions, to the extent that they are basically sound (consistent with accepted theory) and of general utility." To "suppress confusion" their only weapon was the argument, making "these Recommendations as clear and concise that they will find universal acceptance." [6]

During this rather early period, most recommendations of members of the Analytical Chemistry Division were concerned with traditional techniques, such as titrimetry, trace analysis and microchemistry. For example, in the late 1960s and early 1970s the pace picked up and included General Atomic Emission Spectroscopy, Mass Spectrometry, and Analytical Flame Spectroscopy, among others [7]. At the same time, however, many of the other relevant, and booming techniques, such as

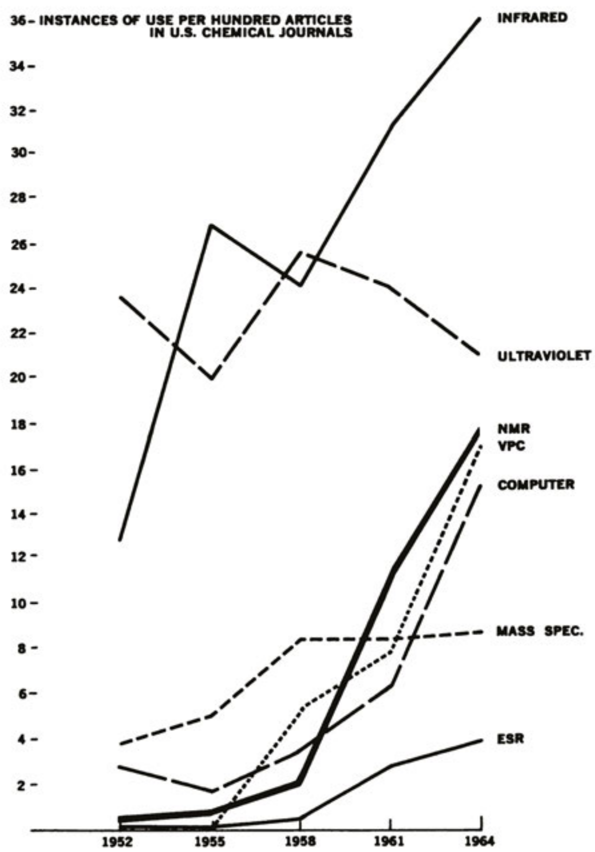

Figure 1. The use rate in chemical research in the United States for seven of the most commonly used types of instruments. The "use rate" is defined as the number of instances of use cited per 100 papers in selected representative journals. *(reproduced from* Chemistry: opportunities and needs; *a report on basic research in U.S. chemistry. National Academy of Science, National Research Council, Committee for the Survey of Chemistry, 1965, fig 16)*

Infrared, Raman, and Mössbauer Spectroscopy, NMR, and Optical Rotary Dispersion, were covered by the Physical Chemistry Division's Commission on Molecular Structure and Spectroscopy [8]. In 1963 they were also aware of the new challenges of computing and creating a sub-commission on storage and retrieval of spectroscopic data [9]. In the mid 1970s, the *Tables of Wavenumbers for the Calibration of Infrared Spectrometers* was IUPAC's best-selling book [10]. This followed an international trend, focusing many spectroscopies in the new subdiscipline of chemical physics, thus not in the general practitioners' domain of analytical chemistry. However, this was subject to change, beginning with the plans starting in 1971 to assemble the recommendations in a compendium. Following the models of compendia on nomenclature in organic and inorganic chemistry, and the Manual of Symbols and Terminology for Physical Quantities and Units, the new compendium was named the “Orange Book,” adopting the tradition of color nicknames for IUPAC titles. Published in 1978, the Orange Book contained the “definitive” (thus, approved by IUPAC) guidelines published before in *Pure and Applied Chemistry*. Today, the Orange Book is in the 3rd edition, first published in 1998, and available online.

In the 1970s, the goals of the IUPAC commissions consisted mainly in solving nomenclature and terminology issues, and there were many. In addition, they focused on calibration and standardization, thus covering the expected range of IUPAC. In the 1980s and 1990s, a new task gained prominence: performance evaluation, and related quality management both with regards to intra- and inter-laboratory evaluations. Increasingly, analysis was seen as a Chemical Measurement Process, a term for an analytical method with defined structure and statistical control. In this regard, Lloyd Currie in 1995 differentiated between sampling; preparation, measurement and evaluation; and presentation, and highlighting the middle pair as the central part of the measurement process. Equally important were the checkpoints of Standard (Certified) Reference Materials, and Standard Reference Data. Here, the IUPAC Analytical Chemistry Division was involved with publications and databases. Clarification of terminology continued, starting with general notions such as Precision, Accuracy, Technique, Methods, Procedure, and Protocol. IUPAC commission members were careful to apply precise definitions to practice, not just terminology. In 1995 the Commission of Analytical Nomenclature of the ACD distinguished between definitive methods (as stand alone, establishing accuracy), reference methods (related to a definitive method, or to certified materials), and standardized chemical measurement processes (used in the general practitioners’s laboratories), thus establishing a hierarchy of status between the methods developed and used. The first, definitive, rank was accorded to methods “of exceptional status...sufficiently accurate to stand alone in the determination of a given property for the Certification of a Reference Material” [11].

On this basis, in the early 2000s, David Moore, then chairman of the Analytical Chemistry Division of IUPAC, very aptly pointed to the Division’s impact during the last 50 years in an article describing the reform of its structure [12]. He emphasized the intermediary role of the IUPAC commissions between communities of academic scientists on the one hand and associations and organizations engaged in standardization on the other hand. Thus, facilitating the instrumental revolution led to an important role of IUPAC in the service of society, a role that continues to the present day.

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A History of CNIC

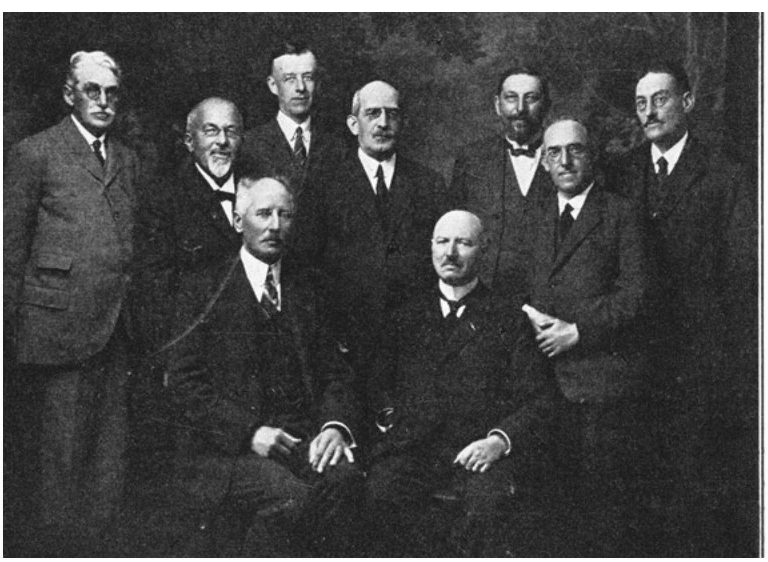
by G. Jeffery Leigh

The systematic nomenclature of inorganic chemistry is much older than IUPAC itself, and so is the history of the Commission for the Nomenclature of Inorganic Chemistry (CNIC). The nomenclature developed as new chemistry originated and grew at the beginning of the 19th century, when the chemical community came to recognise the need for international agreement on the formalisms to be used, to enable practitioners from different countries to understand communications between them. In that period such communications were only written or printed. Since CNIC produced the first of its IUPAC Red Books on the nomenclature of inorganic chemistry in 1957, the Red Books themselves have been continuously rewritten and expanded as the science of chemistry has grown, and they represent a collaborative production, both in the number of people involved and the time-frame they occupy, which is possibly unique in modern science.

The International Union of Pure and Applied Chemistry (IUPAC) was formally founded in 1919 by delegates from Belgium, France, Italy, UK, and USA, as described in Fennell's History of IUPAC [1]. The members of the earlier International Association of Chemical Societies were invited to join the new organisation, though Germany and the former Central Powers were not, and there was no national government of the former Russian Empire. A series of Commissions had been established between 1922 and 1928, amongst them a Commission for the Reform of the Nomenclature of Inorganic Chemistry, which, along with Commissions for organic and biological chemistry nomenclatures, dated from 1922. It was this Inorganic Nomenclature Commission which published a report in both French and German on the reform of inorganic chemistry nomenclature in 1940, though an earlier, largely forgotten report on inorganic nomenclature had appeared as early as 1925. In contrast, international discussions on the nomenclature of organic chemistry date from the Geneva Congress of 1892, when the need for a widely accepted organic nomenclature was formally recognised.

1925 report of CNIC

By 1925, IUPAC comprised 28 adherents, while Germany and Austria were invited to attend meetings only in 1928. In the 1925 *Comptes Rendus of sixth International Conference on Chemistry*, the membership of the International Commissions for the Reform of Nomenclature is listed. Although every member of the Union was entitled to nominate a participant on each Commission, the Commission for the Reform of Inorganic Nomenclature comprised just twenty persons, and its Committee merely six. Presumably these six did most of the work, basing the contents on discussions at a series of international meetings since about 1900. Marcel Delépine (1871-1965) [2] was designated to write the report. The Commission's 1925 report was discussed and adopted unanimously at the meeting of IUPAC in Washington on 13-15 September 1926, with five amendments. The



International Committees on Organic and Inorganic Chemical Nomenclature at Paris in October, 1925

Left to right, standing:
A. J. Greenaway, Great Britain
F. Fichter, Switzerland
A. M. Patterson, United States
A. Pictet, Switzerland
M. Delépine, France
C. S. Gibson, Great Britain
R. Marquis, France

Sitting:
W. P. Jorissen, Netherlands (chairman inorganic)
A. F. Holleman, Netherlands (chairman organic)

The members of the organic nomenclature working group, along with colleagues on an analogous group dealing with inorganic nomenclature (Industrial & Engineering Chemistry 17, no. 12 (December 1, 1925): 1245.) See also E. Helper-Smith, Chem. Int Mar-Apr 2015, p.10.

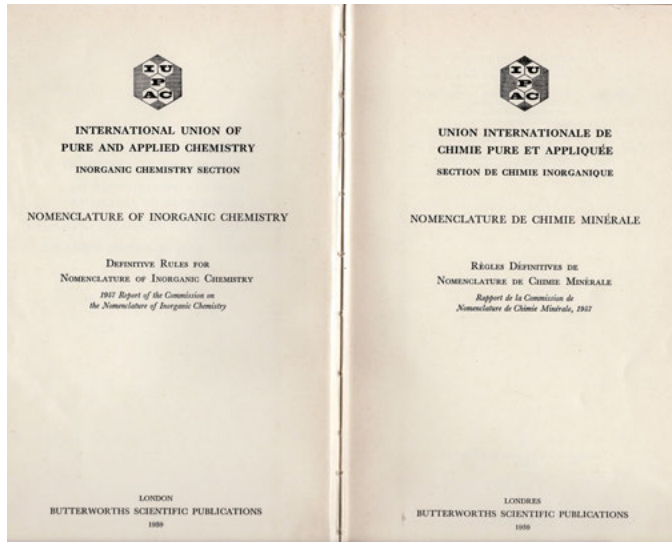
recommendations were presented solely in French. The details are not included in the IUPAC *Comptes Rendus*. Delépine's report provides a list of element symbols for international use because some element names and symbols in use varied with country. It also recommends methods for ordering and writing formulae and noting different valences. Numbers of atoms in a formula are represented by superscripts. Various types of salt are discussed, and two pages are devoted to what are now termed coordination complexes.

The "1940 Rules"

The 1940 Rules were published by CNIC in French and German. The members of CNIC at the time were eminent researchers [3,4], but whose ideas were established well before the renaissance of inorganic chemistry in the late 1950s. This report was finished by 1938, but due to the political situation at that time it was not reviewed internationally before publication. Two English-language versions, which originated independently in Britain [5] and the United States [6], described the parent body of these reports as The International Union of Chemistry. The US version occupied nine pages and the severely abbreviated British account only three. These rules specifically excluded discussing names of new elements, which were the business of the Atomic Weights Commission. Despite this, CNIC became deeply involved in new element names and symbols by the 1960s. The 1940 Rules were actually generally ignored, because they were not circulated for international discussion, and few knew of their existence. They represent an attempt to standardise practices of the time in inorganic nomenclature, not to consider possible future requirements. Structural information, widely discussed today, was almost entirely lacking in 1938.

The Rules cover names and formulae, the order of citation of parts of names, and how to indicate stoichiometry. The report recommends means for expressing formulae as names and for showing valence (today termed oxidation state), and for the ordering symbols in formulae, though formulae were again suggested to adopt patterns such as $NaCO^3$ rather than $NaCO_3$. This report also presages some of the problems which later occupied the efforts of both CNOC and CNIC such as word ordering and symbol ordering. The terminations –*ous* and –*ic* were recognised as often unsatisfactory, which has not prevented them from still being in widespread use today!

Major discussion concerned names and formulae of ternary, quaternary, etc., compounds, especially oxy-acids and their salts and presented long lists of compounds also citing many trivial names.


INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY
INORGANIC CHEMISTRY SECTION
NOMENCLATURE OF INORGANIC CHEMISTRY
DEFINITIVE RULES FOR NOMENCLATURE OF INORGANIC CHEMISTRY
1957 Report of the Commission on the Nomenclature of Inorganic Chemistry
LONDON
BUTTERWORTHS SCIENTIFIC PUBLICATIONS
1959

UNION INTERNATIONALE DE CHIMIE PURE ET APPLIQUÉE
SECTION DE CHIMIE INORGANIQUE
NOMENCLATURE DE CHIMIE MINÉRALE
RÈGLES DÉFINITIVES DE NOMENCLATURE DE CHIMIE MINÉRALE
Rapport de la Commission de Nomenclature de Chimie Minérale, 1957
LONDRES
BUTTERWORTHS SCIENTIFIC PUBLICATIONS
1959

The facing English and French title pages of RB 1957

Coordination compounds are treated by the method essentially devised by Alfred Werner (1866-1919) and dismissed in about a single column. Iso- and hetero-polyacids and their salts are covered in two pages and finally double salts, and hydrates and similar addition compounds are cursorily treated.

The 1957 Red Book (RB 1957)

In 1947 CNIC decided to revise the 1940 Rules. The text, covering 93 pages, was edited after submissions from national bodies and three discussion meetings, and was published in two languages, an English version facing page-by-page a French version, which was current IUPAC practice at the time. These were the first versions of the inorganic rules to be published and circulated commercially, and were intended for widespread use.

The names and symbols of the elements with their atomic numbers are listed in alphabetical name order, and there is no mention of the Periodic Table. The book adopted practices for designating atomic symbols with mass number, atomic number, ionic charge and the number of such atoms in a formula and used The Stock notation, first proposed in 1919. Most of the current methods of writing names and formulae were clearly prescribed by 1957. Treatment of coordination compounds in both languages occupies 24 pages, but a rational system to describe polymorphs was not possible in the absence structural information. RB 1957 essentially reflects the older style of research, devoted to accumulating new facts and materials, but rationalisation of data was much more difficult and rarely attempted. Inorganic chemists were fascinated by the specific facts of chemistry but knew little of electronic structure. Students of inorganic chemistry were expected to absorb large amounts of facts, and, if they could, to make any suitable generalisations. I remember being informed in a lecture by my first university teacher of inorganic chemistry in 1953 that "boron is like aluminium, only moreso." This did not mean much to me.

Nevertheless, the increase of interaction between chemists, limited to slow conventional post, required unequivocal methods of communication, and IUPAC was attempting to provide this through CNIC. Such was still the case when, in 1966, I attended my first meeting of CNIC in Copenhagen, as stand-in secretary. The job entailed writing minutes of the day's discussions so that they could be approved as the first item on the morning of the following day. I had newly moved to work at the Nitrogen Fixation Unit at the University of Sussex, and its Director, Joseph Chatt, was my motivator. RB 1957 was our major reference for solving nomenclature problems.

As chemistry developed, CNIC began to have problems in making decisions about matters that were also of common interest to the Organic Nomenclature Committee (CNOC), and these continued until the reorganisation of IUPAC and the formation of Division VIII in 2000 [6]. The scientists who produced RB 1957 had treated inorganic chemistry research mainly for collecting new facts and were not very interested in rationalisation. However a new generation of researchers were developing in the 1960s as well as new branches of chemistry, such as organometallic and solid-state chemistry and CNIC appreciated these developments. Consequently an enlarged new Red Book was produced in 1970, and though not significantly changed in coverage compared to RB 1957 it was written in English only.

The 1970 Red Book (RB 1970)

Work on this Red Book started in 1959, and involved most of the membership of CNIC as well as outside helpers, such as when considering macromolecular chemistry. Interim proposals had been published for comment in the *IUPAC Information Bulletin* before final editing of the text, so that the views of the chemistry community could be taken into account. The result was a much extended treatment of inorganic nomenclature and new formalisms to describe newly recognised phenomena. Work on organic derivatives of boron, silicon and phosphorus had been carried out jointly with the Commission for the Nomenclature of Organic Chemistry (CNOC) and had led to tentative proposals, which were also under review. RB 1970 contained a useful preamble, new treatment of coordination chemistry describing names of coordination compounds and of ligands, including unsaturated organic ligands, showing how they are bound. There is no mention of the Periodic Table, though the elements are listed as labelled groups, for example, Br, I, and At are labelled 7B, but without explanation.

The Commission on Nomenclature of Inorganic Chemistry, University of Reading, UK: 1956. Back row (left to right): Dr. C. L. Leese (UK), Prof. E.H. Buchner (Netherlands), Prof. A. Ölander (Sweden), Prof. J. Benard (France), Prof. S. Veibel (Denmark). Front row: Prof. W. Feitknecht (Switzerland), Prof. H. Remy (German), Prof. H. Bassett (UK, Hon. President), Prof. A. Silverman (USA, President), Prof. K.A. Jensen (Denmark, Vice-President), Prof. N. Bjerrum (Denmark), Dr. G.H. Cheesman (Australia, Secretary.)

CNIC meeting, Brisbane, Australia, June/July 2001. Seated, from left: Bernadette Donovan-Merkert, Ture Damhus (Secretary), Herbert D. Kaesz (Chair, holding the Red Book), Wim Koppenol. Standing: Alan T. Hutton, Neil G. Connelly, James Casey, Richard M. Hartshorn, Risto Laitinen, Dan Meyerstein, Vince Pecaro, and Lars Elding. Photo courtesy W. Koppenol.

The RB 1990 Red Book (RB 1990)

This was more than an update of the previous Red Book. The text was reviewed by specialists who were not members of the Commission. Much care was taken to reflect the new types of structure and bonding which had been discovered since RB 1970 had been written. In addition, an IUPAC Periodic Table appeared on the end-paper preceding the title page, and a short form is contained in an Appendix. RB 1990 also used long forms of the Periodic Table with the Group numbering I-XVIII which CNIC had introduced: indeed the two different A/B systems were liable to sow confusion amongst readers of chemistry papers and needed to be abandoned. CNIC had also been aware that though it carried responsibility at the time for deciding upon names and symbols for new elements it was sometimes necessary to provide names and symbols for elements which had not been unequivocally prepared but were the subject of academic discussion. RB 1990 described how to provide systematic provisional names and symbols for such elements [8].

RB 1990 took 10 years to complete, beginning in 1978. The 110 pages of RB 1970 had expanded in RB 1990 to 289. The new version, with specific authors nominated for particular subjects, aimed at providing users with a greater understanding of the methodology of inorganic chemistry nomenclature, not simply a book to be scanned to discover a name which seemed to deal with the reader's naming problem at issue. Coordination compounds occupy more than 60 pages, a 50 % increase on RB 1970. The problems of accommodating the names of large organic and organometallic ligands into the coordination nomenclature are broached, and the now widely used kappa method was used to designate coordination sites. The five-page chapter in RB 1970 devoted to boron compounds was here expanded to a thirty-page chapter on boron hydrides and related compounds, which included compounds with skeletal replacement, such as metallaboranes.

The 2000 Red Book (RB 2000)

This book, entitled *Nomenclature of Inorganic Chemistry II*, is an extension of RB 1990 (retrospectively regarded as Part I) and the topics covered are additional to those selected for Part I. Many of the species discussed in this version of the Red Book were new, unknown to traditional inorganic chemistry, and were not nameable by the established methods. Topics covered included polyanions including defect structures, isotopically modified inorganic compounds specific classes of compound, metal complexes of tetrapyrroles, hydrides of nitrogen and derived cations, anions, and ligands, inorganic chains and rings, graphite intercalation compounds, and regular single-strand and inorganic and coordination polymers.

A wholesale revision of both RB 1990 and RB 2000 was already underway by 2002 [9,10], leading to RB 2005. However, large organisational changes occurred after 2000. Both CNIC and CNOC were wound up in 2001, and many of their activities taken over by a newly established Division of Chemical Nomenclature and Structural Representation (Division VIII) and by the Division of Inorganic Chemistry (Division II) [8-10]. This new arrangement was expected to avoid the disagreements and confrontations which occasionally bedeviled CNIC and CNOC. The Commissions had worked and met quite independently of each other, but then experienced difficulties in arranging collaborative studies on topics, such as organometallic compounds and boranes, which were of joint interest. The duty of deciding priority for discovery of new elements became a joint exercise of both IUPAC and IUPAP. During the Cold War, claims to the preparation of new synthetic heavy elements, became matters of political interest and provoked heated discussions within CNIC, to the embarrassment of many of those present. The chemist members of CNIC were not capable alone of properly judging the physics of such claims. The new IUPAC/IUPAP procedure is wider both in its use of expertise and its objectivity. However, the task of considering and recommending new element names and symbols remains with Division VIII.

Red Book 2005 (RB 2005)

This version was considerably expanded and updated compared to RB 1990 and RB 2000, and presented much tabulated data. For persons attempting to construct new names, it is the most accessible yet produced. Different classes of nomenclature (compositional, additive and substitutive) and their uses, organometallic nomenclature, and nomenclature of various types of inorganic solid were introduced. The treatment of coordination compounds was much expanded.

Nomenclature still needs to be regularly adapted to meet the requirements to name new types of compound, as exemplified by nanotubes, graphene, and fullerenes and to settle discussions within the community find an acceptable solution to problems such as the wider use of kappa, and where to place locants in complex names in order to specify positions of substituents *etc.* in long names. Amongst the inorganic nomenclature problems currently under discussion in Division VIII are the nomenclature of metallacycles containing d-block elements and a detailed description of the kappa convention for specifying the coordination sites of ligands.

Conclusion

CNIC in one form or another existed for some eighty years. The Commission witnessed the amazing development of inorganic chemistry, which occurred principally after the 1950s, and the discovery of new kinds of compounds, the existence of which could never have been envisaged in 1919. The nomenclature necessary to specify the composition and structure of such had to be invented. CNIC also saw tremendous developments in computers and communication. These have eased collaboration between chemists, but also posed further questions. It is unsure whether we shall ever see a new comprehensive Red Book such as CNIC attempted to provide in the past.

Division VIII was designed to provide an integrated approach to nomenclature. Among the prime inorganic objectives still outstanding are the extension of the system of IUPAC-preferred names, inorganic InChIs, more databases of commonly used synonyms, and organometallic nomenclature, computer-assisted nomenclature of clusters, stereochemical nomenclature, fullerene nomenclature, dendritic and hyper-branched polymer nomenclature [8-10]. How these will develop is not yet evident.

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IUPAC and the Naming of Elements

by Ann E. Robinson

It was once not uncommon for elements to have more than one name. Tungsten and wolfram. Columbium and niobium. Beryllium and glucinum. The multiple names were generally due to language differences, personal preference, and nationality. These different names were ultimately harmonized into a single set of names after World War II with the development of a standardized nomenclature for inorganic chemistry (IUPAC's famous Red Book). At the same time, new elements ceased be to found in naturally-occurring substances. Rather, new elements began to be created in accelerators. The advent of synthesized elements raised new questions regarding the discovery of new elements. It also created a new set of challenges for their naming, one of the tasks of the old Commission on Nomenclature for Inorganic Chemistry (CNIC) of IUPAC. As we will see, to face these challenges the CNIC relied successively on the adjudication of the US National Research Council (US NRC) for the naming of promethium in 1948, and then on an ongoing partnership with the International Union of Pure and Applied Physics (IUPAP).

What constitutes discovery

Element 61 was one of the first synthetic elements with multiple discovery claims that came to the attention of the CNIC. Two claims were made in the 1940s by groups who were using accelerators. During their investigations into artificial radioactivity, a group at the Ohio State University obtained activities they attributed to an isotope of element 61. Experiments with the alpha bombardment of praesodymium at the University of California Berkeley seemed to validate this claim. In honor of the equipment they were using, they suggested the name cyclonium, symbol Cy, in 1941. Another claim was put forward by a group at the Clinton Laboratories in Oak Ridge, Tennessee. In the course of work on the Manhattan Project, this group claimed to have observed five isotopes of element 61 as fission products of uranium. In 1945, they proposed the name prometheum, symbol Pm. Just as Prometheus stole fire from the gods, man was harnessing the power of nuclear fission.

As the discovery claims had come from American groups, the US NRC's Division of Chemistry and Chemical Technology was asked to examine the claims and to make a recommendation to the CNIC as to a name and symbol for element 61. After gathering publications, reports, and other evidence, the US subcommittee tasked with this assignment was faced with several questions concerning the discovery of new elements, the most basic being what constitutes discovery. It was in answering these questions that they were able to make the judgement that the Oak Ridge group had made the discovery as they had provided chemical proof that the isotopes were those of element 61. It was recommended to the CNIC that it should be named promethium (the spelling was changed by the CNIC in 1949).

Dealing with controversies

From the 1950s into the 1980s, most new elements were synthesized in only two laboratories: the Lawrence Berkeley Laboratory in the United States and the Joint Institute for Nuclear Research in Dubna, Russia. Each lab claimed to have discovered elements 102 through 106, creating confusion and tension not only between themselves but in the wider scientific community. As the body that named new elements, the CNIC was placed in the position of attempting to adjudicate discovery claims. This was not a task they desired nor one they felt was suited for a nomenclature commission.

In 1987, a joint group was formed with IUPAP. This Transfermium Working Group (TWG) developed a set of criteria that needed to be met in order to determine if an element had been discovered [1]. The TWG then applied their criteria to the claims of Berkeley, Dubna, and the Gesellschaft für Schwerionenforschung (GSI), a West German laboratory that began synthesizing superheavy elements in 1981 [2]. Once the claims had been judged and priority of discovery determined, the new elements could be named by the CNIC.

IUPAC has been in charge of naming new elements since its founding. Until the 1970s, elements that had not yet been officially declared to have been discovered by the IUPAC had spaces on the periodic table bearing only their atomic number. However, with both Dubna and Berkeley using names for the elements they claimed to have discovered, it was decided that placeholder names were desirable until the IUPAC could make a decision as to who had discovered them. A systematic nomenclature for elements with an atomic number greater than 100 was put into place in 1979 [3]. Elements were named for the numbers, leading to names such as ununoctium, symbol Uuo, for element 118. The placeholder names could be replaced with names suggested by their discoverers only after the TWG established the discovery.

How to name an element

The names of elements have generally been based on a property of the element, the mineral from which it was isolated, the place in which it was discovered,

(from left) Georgy Flerov, Ivo Zvára, and Yves Jeannin meeting at the Joint Institute of Nuclear Research, Flerov Laboratory for Nuclear Research, in Dubna in March 1990. Photo courtesy Yves Jeannin.
The TWG visited Dubna 12-16 February 1990, but Y. Jeannin, IUPAC President at that time, was ill. Jeannin made a separate visit 7-8 March 1990 and met with Flerov, Zvara, Oganessian, and Ter-Akopian. Flerov passed away that year in November. Element 114, flerovium, is named after the Flerov Laboratory of Nuclear Reactions of the Joint Institute for Nuclear Research in Dubna, Russia, where the element was discovered in 1998. The name of the laboratory, in turn, honors the Russian physicist. The name was adopted by IUPAC on 23 May 2012 (PAC 84(7), 1669–1672, 2012; https://doi.org/10.1351/PAC-REC-11-12-03). The year prior, the TWG visited the Berkeley Laboratory 19-23 June 1989, and met with Glenn Seaborg; a photo of that group was recently published in Chemistry International January 2019, p.10 (https://doi.org/10.1515/ci-2019-0103)

a mythological character, or an astronomical object. Elements were rarely named after people [4, 5]. However, with the discovery of synthetic elements this has changed. Fourteen of the elements from 93 through 118 have been named after eminent scientists. This change raised a variety of issues for the CNIC.

A seemingly minor, but nevertheless highly debated, issue occurred with element 103. Named after Ernest O. Lawrence, lawrencium was originally given the symbol Lw. The point was raised that the letter w is one not found in many languages. It was proposed to change the name to laurencium and the symbol to Lr. After some discussion, it was agreed that the spelling of a person's name could not be changed. Element 103 remained lawrencium, although its symbol was changed to Lr in 1963.

Perhaps the most controversial issue was the prospect of naming new elements after persons who were still living. This was something of a gray area as both Albert Einstein and Enrico Fermi were alive when elements 99 and 100 were first discovered in the debris of the first US hydrogen bomb test, but both had died by the time the discoveries were declassified in 1956. The controversy arose when the group at Lawrence Berkeley Laboratory proposed naming element 106 seaborgium after Glenn T. Seaborg who was still alive. In 1994, the CNIC decided that elements should not be named after living persons so as to have the perspective of history but they reversed that decision only a few years later in 1997 [6, 7].

The Next Row of the Periodic Table

The 7th row of the periodic table was filled in 2016 and the search for elements that will fit in the 8th row has already begun. Looking ahead to those yet-to-be discovered elements, the documents outlining the criteria that need to be met to determine discovery and how to name an element have recently undergone revision to account for the changes that have occurred since they were first put into place several decades ago [8, 9]. These documents have served to secure a common language for chemists around the world and should continue to do so in the future.

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A Century of Nomenclature for Chemists and Machines

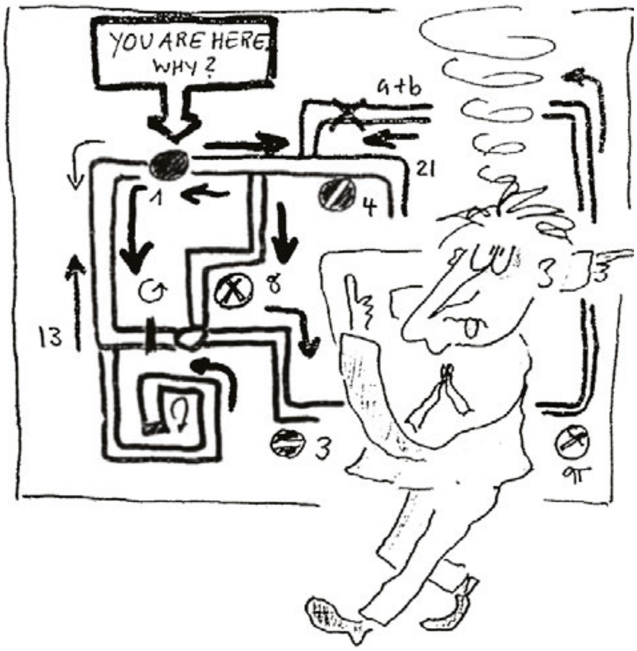
by Evan Hepler-Smith and Leah McEwen

The chemist's tongue is sticking out and his eyes are upturned in concentration. Spirals circle above his head; the chemist is confused. His body twisted into a knot, he slowly backpedals, one finger pointing straight up, the other pointing backwards. To his side, a chart displays a maze, or perhaps a diagram of a complex logic circuit, illustrating an arcane web of decisions and procedures. A dot sits at rest within the diagram, marking the stymied chemist's progress through this maze. It is annotated with a comment: "You are here. Why?"

A good-humored manuscript author sent this sketch to M. Volkan Kisakürek, editor of *Helvetica Chimica Acta* and member of the IUPAC Commission on Nomenclature of Organic Chemistry from 1987–2001, as an illustration of the challenges of systematic chemical nomenclature. Following nomenclature rules, the cartoon suggests, was a task more fit for a machine than for the poor confused chemist.

From the founding of IUPAC a century ago, codifying rules of chemical nomenclature has been one of the Union's central functions. Since 2001, IUPAC has concurrently pursued the parallel project of establishing a method for generating unique, machine-readable chemical identifiers, the notation now known as the IUPAC International Chemical Identifier (InChI). The impressive InChI project combines IUPAC's deep institutional experience developing chemical nomenclature standards with the distinctive challenges of a digital, globally networked information landscape [1-3].

Though the InChI project is relatively new, the history of IUPAC efforts to standardize chemical representation in the digital world stretches back to the 1940s. Whereas the history of IUPAC nomenclature testifies to the role of the Union in maintaining the continuity and accessibility of chemistry's massive treasury of past results, the history of IUPAC efforts in machine documentation shows how chemists have made the Union an instrument for grappling with technological change. In contrast to the broad uptake of InChI, IUPAC's past machine documentation efforts had relatively little visible impact on the practice of chemistry. Yet they nevertheless provide valuable clues as to the enabling role of IUPAC-based work in the development of global chemistry over the past century. Studying the history of how IUPAC addressed chemical structure representation as a job fit for machines can shed light on the stewardship opportunities and challenges for IUPAC's next 100 years.



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Courtesy M. Volkan Kısakürek.

We tend to think about the impact of standards-setting organizations in terms of the enduring standards that they manage to set. This is a particularly sensible starting point for summing up the work of the IUPAC nomenclature commissions, which publish cumulative collections of guidelines in their respective "color books": the Blue Book (organic nomenclature), the Red Book (inorganic nomenclature), and so on [4]. For example, starting from the 1500 pages of guidelines contained in the latest edition of the Blue Book, one can trace their genealogy back to the resolutions of the 1892 International Congress of Geneva for the Reform of Chemical Nomenclature. (It is worth noting, however, that decisions *not* to sanction proposals or practices are just as important a part of the work of standards organizations. The intellectual memoirs of the Dutch chemist P.E. Verkade (1891–1979, chair of the IUPAC Commission on Nomenclature of Organic Chemistry 1934–1971), are packed with naming schemes that his commission considered but dismissed [1].)

The "Geneva Nomenclature" launched a century and a quarter of negotiations in which the pendulum of standards-setting swung back and forth between pristine logic and pragmatism. Though guided by a systematic ideal of rule-bound correspondence between chemical names and structural formulas, the

Commission on Nomenclature of Organic Chemistry most often proceeded in a spirit of “systematic flexibility” [5]. By allowing for alternative naming procedures, the commission accommodated the differing conventions of publications like *Beilsteins Handbuch* and *Chemical Abstracts* and provided workarounds for the shortcomings of specific nomenclature rules. E. J. Crane (1889–1966), who worked extensively with IUPAC nomenclature commissions during his long term as editor-in-chief of *Chemical Abstracts* (1915–1958), summed up this attitude nicely in a 1937 letter: “Rules are sometimes to be ruled instead of always to apply” [6].

Recovering the history of IUPAC efforts to standardize chemical identification on machines requires starting in the past rather than working backwards from the present. As IUPAC officers and committee members returned to Union activities after the end of World War II, one of the first subjects that attracted their attention was how to facilitate the continued production of chemists’ precious reference compendia. Between 1947 and 1952, an Advisory Council on *Beilstein* and *Gmelin* chaired by the British chemist Alexander Todd (1907–1997) set to work getting the war-torn German publications *Beilsteins Handbuch der organischen Chemie* and *Gmelins Handbuch der anorganischen Chemie* (*Beilstein* and *Gmelin*) back into production.

But the specter of information overload threatened even publications that were not directly affected by the war, such as *Chemical Abstracts*. The war-catalyzed growth in chemical research and the postwar declassification and publication of large quantities of state-sponsored research brought additional urgency to this challenge. Wartime advances in mechanical and electronic computing, coupled with increasing use of business machines such as punched card sorters and tabulators for managing myriad recordkeeping problems, suggested a solution: notations designed for handling molecular structure on machines [7].

G. Malcolm Dyson (1902–1978), technical director at the British pharmaceutical firm Genatosan, firmly believed that the day of machine-based chemical documentation had come. Dyson reasoned that a machine-readable code or “cipher” offered two distinct advantages over systematic names. First, by starting from the ground up rather than from names already in use, a system of ciphers could aim for the logical consistency that eluded IUPAC nomenclature, which had to accommodate existing usage. Second, machine-readable ciphers would enable reference libraries and publications like *Chemical Abstracts* and *Beilstein* to use machines to overcome a bottleneck in the work of chemical documentation: the expert labor involved in writing and interpreting systematic chemical names.

Dyson’s publication of his cipher system in 1947 earned him widespread attention among chemists working with nomenclature and documentation. He was named to the IUPAC Commission on Nomenclature of Organic Chemistry in 1947; he remained a member through 1971, cultivating friendships with Verkade and the American organic nomenclature guru Austin Patterson (1876–1956). Dyson was also appointed chair of a new IUPAC Commission on Codification, Ciphering, and Punched-Card Techniques (1947–1961). Other members included Howard Nutting (1901–1986) of Dow Chemical, the British nomenclature expert Alec Duncan Mitchell (1888–1963), and James W. Perry (1907–1971) of MIT, a detergent chemist turned punched-card expert. Verkade was the lone non-Anglo-American among the commission’s nine members. The commission also worked with collaborators who were not formal commission members, including Madeleine (Berry) Henderson (1922-2011) of MIT [8].

Numerous other chemists saw the same opportunity as Dyson in the blank slate afforded by machine-oriented ciphers. Chemists proposing alternative schemes were unhappy to see one of their competitors in charge of an IUPAC commission to determine which scheme would gain international sanction. Sure enough, in 1951, the IUPAC commission provisionally adopted Dyson’s notation, a decision which became permanent in 1961. By that time, however, the decision had little direct impact. Chemical firms and other organizations that dealt with chemical information had adopted one or the other of various notations according to local needs and preferences. Still, Dyson parlayed his reputation into a position as research director at Chemical Abstracts Service (CAS). In this role, he oversaw the initial stages of the computerization project that became the CAS Chemical Substances Registry and gave birth to the soon-to-be-ubiquitous CAS Registry Number.

In 1969, in light of the increasingly widespread application of computers to the management of chemical information, IUPAC’s Executive Committee commissioned a report on machine documentation in chemistry. Working in consultation with *Chemical Abstracts* staff, the authors of this report recommended that IUPAC appoint a committee to pursue standardization in machine handling of chemical information. The primary task of this commission was to be “the machine handling of chemical structures and the computer generation of nomenclature,” including “a unique definition of chemical structure which is understandable on the printed page and yet logical, unambiguous to a computer program" [9].

The Union accordingly formed an International Committee on Machine Documentation in the Chemical Field, with the kind of international membership that was typical of IUPAC, in contrast to Dyson's predominantly Anglo-American group. The abbreviated description of the duties of this committee left substantial room for alternative interpretations of its purpose. The French physical chemist and cheminformatics pioneer Jacques-Émile Dubois (1920–2005), nominated as chair of this commission, focused on the mandate to study *machine handling of chemical structures*. To Dubois, this meant establishing requirements for computer-based exchange of information about molecular structure among a diverse international constituency searching for chemical information and analyzing chemical data. To committee member and CAS associate director Fred Tate (1920–1980), the committee's job was *computer generation of nomenclature*, that is, identifying and promoting opportunities to revise IUPAC nomenclature to accommodate it to processing and handling on machines. French nomenclature commission member Noël Lozac'h (1915–2003) saw the machine documentation committee as an opportunity to swing human-oriented chemical names back toward the pristine logic of the Geneva Congress. Nobody gave much thought to Dyson's IUPAC-sanctioned notation. The committee continued to meet, correspond, and liaise with IUPAC nomenclature commissions through the mid-1970s without the members ever quite agreeing what their job was supposed to be [10].

IUPAC continued to sponsor work in this domain, including an International Symposium on Techniques for the Retrieval of Chemical Information, held in London in 1976 [11]. Union commissions pursued various projects in other areas involving computerization and automation. However, IUPAC did not return in earnest to work on machine-readable chemical identifiers until the InChI project.

Neither Dyson's nor Dubois's commissions seems to have had much of a direct impact on chemical information management or on chemistry more broadly. Nevertheless, juxtaposing these histories with those of IUPAC nomenclature commissions and the InChI project can teach us something about IUPAC and its relationship to the development of global chemistry over the past 100 years.

First, IUPAC was no technological laggard. The Union took up the question of machine-readable notation in 1947, around the same time that national chemical organizations did so, just a few years after punched cards migrated out of accounting departments into chemists' broader awareness. The machine documentation committee was convened within a few years of the launch of large-scale computer-based information systems like the CAS Registry.

Second, the Union's quick response to emerging information technologies proved less effective (or at least less enduring) than standardization efforts addressing well-established information technologies: reference works like *Chemical Abstracts* and *Beilstein*, in the case of the Commission on Nomenclature of Organic Chemistry, and the host of chemical databases and software widely relied upon by the year 2000, in the case of InChI. This would seem to be counterintuitive. Shouldn't a standardization effort be more effective when able to start from a clean slate in a new medium, as Dyson and other members of the ciphering committee hoped would be true for an IUPAC punched card notation?

It turns out that the snarled, frustrating limitations of nomenclature—trivial names sanctioned by long-standing use, the inconsistent schemes of *Beilstein* and *Chemical Abstracts*, the conflicts of 1920s international politics—were opportunities as well as obstacles. The Commission on Nomenclature of Organic Chemistry managed to codify a set of rules in 1930, a landmark achievement for the young Union, precisely *because* the respective conventions of *Chemical Abstracts* and *Beilstein* were so entrenched. The broadly-acknowledged importance of fostering incremental harmonization of the nomenclatures used by these major reference works allowed IUPAC's nomenclature efforts to seem well worth pursuing. The added stakes of nomenclature's entanglement with questions of interwar politics just encouraged more interest and engagement in the subject.

The ubiquity of electronic databases, chemical drawing programs, and other computer-based resources around the turn of the 21st century meant that the InChI effort began under similar conditions. While InChI, in marked contrast to nomenclature, did in fact start fresh, it was operating in a well-established field of machine-based analysis of chemical structures. There was widespread appreciation for the challenges imposed by the divergent notations and file formats for representing chemical structure.

This brings us to the third lesson of this story. Within a consensus-based international organization like IUPAC, standard-setting efforts seem best positioned to take hold when conflicting practices have already taken root. This has been the case for chemical structure representation, at least; it is likely true more generally. It is easier to recognize what it will take to mitigate a community-wide problem, and to secure broad-based support for doing so, after things have already gotten into a muddle. In the terminology of information scholars, IUPAC does not typically traffic in *systems* (rationally planned, centrally controlled, constraint-heavy but smoothly operating environments). IUPAC more often addresses *networks* and *gateways*, that is, protocols for coordinating different systems so that users can hop, perhaps a bit awkwardly, from one to another and back. This is not to say that Dyson's and Dubois' efforts were ill-founded. IUPAC has been a valuable site for studying emerging problems in information management, too. But for getting rules in place that can be made to stick, history suggests that you sometimes have to wait until heads are already spinning.

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The mole and IUPAC: a brief history

by Roberto Marquardt

The mole is the unit of amount of substance in the International System of Units (SI). The amount of substance of a system is a measure of the number of specified elementary entities defining that system. As a matter of fact, the mole is the sole unit currently in use for amount of substance.

Its former definition was given in 1971 and reads as follows [1]: "1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12; its symbol is 'mol.' 2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles." The year 1971 marks the end of a rather long debate that took place in the first half of the 20th century, and in the course of which the need to introduce the quantity amount of substance, an appropriate unit for it, and the differentiation between both were thoroughly discussed. The present text gives a brief account of this history, and sheds light on the role played be the International Union of Pure and Applied Chemistry (IUPAC) in the formation of the concepts underlying this quantity and the definition of its unit.

With the publication of a Technical Report [2] and a Recommendation [3], IUPAC was also quite influential in the new definition of the mole, which was adopted by the 26th General Conference of Weights and Measures on 16 November 2018, and which came into force, together with the definitions of the kilogram, the ampere and the kelvin on 20 May, the "World Metrology Day," 2019. The new definition of the mole reads [4]: "The mole, symbol mol, is the SI unit of amount of substance. One mole contains exactly $6.022\,140\,76 \times 10^{23}$ elementary entities. This number is the fixed numerical value of the Avogadro constant, N_A, when expressed in mol^{-1}, and is called the Avogadro number." We shall return to this more recent evolution of the mole at the end of this very brief historical review.

The history of the mole is closely related to the history of the quantity amount of substance and that of the Avogadro constant. Ref. [2] covers a small portion of this history and the reader is referred to further references cited therein, which are not exhaustive either. Here we mention only a few points, partly from the original literature, that will be of relevance for the aforementioned definitions of the mole.

Wilhelm Ostwald (1853-1932) introduced the "Mol" (mole in German), probably in 1893 [5]. However, he used this term to mean "molecular weight in gram":

E. A. Guggenheim, courtesy of Prof. I. M. Mills, Reading

"We generally call one mole the weight in grams that is numerically identical with the molecular weight of a given substance" (translated sentence on page 119, ref. [5]). In 1900 Max Planck (1858-1947) determined the value of the Avogadro constant from his famous law on the blackbody radiation [6]. He wrote (on page 244): "To one gram-molecule of a substance correspond 6,175 10^{23} molecules." In 1905 Albert Einstein (1879-1955) developed a theory of the Brownian motion, from which he derived a formula that enabled an additional determination of the Avogadro constant (it is the formula on page 560 of ref. [7]). In a subsequent paper [8] he added the precision that "N is the number of real particles in one gram-molecule" (he wrote 'Grammmolekül').

Indeed, scientists in those days were referring to an *extensive* quantity (N), but meaning an *intensive* quantity, such as N/m, where m is the mass of N particles. Today we would write N/n. The quantity n is the amount of substance. However, it was neither explicitly mentioned in those days, nor was the need discussed to introduce a special unit for it.

Jean Perrin (1870-1942) verified Einstein's formula experimentally in 1909 and obtained, in today's language, $N/n \approx 70\ 10^{22}\ mol^{-1}$. But he did not use n! He wrote [9, page 16]: "This invariable number is a universal constant that merits to be called *the Avogadro constant*."

Perrin also wrote [9]: "It has become common language to call gram-molecule ('molécule-gramme') of a body the mass of this body which occupies, in the gaseous state, the same volume as 2 g of hydrogen at the same temperature and pressure. Avogadro's proposition then reads: 'Any two gram-molecules contain the same number of molecules.'"

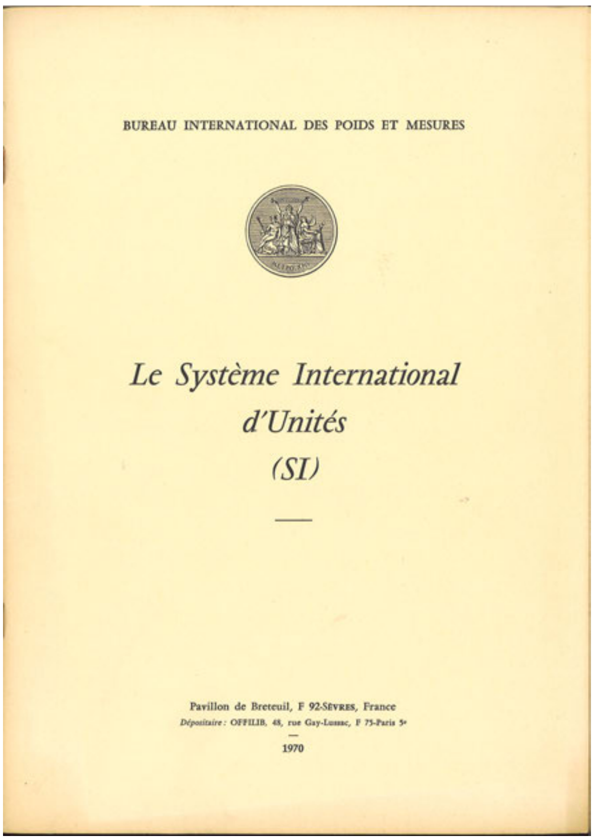
Very clearly a quantity was there that scientists were referring to as the "number of particles occupying a given volume," without calling it a number density, or the "number of particles contained in a mass that is equivalent to a molecular weight," without calling it amount of substance. The need to introduce the concept of the amount of substance, hidden so far, was obvious. The name gram-molecule was introduced to serve as a short-cut for a measurement unit of a quantity that was not actually a mass. That name was more than clumsy, because it uses a unit (gram) while referring to a quantity (weight or mass). Rather than being a clarification, it further increased the confusion. Until the 1960s one used to read: "1 mole of water is 18.016 grams." In an article of 1961 [10] one can read: "The result is a multiplicity of units which does not appeal to the scientific mind." The mixing up of units and quantities, whether interrelated or not, became a nightmare, in particular in chemistry education.

In physics, clarifying steps have been undertaken somewhat earlier. In 1957, the Commission for Symbols, Units and Nomenclature (SUN) of the International Union of Pure and Applied Physics (IUPAP) formulated a recommendation (published in ref. [11]) to consider the unit "mole" as a unit for "quantity of substance".

In 1961 Edward Guggenheim (1901-1970) wrote [12]: "...it is hoped that the term 'atomic weight' may fall into disuse so that eventually it may become unnecessary to explain to every novice that 'atomic weight' does not mean weight of an atom." Further: "During the past score of years the view has been accepted by a rapidly increasing number of physicists and chemists that there is a third quantity different from mass and weight but proportional to both. This quantity was first named 'Stoffmenge' in German and the English translation is 'amount of substance.'" In the last citation, Guggenheim was referring to a name mentioned by Ulrich Stille (1910-1976) [13].

Finally, Guggenheim wrote [12]: "The mole is the amount of substance containing the same number of molecules (or atoms or radicals or ions or electrons as the case may be) as there are atoms in 12 grams of ^{12}C." Guggenheim was a member of the SUN Commission of IUPAP and the Commission of Symbols, Terminology and Units (Commission I.1) of of the Physical Chemistry Division (Division I) of IUPAC [14, page 312]. In the minutes of the Council meeting at the 22nd IUPAC Conference in 1963 one can read that Commission I.1 was authorized to revise the Manual on Physico-chemical Symbols and Terminology, and that it was instructed to pay particular attention to the definition of the mole as a unit of the quantity of substance as well as to the adoption of the abbreviation mol proposed by IUPAP. Guggenheim's recommendation was adopted by the IUPAC Council at Cortina d'Ampezzo in 1969 [15]. The liaison with the IUPAP SUN Commission and the Technical Committee 12 of the International Organization for Standardization (ISO/TC 12) on this recommendation is explicitly mentioned in ref. [15].

Later, in 1971, it was adopted, in a slightly modified wording, as resolution 3 by the 14th General Conference of Weights and Measures, by which the mole was included as a base unit of the SI (see above). Both IUPAP and IUPAC recommendations are explicitly mentioned in ref. [1].



BUREAU INTERNATIONAL DES POIDS ET MESURES

Le Système International d'Unités (SI)

Pavillon de Breteuil, F 92-Sèvres, France
Dépositaire: OFFILIB, 48, rue Gay-Lussac, F 75-Paris 5e
1970

the cover page of the 1971 resolution from the Bureau International des Poids et Mesures

In the 1980s, the idea came up to redefine the kilogram and with it other units of base quantities of the SI [16], and in 2005 preparative steps towards redefining the kilogram, ampere, kelvin and mole started to be taken [17].

In 2013 IUPAC launched a project with the aim to critically review the then proposed new definitions in the SI of fundamental chemical quantities and their impact on chemical communities (IUPAC project 2013-048-1-100). In this project, published work related to the definition of the quantity amount of substance, and its unit, the mole, was compiled, discussed and critically reviewed, together with the consequences of these definitions on the unit of the quantity mass, the kilogram. All possible aspects were assembled in order to enable IUPAC to judge the adequateness of the existing definitions or new proposals. Compilation and critical review relies on the broadest spectrum of interested IUPAC members.

The Technical Report [2] is one result of this project. The report also covers aspects related to chemical education and one particular result is alarming: only about 2 out of 10 students at High School or initial University level know the physical quantity 'amount of substance,' and even less know the 1971 definition of its unit, the mole. A replacement of the definition of the mole seemed then to be mandatory alone for educational reasons.

The definition text proposed until September 2017 to replace the current definition was technically correct, but difficult to understand, in particular to less specialized readers [2]. As a result, IUPAC issued a Recommendation [3] which had a positive impact on the aforementioned new definition of the mole. Future generations of chemists will learn this new definition and will finally benefit from the fact that the "Avogadro number" is now properly defined.

The author acknowledges help from Prof. Ian Mills and members of the task group involved in the IUPAC project 2013-048-1-100.

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Women's Increasing Responsibilities in IUPAC since 1975

by Nicole Moreau

IUPAC was founded in 1919, but it was in 1911 that the International Association of Chemical Societies, IACS, considered as the precursor of the Union, was created. A look at the picture of the third meeting of IACS, held in 1913 in Brussels [1], makes obvious the absence of any woman—and the quasi-absence of any man without a beard or a moustache! A look at the population of women in IUPAC fifty years later showed the same situation, although by then beards and moustaches had lost ground. A thorough examination of the composition of IUPAC's Divisions and Committees reveals a few women members before 1975 [2]. In the 70s and early 80s, the presence of a few women become noticeable. The names of these women, with their position and years of membership are tabulated here in chronological order by their initial membership on Divisions or Committees. Until 1990, all women are included in the table. From 1990 to 2010, only those with Titular Member (TM) status are listed, and after 2010 only those involved in the Bureau (BU), either as division president (DP), standing committee chair (SCC), or elected member (EM) and officer.

In 1975, the only woman member of an IUPAC committee was Ursula Hohacker, from Germany. She was a National Representative (NR) on the Committee on Teaching of Chemistry (CTC, after 2002 CCE, Committee on Chemistry Education) from 1975 to 1985. Two other women were also present before 1980, Irene Dilaris from Greece, also an NR on CTC, from 1976 to 1985 (although she appears to have been an observer in 1965), and Eloisa Mano, from Brasil, an NR on the Macromolecular Division (Div IV, known today as the Polymer Division), from 1979-1985.

Between 1981 and 1990, we count a dozen women, of whom Mary Good, from the USA, became President of the Inorganic Chemistry Division (Div II) from 1981 to 1985. The next woman President of a Division was Irina Beletskaya from Russia, member from 1985 and then President of the Organic Chemistry Division (Div III), from 1989 to 1991.

In the early 2000s, more than two dozen women were either TM or member of the Bureau, while it is only in the 2010s that we find the first women Presidents of the Union, Nicole J. Moreau from France, 2010-2011, and Natalia P. Tarasova from Russia, 2016-2017. The President (P) term is two years, which follows

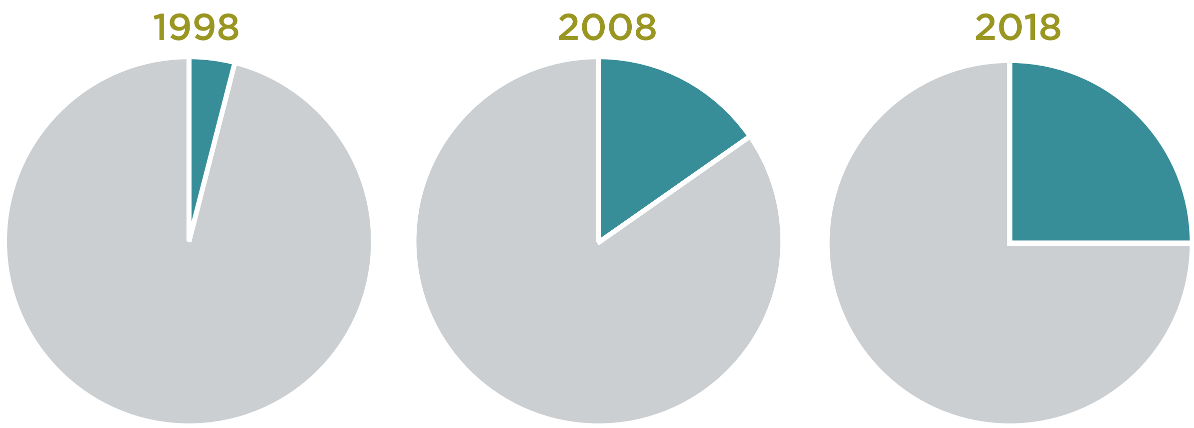
Meeting of the IUPAC Executive Committee at the headquarters of the Russian Academy of Sciences, in Moscow 1988 (16-17 May). Front row from left: Valentin Koptyug (USSR), IUPAC President, Yves Jeannin (France), Vice President, Mary Good (USA), and Ramachandra Rao (India), Past President. Middle: Norman Sheppard (UK) and Sho Ito (Japan). Back row: Thomas West (UK), Secretary General, and Mo Williams, Executive Secretary (EC member present in part at the 111th EC meeting in Moscow but not on the photo: Anders Bjorkman (Denmark), Treasurer). Courtesy Yves Jeannin.

Women's Increasing Responsibilities in IUPAC since 1975

Name	Position	Entity	Period	Country
Ursula Hohacker	NR	CTC	1975-1985	Germany
Irene Dilaris	NR	CTC	1976-1985	Greece
Eloisa Mano	NR	IV	1979-1985	Brasil
Mary Good	DP	II	1981-1985	USA
	EM	BU/EC	1985-1993	
Marguerite Rinaudo	AM	IV	1981-1985	France
Mirna Micač Dević	M	VII	1981-1985	Yugoslavia
Marjorie Gardner	M	CTC	1981-1989	USA
Aleksandra Kornhauser	M	CTC	1981-1989	Slovenia
Evdokia Sokolowskaya	M	CTC	1981-1989	Russia
Maroulio Talieri-Gianopoulou	NR	VII	1983-1985	Greece
Edith Jarisch	NR	CTC	1983-1985	Austria
Claudine Noël	TM	IV	1985-1993	France
Irina P. Beletskaya	TM	III	1985-1993	Russia
	DP	III	1989-1991	
Elisa Pestana	M	CCE	1996-2005	Portugal
Wendy Warr	Chair	CPEP	1998-2003	UK
Ingrid Meisel	TM	IV	2000-2001	Germany
Tania M. Tavares	TM	VI	2000-2003	Brasil
Norma S. Nudelman	TM	III	2000-2003	Argentina
	TM	CR	2004-2007	
Silvia Braslavsky	TM	III	2000-2003	Germany
Rita Cornelis	TM	VII	2000-2003	Belgium
	DP	VII	2018-2019	
Sandra Rondinini	TM	V	2000-2001	Italy
Nicole Moreau	**EM**	**BU**	**2000-2013**	France
	EM	**EC**	**2006-2013**	
	P		**2010-2011**	
Elsa Reichmanis	TM	IV	2000-2001	USA
	EM	**BU**	**2006-2013**	
	EM	**EC**	**2008-2013**	
Ruth M. Lynden-Bell	TM	I	2002-2009	UK

Name	Position	Entity	Period	Country
Lisa McElwee-White	TM	III	2002-2005	USA
Lida Schoen	TM	CCE	2002-2011	
Laura McConnell	TM	VI	2004-2007	USA
	DP	VI	2014-2015	
Jytte Molin Christensen	TM	VII	2004-2005	France
Maria Fatima das Graças Da Silva	TM	III	2004-2007	Brasil
Mary J. Garson	TM	III	2004-2016	Australia
	DP	III	2014-2015	
	EM	BU	2018-2019	
Natalia Tarasova	TM	CCE	2004-2007	Russia
	EM	BU	2008-2019	
	EM	EC	2010-2019	
	P		**2016-2017**	
Myunghyun Paik Suh	TM	II	2006-2009	Korea
Janine Cossy	TM	III	2006-2009	France
Hemda Garelick	TM	VI	2006-2009	UK
	EM	**BU**	**2016-2019**	
Monica Norberg	TM	VII	2006-2009	Sweden
Eva Åkesson	TM	CCE	2006-2013	Sweden
Maria van Dam-Mieras	**EM**	**BU**	**2006-2013**	Netherlands
Maria F. Camões	TM	V	2008-2015	Portugal
	DP	V	2012-2013	
Françoise Pontet	TM	VI	2008-2011	France
	DP	VII	2012	
Mei-Hung Chiu	Chair	CCE	2012-2015	China Taipei
	EM	BU	2016-2019	
Helen Lawlor	Chair	CPCDS	2014-2019	USA
Margaret Brimble	DP	III	2016-2017	New Zealand
Angela K. Wilson	DP	I	2016-2017	USA
Carolyn Ribes	Chair	COCI	2018-2019	USA

The table lists the names of women present in Divisions, Standing Committees, and Bureau with their position and years of presence. Membership on the Bureau are shaded per position. See text for details (abbreviations not cited in the text: CR or CHEMRAWN, AM or Associate Member, and CPEP or the Committee Printed and Electronic Publication, which in 2014 became CPCDS, the Committee on Publications and Cheminformatics Data Standards).



The charts show the increasing fraction of women (in teal) involved in the IUPAC Bureau since 1998.

a 2-year term as Vice President (VP) and precedes a last 2-year term as Past President (PP). In that same decade, 10 women became Presidents of Divisions, I (Physical and Biophysical Chemistry), III (Organic and Biomolecular), V (Analytical), VI (Chemistry and the Environment), and VII (Chemistry and Human Health), or Committees, CCE (Education), COCI (Industry), and CPCDS (Publications and data standards). This is a significant change and improvement, raising the percentage of women on the Bureau from 4% in 1998 to 15% in 2008 and to 25% in 2018. Of the 44 women mentioned, about a quarter of them are engaged in matters of teaching and education, a rather traditional female niche. The next most common areas are organic and biomolecular chemistry (Div III) and chemistry and human health (Div VII). This is a striking contrast with the first female presence inside IUPAC, Ellen Gleditsch, who was a delegate for the International Commission of the Tables of Constants (1921-28) before joining the Commission on radioactivity after WWII [3].

A closer look at the first two women who were Presidents of Divisions

Mary L. Good was born in Grapevine, Texas. Both her parents were teachers; when she was 11 they moved to Arkansas, where she received her PhD in 1955. She then spent 25 years teaching and conducting research in Baton Rouge and New Orleans. In 1972, she became the first woman to be elected to the board of the American Chemical Society. In 1980, she left academia for industry. At that time, she also started to hold government positions, serving in such roles under the administrations of four Presidents: Jimmy Carter, Ronald Reagan, George H. W. Bush, and Bill Clinton. In 1993, she left industry to become the Under Secretary for Technology in the Department of Commerce. In IUPAC, she was President of the Inorganic Chemistry Division for two biennia, in 1981-3 and 1983-5; she then was elected member (EM) on the Bureau and directly served on the Executive Committee (EC) from 1985 to 1993.

Irina P. Beletskaya was born in Leningrad (now St Petersburg). No information about her parents has been found. She graduated from the Department of Chemistry of Lomonosov Moscow State University, where she received her PhD and then became a professor. She served in the Organic Chemistry Division of IUPAC starting in 1985, acting as President in 1989-1991; she then served in the Committee on Chemical Weapons Destruction Technology (CWDT). In 1992, she became a member of the Russian Academy of Sciences. She had a purely scientific carreer.

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2. Membership sources in *Comptes rendus* des Conférences internationale de la chimie, années 1920-1975.
3. See A. Lykknes, this issue, p. 26.

Nicole J. Moreau <nj.moreau@free.fr> was IUPAC president in 2010–2011. Prior, she has been a member of the Bureau since 2000 and a member of the Executive Committee since 2006. After her involvement in IUPAC and till recently, she was a member on the Executive Board of ICSU, now known as the International Science Council.

The Historical Archives of IUPAC at the Science History Institute

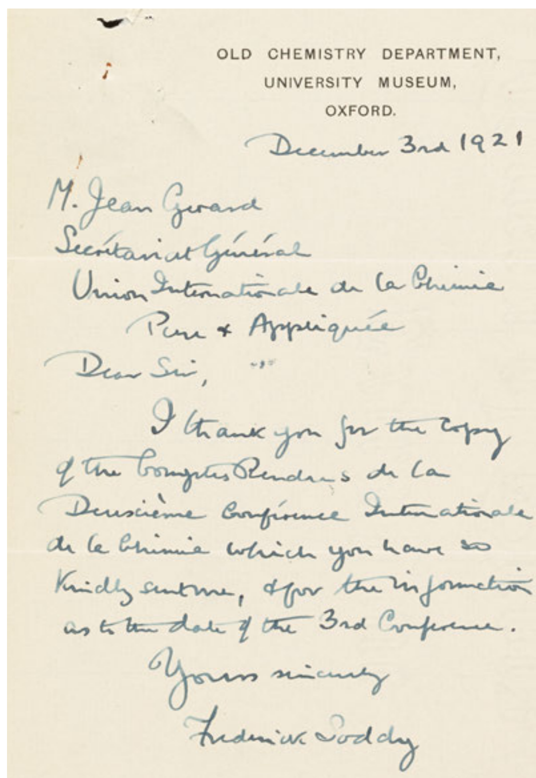
by Ronald Brashear

As IUPAC begins celebrating its centennial this year, it seems appropriate to remind everyone that the historical record of IUPAC is preserved in the archives of the Science History Institute's Othmer Library. For the rich history of IUPAC to be told correctly and effectively, the archive is absolutely critical. And the existing archive speaks to the importance of the Institute's desire to continue to build the collection, filling in gaps that currently exist and adding future materials so that we can craft an even better history when IUPAC celebrates in bicentennial in 2119.

The Science History Institute (formerly the Chemical Heritage Foundation) was founded in 1982 at the University of Pennsylvania as the Center for the History of Chemistry. We were a small organization of a few people based in the Edgar Fahs Smith Collection at the University's Van Pelt Library. In 1987–88, two significant gifts established the Beckman Center for the History of Chemistry and the Othmer Library of Chemical History. These two entities moved out of Van Pelt Library and later formed the core of the new Chemical Heritage Foundation (CHF). We began building a historical library collection that would enhance and complement what was already at the University. One significant area of enhancement would be in collecting the archives of individuals, companies, and organizations involved in the chemical and molecular sciences and chemical engineering and technology.

Fortunately, at nearly the same time as the formation of the Othmer Library, we were contacted by the person who was primarily responsible for our having the IUPAC archive, Herbert Steffen Peiser. Peiser (1917–2005) was born in Berlin and educated at Cambridge University and worked as a crystallographer and metallurgist in British industry until 1957 when he moved to the United States to become a research chemist at the National Bureau of Standards in Washington, DC. He eventually became the head of the Bureau's Office of International Relations which connected him to a variety of organizations including IUPAC where he was the US national representative on the Commission for Atomic Weights and Isotopic Abundances (CAWIA) starting in 1987. That same year Peiser contacted CHF and began to explore the possibility of CHF maintaining the repository of CAWIA papers, documents, and significant correspondence. At a site meeting in Philadelphia in 1988, members of the CAWIA informed us that a European organization had offered to host the archives but that it was a secure facility that would not permit easy access. But as the commission members preferred easy access to the materials and since the Oxford IUPAC headquarters did not have room for the archive, the CAWIA members would be willing to give the materials to CHF, assuming they get permission at the next Congress. CHF quickly drew up a deed of gift and Peiser arranged for Glassblowing Enterprises to provide US$900 to assist with the transfer of materials, and in May 1989 an agreement was signed to transfer the CAWIA archive to CHF.

With the transfer of the CAWIA archive to CHF, the IUPAC leadership became interested in transferring the organization's archives as well. The Inorganic Division records were the first to arrive. By 1996 CHF had become an Associated Organization of IUPAC and had received 186 boxes of IUPAC records. The transfer was timely as Ted Becker, then IUPAC Secretary General,



OLD CHEMISTRY DEPARTMENT,
UNIVERSITY MUSEUM,
OXFORD.

December 3rd 1921

M. Jean Gerard
Secrétariat Général
Union Internationale de la Chimie
Pure & Appliquée

Dear Sir,

I thank you for the copy of the Comptes Rendus de la Deuxième Conférence Internationale de la Chimie which you have so kindly sent me, & for the information as to the date of the 3rd Conference.

Yours sincerely
Frederick Soddy

Frederick Soddy letter to IUPAC Secretary general Jean Gerard, dated 3 Dec 1921. Records of the Commission on Atomic Weights and Isotopic Abundances of IUPAC, Box 13, Folder 3. Science History Institute. Philadelphia. https://digital.sciencehistory.org/works/zp38wc642. Interesting time for Soddy who was awarded the 1921 Nobel Prize in Chemistry but who received it one year later, in 1922. Learn more at https://www.nobelprize.org/prizes/chemistry/1921/summary/

wrote, "Permanence of the location [of the archive] has assumed even more importance than it had when the plan was initially developed, since IUPAC will move its secretariat to Research Triangle Park, North Carolina, next year, and I fear that we would probably lose old records or render them inaccessible in that process."

Today the IUPAC archives rest securely in the collection storage areas of the Science History Institute in our headquarters in Philadelphia, available to researchers who come to work in the Othmer Library. The IUPAC archives consist of four record groups:

- Records of the Commission on Atomic Weights and Isotopic Abundances of IUPAC, 1927–2007 (bulk 1920–1995), 20 boxes (9.24 linear feet)
- International Union of Pure and Applied Chemistry (IUPAC) Records, 1919–1965, 165 boxes (73 linear feet)
- Addenda to the International Union of Pure and Applied Chemistry (IUPAC) Records, 1919–1995 (bulk 1965–1995), 221 boxes (130 linear feet)
- Photographs from the Records of the International Union of Pure and Applied Chemistry (IUPAC), 1925–1995 (bulk 1980s), 2 boxes (ca. 150 print photographs)

There are finding aids to these record groups that provide a much more detailed listing of their contents. The finding aids can be downloaded from each of the above catalog listings in the Othmer Library online catalog.

As described by Patrick H. Shea (Chief Curator of Archives at the Science History Institute) in an article from 2013 in this journal, "The broad range of IUPAC activities has attracted scholars from around the world to use this collection. Indeed, it is perhaps one of the most highly used collections in the entire CHF [now Science History Institute] archive, as researchers explore topics such as scientific nomenclature, environmental science, and scientific education, as well as topics related to the interdisciplinary role of chemistry as the central science." We are happy to be the home of IUPAC's archives and to be able to work with IUPAC and historians from around the world to preserve the history of this important organization.

In the next one hundred years, we hope to build on our existing collection of IUPAC materials. In 2018, Patrick Shea and I visited IUPAC headquarters in North Carolina to identify additional materials that are no longer needed at the secretariat to be transferred to the Institute. We expect that this material will come to us sometime in 2019. We also hope that the centennial celebrations this year will encourage those who have participated in IUPAC Commissions, Divisions, and Committees to contact Patrick Shea (pshea@sciencehistory.org) regarding records, documents, and correspondence that they may have so that we can ascertain if they would be appropriate to add to our IUPAC collection. Please help us keep the IUPAC collection up to date and relevant to historians both now and in the future.

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3. Andrew Mangravite, "Processing Addenda to the Records of IUPAC," *Chem Int,* 27(4) (July–August 2005), 10–12; https://doi.org/10.1515/ci.2005.27.4.10
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5. Othmer Library online catalog, http://othmerlib.sciencehistory.org/
6. Science History Institute Digital Collections, https://digital.sciencehistory.org/

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Not an Epilogue, but a Commencement!

by Brigitte Van Tiggelen

To many non-native, or non-American, English speakers, the word "commencement" sounds like a strange choice to designate the end of a university curriculum. But then, all speeches and celebration talks given on commencement day focus on the future, and what students must take away from the years leading to graduation in a world full of opportunities, challenges, and unknowns. The same applies to our work on the history of IUPAC. It was started in the wake of the IUPAC 100th anniversary, and it will be mentioned among other presentations during the IUPAC centenary celebrations, but for both IUPAC and the writing of its history, 2019 does not mark an end but a beginning, a step on a path full of challenges and opportunities.

This special issue demonstrates at length the challenges met in the past by an international scientific organization in a world where geopolitical and cultural contexts shift constantly, and in which science, and in particular the chemical sciences, evolves and grows, even as its role and responsibility in a globalized society grows in parallel. Born as an alliance of WWI's victors, the Union soon morphed into an international union, and became global after WWII, despite the tensions between geopolitical blocs, and the initial predominance of the Western world. In the same way, the slow but steady increase in the number of women at leadership levels reflects the evolution of mentalities and society. While the Union's traditional responsibilities, such as nomenclature and standardization, have remained at the core of activities such as naming elements and defining the mole, IUPAC has also adapted to technological changes with the management of chemical information through digital means.

The general narrative covered in this special issue of CI ends in the '80s, while a few close-ups provide a glimpse at the last decades of the 20th century. In the '90s, the Union embarked on a complete transformation of its structure and mode of action. This reorganization came as a response to the development of international scientific work, the growth of chemistry in all its dimensions, and the evolving societal role of science in general and of chemistry in particular. To some extent, the elements of the story told in this special issue explain why changes were needed at the turn of the century, and how the responses given in the past could no longer adequately answer the demands of the present and the future.

The topic of this fundamental reorganization, including, for example, the deployment of the

First published in** Chemistry International **in May 1990, this cartoon captures a recurring challenge, or simply an eternal (re-)commencement?

exemplary CHEMRAWN initiative or the evolution of IUPAC's publishing strategy from paper to web, will be picked up in coming feature contributions in *CI*. A more comprehensive publication on the history of IUPAC is in incubation. Another captivating aspect is the opening of the Union to new categories of members, beyond the National Adhering Organizations (NAOs) and chemists. This began first as a specific campaign targeted at corporations and businesses with the *Company Associates Group* (established in the 60s) and later including organizations for which the connection with chemistry was more tangential, referred to as *Associated Organizations*.

Many more topics wait to be explored, even as more documents, archives, and testimonies remain to be collected. Historical material no longer immediately useful or needed at the IUPAC headquarters will soon join the archives kept at the Science History Institute. Beyond the headquarters, the archives of IUPAC commissions, divisions, and task groups are also to be gathered. As we embark on the next century of IUPAC, we look forward to pursuing the historical work with the IUPAC community and want to end this special issue with a call to arms: if you have historical material (pictures, manuscripts, publications), please join in the celebratory mood that spurs memories, and share them with us!

Brigitte Van Tiggelen (bvantiggelen@sciencehistory.org) is Director of European Operations at the Science History Institute, USA.
Share your information also with Danielle Fauque (danielle.fauque@u-psud.fr) and Fabienne Meyers (fmeyers@iupac.org).

Mark Your Calendar

Upcoming IUPAC-endorsed events
See also www.iupac.org/events for links to specific event websites

2019 after July 5

5-12 July 2019 • IUPAC Congress/General Assembly • Paris, France
contact@iupac2019.org, www.iupac2019.org

IUPAC and Chemistry: a Century of Intertwined History, a Common Heritage for the Future
IUPAC Congress—Symposium 6
Conveners: Danielle Fauque <danielle.fauque@u-psud.fr>, Université Paris Sud/Paris Saclay, France, and Brigitte Van Tiggelen <vantiggelen@memosciences.be>, Louvain-la-Neuve, Belgium, and Science History Institute, Philadelphia, USA, https://www.iupac2019.org/a-century-of-history

21-26 July 2019 • Novel Aromatic Compounds • Sapporo, Japan
The 18th international Symposium on Novel Aromatic Compounds (ISNA-18)
Prof. Dr. Shigehiro Yamaguchi, Chair of Program Committee,
E-mail: yamaguchi.shigehiro@b.mbox.nagoya-u.ac.jp, www.isna18.org

21-25 July 2019 • Organometallic Catalysis • Heidelberg, Germany
20th International Symposium on Organometallic Catalysis Directed Towards Organic Synthesis (OMCOS)
Contacts: A. Stephen K. Hashmi <hashmi@hashmi.de> (Chair), Mark Lautens <Mark.lautens@utoronto.ca>, Congress and Conference Management (UniKT) <unikt-kongresse@zuv.uni-heidelberg.de>
https://www.omcos2019.de/

26-28 July 2019 • Mendeleev 150 • Saint Petersburg, Russia
Mendeleev 150: 4th International Conference on the Periodic Table endorsed by IUPAC
Co-organizers: Mikhail V. Kurushkin (ITMO University, Russia), Eric R. Scerri (University of California, Los Angeles, USA), Philip J. Stewart (Oxford University, UK)
E-mail: mendeleev150@scamt-itmo.ru, http://mendeleev150.ifmo.ru/

28 July 2019 • IUPAC 100th birthday!

30 July - 1 August 2019 • Inter-Asian Chemistry Educators • Taipei, Taiwan
8th International Conference for Network for Inter-Asian Chemistry Educators (NICE)
Chin-Cheng Chou, Department of Science Education, National Taipei University of Education
E-mail: ccchou62@tea.ntue.edu.tw, http://www.8thnice.org/

4-8 August 2019 • Solution Chemistry • Xining, China
36th International Conference of Solution Chemistry
Dr. Yongquan Zhou, Qinghai Institute of SaltLakes, Chinese Academy of Sciences, Xining 810008, China,
E-mail: icsc2019@isl.ac.cn, http://icsc2019.csp.escience.cn/

4-9 August 2019 • Electrochemistry • Durban, South Africa
70th Annual Meeting of the ISE - Electrochemistry: Linking Resources to Sustainable Development
Chair: Kenneth I. Ozoemena, University of the Witwatersrand, E-mail: kenneth.ozoemena@wits.ac.za,
https://annual70.ise-online.org/

25-30 August 2019 • Transactinide Elements • Wilhelmshaven, Germany
6th International Conference on the Chemistry and Physics of the Transactinide Elements (TAN19)
Co-Chairs: Prof. Dr. Christoph Düllmann, Institute of Nuclear Chemistry, Johannes Gutenberg University Mainz, Germany and Prof. Dr. Michael Block, GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany. E-mail: tan19@gsi.de, https://www.gsi.de/tan19/

25-31 August 2019 • Glycoconjugates • Milano, Italy
25th International Symposium on Glycoconjugates
Co-Chairs: Sandro Sonnino <sandro.sonnino@unimi.it> and Alessandro Prinetti <alessandro.prinetti@unimi.it>, General contact: <info@glyco25.org>, http://www.glyco25.org/

Mark Your Calendar (cont.)

2-6 September 2019 • Noncovalent Interactions • Lisbon, Portugal
1st International Conferences on Noncovalent Interactions (ICNI)
Armando J. L. Pombeiro, Universidade de Lisboa, and Kamran T. Mahmudov, E-mail: kamran_chem@mail.ru. General E-mail: icni2019@chemistry.pt, http://icni2019.eventos.chemistry.pt

8-13 September 2019 • Ionic Polymerization • Beijing, China
13th International Symposium on Ionic Polymerization (IP 2019)
Yixian Wu, E-mail: wuyx@mail.buct.edu.cn, Beijing University of Chemical Technology, and Junpo He, E-mail: jphe@fudan.edu.cn, Fudan University, Dept. Macromolecular Science, co-chairs. www.ip19.net

9-13 September 2019 • General and Applied Chemistry • Saint Petersburg, Russian Federation
The 21st Mendeleev Congress on General and Applied Chemistry
Co-chairs: A.M. Sergeev, and M.M. Kotyukov, General Contact: Yulia Gorbunova, Corresponding Member of RAS, A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of RAS, Leninsky prospect, 31, building 4, Moscow, Russian Federation, 119087, Tel: +74959545483, E-mail: yulia.gorbunova@gmail.com, http://mendeleev2019.ru

22-26 September 2019 • Environmental Best Practices • Olsztyn, Poland
Sustainability schemes for bio-based products in the framework of the circular bioeconomy
Chair: Janusz Gołaszewski, janusz.golaszewski@uwm.edu.pl, University of Warmia and Mazury in Olsztyn; General contact: ebp6@uwm.edu.pl, https://ebp6.eu

4-16 October 2019 • WMFmeetsIUPAC2019 • Belfast, Northern Ireland
The World Mycotoxin Forum and the IUPAC International Symposium on Mycotoxins,
Rudolf Krska, BOKU Vienna, Austria, and Chris Elliott, Queen's University Belfast, Northern Ireland, conference co-chairs, E-mail WMF@bastiaanse-communication.com, www.worldmycotoxinforum.org

15-18 October 2019 • Coordination Chemistry • Kuala Lumpur, Malaysia
7th Asian Coordination Chemistry Conference (ACCC7)
Chair: Geok Bee Teh, E- mail: sharonteh2009@gmail.com; Contact: ACCC7 Secretariat, c/o Institut Kimia Malaysia, E-mail: secretariat@accc7.org.my, https://accc7.org.my

5 Dec 2019 • IYPT2019 Closing • Tokyo, Japan
The Official IYPT2019 Closing Ceremony will be hosted by Science Council of Japan IUPAC subcommittee; http://www.iypt2019.jp/eng/index.html

United Nations Educational, Scientific and Cultural Organization
International Year of the Periodic Table of Chemical Elements

2020

19-21 February 2020 • Chemistry Conference for Young Scientists • Blankenberge, Belgium
Chair: Karel Haesevoets, secretary@chemcys.be, Koninklijke Vlaamse Chemische Vereniging vzw, support@chemcys.be, www.chemcys.be

5 9 July 2020 • MACRO2020 • Jeju Island, Korea
48th World Polymer Congress
Chair: Doo Sung Lee, ex-President, PSK; program chair: Jun Young Lee; secretary general: Dong June Ahn (ahn@korea.ac.kr); E-mail: secretariat@macro2020.org; www.macro2020.org

16-21 August 2020 • Theoretical and Computational Chemists • Vancouver, Canada
12th Triennial Congress of the World Association of Theoretical and Computational Chemists
Chair: Russell J. Boyd, Dalhousie University, E-mail russell.boyd@dal.ca; contact Chemical Institute of Canada (CIC), 222 Queen St, Suite 400, Ottawa, Ontario, Canada, toll free: 1-888-542-2242, http://watoc2020.ca

13-17 July 2020• Chemistry Education • Cape Town, South Africa
26th IUPAC International Conference on Chemistry Education (ICCE 2020)
Contact/chair of the local organizing committee: Bette Davidowitz <Bette.Davidowitz@uct.ac.za>, Chemistry Department, University of Cape Town, Rondebosch, South Africa, www.icce2020.org.za

IUPAC | CCCE
Montréal
2021
August 13-20

IUPAC GENERAL ASSEMBLY and WORLD CHEMISTRY CONGRESS

CANADIAN CHEMISTRY CONFERENCE and EXHIBITION

Frontiers in Chemistry: Chemistry for Health, Energy, Sustainability and Society

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

CCCE MONTRÉAL, QC 2021 August 13-20

Canada Welcomes the IUPAC General Assembly and the World Chemistry Congress with the Canadian Chemistry Conference and Exhibition August 13-20, 2021

Important Dates

Call for Papers Opens
December 2020

Delegate Registration Opens
January 2021

Exhibition Registration Opens:
January 2021

Program Symposia Themes

Chemistry for Health
Chemistry for Energy
Chemistry for Sustainability
Chemistry for Society
Chemistry at the Frontiers
Young Scientists Program
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