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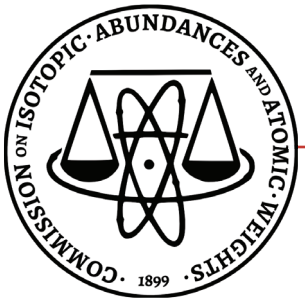
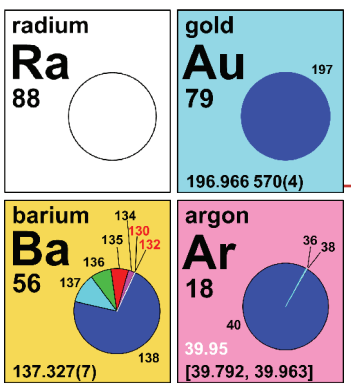
2019 IYPT International Year of the Periodic Table of Chemical Elements





1001 inventions ®

The International Year of the Periodic Table 2019

Jan Reedijk and Natalia Tarasova
co-chairs of the InterUnion Management Committee IYPT2019

This year we celebrate the Periodic Table of Chemical Elements in the format proposed by Mendeleev in 1869, and its continued development to this day. This issue of *CI* describes several aspects of the Periodic Table, its history and celebration, and also addresses the pathways to possible new elements. In this preface we address some highlights of the papers and pay attention to the history of events that have led to IYPT2019.

In July 2016, professor Martyn Poliakoff hinted that in 2019 the Periodic Table would celebrate its 150th anniversary, and the ball started to roll. On 30 September 2016, 3000 participants of the 20th Mendeleev Congress, held in Ekaterinburg, Russia, unanimously voted for the proclamation of the International Year of the Periodic Table (IYPT) in 2019. The resolution was supported by the Mendeleev Russian Chemical Society and the Russian Academy of Sciences. In early 2017, during and after the celebrations of the discovery and naming of nihonium, moscovium, tennessine and oganesson, the Mendeleev Chemical Society from Russia took the initiative to explore the possibility to have 2019 named as the International Year of the Periodic Table. The Russian Academy of Sciences invited IUPAC to be the leading union for the IYPT, as the identification of a leading international science union is a compulsory part of the UNESCO application procedure. IUPAC 's Executive Committee embraced the initiative and approached other International scientific unions to join forces, *i.e.* the International Union of Pure and Applied Physics (IUPAP), International Astronomical Union (IAU), European Chemical Society (EuChemS), the International Union of History and Philosophy of Science and Technology (IUHPS), and the International Science Council (ISC, previously known as ICSU, the International Council for Science which merged in July 2018 with ISSC, the International Social Sciences Council).

A steering committee of 16 people, consisting of leaders of the unions and other experts, was formed in the fall of 2017, and a prospectus was produced for submission and application to UNESCO and the United Nations. Ultimately, the final application for the IYPT was endorsed by a number of international scientific unions, including IUPAC, IUPAP, EuChemS, IAU, and IUHPS.

About the UN decision, we copy from the 2018 CI April issue [1]*:*

Jan Reedijk and Natalia Tarasova meeting at UNESCO on 29 November 2018 to review the preparations for the IYPT2019 Opening Ceremony.

"On 20 December 2017, the United Nations General Assembly proclaimed 2019 the International Year of the Periodic Table of Chemical Elements (IYPT 2019) during its 74th Plenary Meeting, at its 72nd Session. In proclaiming an International Year focusing on the Periodic Table of Chemical Elements and its applications, the United Nations has recognized the importance of raising global awareness of how chemistry promotes sustainable development and provides solutions to global challenges in energy, education, agriculture and health. Indeed, the resolution was adopted as part of a more general Agenda item on Science and technology for development. This International Year will bring together many different stakeholders including UNESCO, scientific societies and unions, educational and research institutions, technology platforms, non-profit organizations and private sector partners to promote and celebrate the significance of the Periodic Table of Elements and its applications to society during 2019."

The IYPT activities will be supervised and managed by the International Steering Committee (founding team), an International Management Committee in collaboration with the Innovation and Capacity Building Section, Division of Science Policy and Capacity Building

United Nations Educational, Scientific and Cultural Organization

International Year of the Periodic Table of Chemical Elements

Dates	Activity Description	Website
Jan 29	Official Opening at UNESCO	www.iypt2019.org
Feb 11-12	Murcia Symposium: Setting their Table: Women and the Periodic Table of Elements	www.iypt2019women.es/scientific_topics.php
All year	EuChemS special periodic table showing relative amounts of the elements	www.euchems.eu/euchems-periodic-table/
All year	IUPAC Periodic Table Challenge: Online quiz	www.iupac.org/100
All year	EuChemS young chemists: Chemistry Rediscovered game	www.euchems.eu/divisions/european-young-chemists-network/chemistry-rediscovered/
All year	Periodic Table of Younger Chemists: International younger chemists network	iupac.org/100/pt-of-chemist/
Dec 5	IYPT2019 Closing Ceremony in Tokyo, Japan, endorsed by UNESCO and hosted by Science Council of Japan IUPAC subcommittee	www.iypt2019.jp/eng

Table 1: Selection of International Activities to celebrate the International Year of the Periodic Table 2019

Natural Sciences Sector UNESCO and an International Secretariat, located in the Netherlands, that started operating on 1 April 2018.

In early 2018, IUPAC has started the execution by formation of a Management Committee (MC), initially consisting of six members from IUPAC, and a little later extended to include six UNESCO members, representatives of the other scientific unions and of a few major chemical societies representing different regions of the world. (see full composition online at iypt2019.org/about-us)

Apart from planning the opening ceremony on 29 January 2019 and the closing ceremony in December 2019, this Management Committee will not organize many other events. In fact, the main duty of the Management Committee is the coordination and facilitation of activities and where needed give assistance in the initiation, relevant publicity, and sponsoring dealing with these activities, as well as dissemination via the website and social media and in collaboration with co-applying International Unions. An important duty of the Management Committee has been and still is finding proper sponsors for the several international events.

It is to be stressed that IYPT is not IUPAC only and the list a few selected activities (Table 1) illustrates that diversity.

UNESCO offered the option that countries appoint an IYPT ambassador (secondment) based at UNESCO in 2018/2019 for IYPT duties. The first of these appointees has started has started already: Dr. Natalia Tsivadze from Moscow, and is assisting the Management Committee in planning several activities, including the Opening Ceremony.

Table or System?

In the 19th century most publications in Chemistry were in German. This included Mendeleev, Meyer, and other colleagues who published their work in German scientific journals. They were writing about the "System," as there was no "Table" in the beginning. The first indication of a tabular format—rotated by 90 degrees from the present Tables—came from Mendeleev (see figure 1, left side).

A number of others also worked on understanding the System, but is was Mendeleev who first shaped it into tabular form (see figure 1 right), which is the basis of the current Periodic Tables, including the one commonly called IUPAC Periodic Table (see back cover of this issue).

To illustrate the history and process of the discoveries, we cite from the IYPT application prospectus:

> "The Periodic Table (System) was discovered in an era when atomic structures and electrons where not known, and equipment to purify and separate elements was still primitive. The discoveries

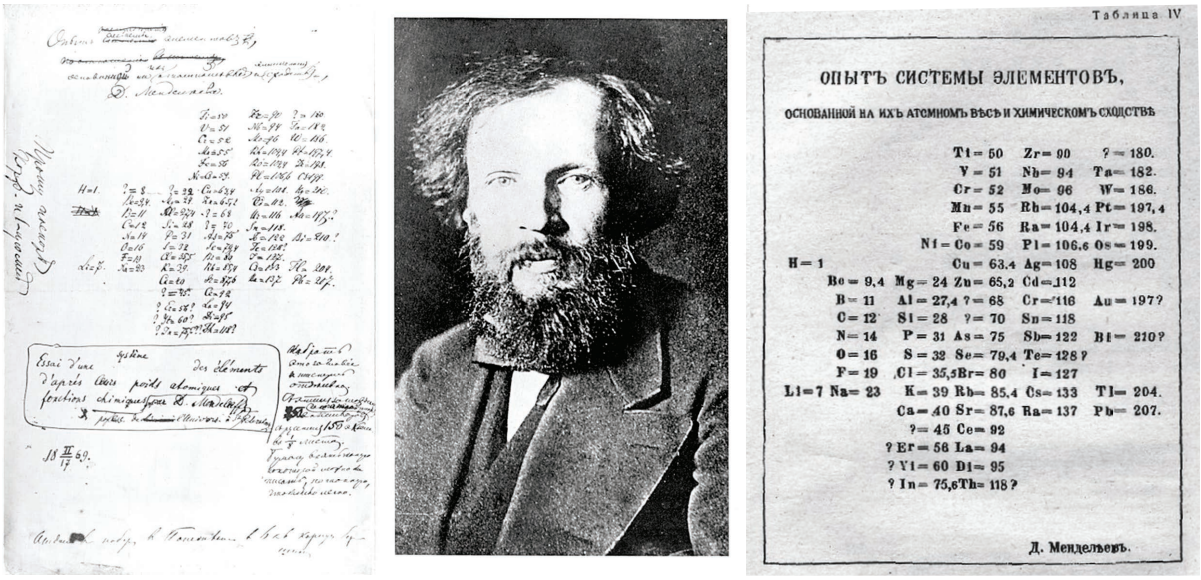


Таблица IV

ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ,

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

				Ti = 50	Zr = 90	? = 180.		
				V = 51	Nb = 94	Ta = 182.		
				Cr = 52	Mo = 96	W = 186.		
				Mn = 55	Rh = 104,4	Pt = 197,4		
				Fe = 56	Ru = 104,4	Ir = 198.		
				Ni = Co = 59	Pl = 106,6	Os = 199.		
H = 1				Cu = 63,4	Ag = 108	Hg = 200		
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112				
	B = 11	Al = 27,4	? = 68	Cr = 116	Au = 197?			
	C = 12	Si = 28	? = 70	Sn = 118				
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?			
	O = 16	S = 32	Se = 79,4	Te = 128?				
	F = 19	Cl = 35,5	Br = 80	I = 127				
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.			
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.			
		? = 45	Ce = 92					
		? Er = 56	La = 94					
		? Yt = 60	Di = 95					
		? In = 75,6	Th = 118?					

Д. Менделѣевъ.

Figure 1: The vertical version of Mendeleev's Table in 1869, in original handwriting (left) and the first vertical Table in print (right). (courtesy Mendeleev Society)

of Mendeleev, Meyer and others are therefore to be seen as immense. After the first International Conference of Chemists in 1860 (Karlsruhe), which both Mendeleev and Meyer attended, it became clear that a number of scientists had noted some regularities between chemical elements. The discoveries published in 1869 by Mendeleev, first in a vertical order, later that year in a horizontal arrangement, were preceded by discoveries of similar "regularities" from Béguyer de Chancourtois, Newlands, Odling, Hinrichs and Lothar Meyer. Only Meyer produced a quite similar tabular arrangement, in fact just after Mendeleev. There is little discussion that Mendeleev published his system noting that there was a periodic classification, *i.e.* the periodic law and the systematic arrangements of the elements, including some of the not yet discovered elements for which he even predicted chemical properties. Despite the fact that some of these predictions were incorrect and that in his system there was no place for the Noble Gases, he is still generally accepted as the chief architect, since he discovered the "system"; only later it was changed to "Table" as we now use in Periodic Table of Elements in English. Remarkable, the word "System" is still used as in "Periodic System" in a number of languages, *e.g.* Danish ("Periodiske system" and also: "periodesystemet"), Dutch ("Periodiek systeem") and German ("Periodensystem"), just as Mendeleev and Meyer used it in their papers. In Russia at least the Periodic Table is considered to be the illustration of the Periodic System."

Periodische Gesetzmässigkeit der Elemente nach Mendelejeff.

Reihen	Gruppe I R^2O	Gruppe II RO	Gruppe III R^2O^3	Gruppe IV RH^4 RO^2	Gruppe V RH^3 R^2O^5	Gruppe VI RH^2 RO^3	Gruppe VII RH R^2O^7	Gruppe VIII RO^4
I	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	Sc=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	Ga=68	-=72	As=75	Se=79	Br=80	
6	Rb=85	Sr=87	Yt=88	Zr=90	Nb=94	Mo=96	-=100	Ru=104, Rh=104 Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	Ce=137	La=139	-	Di=145?	-	- - - -
9	(-)	-	-	-	-	-	-	
10	-	165	-	169	Er=170	-=173	Ta=182	W=184 - Pt=194, Os=195(?) Ir=193, Au=196
11	(Au=196)	Hg=200	Tl=204	Pb=206	Bi=210		-	-
12	-	-	-	Th=231	-	U=240	-	- - - -

Figure 2: An old periodic Table from around 1880, available at the University of St. Andrews (UK).

The "System" terminology is still used in English today. An analysis on October 3, 2018, of the

Web of Science shows that since 1946 as many as 533 articles in English have "Periodic System" in the title, whereas 944 articles have "Periodic Table" in the title.

March 1, 1869 is often considered as the day of the discovery of the Periodic Law. That day Dmitry Mendeleev completed his work on "The experience of a system of elements based on their atomic weight and chemical similarity." Meyer published an updated version of his table, which was very similar to that of Mendeleev, in December, 1869. In the early days, both Mendeleev and Meyer were honored for their discovery of the "periodic relations of the atomic weights," sharing the Davy Medal of the Royal Society in 1882. Nowadays, Mendeleev is almost universally accepted as the originator of the Periodic Table of the Elements, perhaps because he included all known elements and because he used the Table predictively. Subsequently, the unknown elements he had predicted, gallium (1875), scandium (1879) and germanium (1887) were discovered and had the properties he predicted for them.

One of the earliest Tables left in hard copy, from around or just after 1880 is shown in figure 2. It was discovered in the archives of the University of St. Andrews (UK), and is there now on display. Note the empty space for germanium that was discovered only in 1887 (scandium and gallium are already listed in this Table). It is also interesting to note the "double" mentioning of Cu, Ag and Au. In a very nice stamp from Spain, these missing elements were elegantly shown (see figure 3).

Figure 3: A Periodic Table schematically projected on a stamp from Spain (2007), also showing the "missing" elements at the time Mendeleev published his findings.

Final Remarks

Other articles in this special issue of *Chemistry International* are highly recommended to read. They include an article by G. Jeffery Leigh, with a focus on the role of IUPAC in the development of the periodic table during the last century, and of the preceding Atomic Weights Commission, which oversaw the Periodic Table before 1919. In the next article, Sigurd Hofmann addresses the detailed history of the criteria for new element discoveries and its acceptances [2].

To illustrate that the discussions on the format of the Periodic table is not yet finished, Eric Scerri has written a contribution *"Looking Backwards and Forwards at the Development of The Periodic Table,"*, also discussing group 3 elements—including lanthanoid and actinoids—and how to place them in the Periodic Table, including the international discussions going on about this item.

Juris Meija, as chair of the IUPAC Commission on Isotopic Abundances and Atomic Weights (CIAAW) offers a short update summary of the history of this commission.

Peter Mahaffy, Norman Holden, and Ty Coplen review why "Isotopes Matter," a story recently featured in the IUPAC100 blog story (https://iupac.org/100/stories/why-isotopes-matter/), and supported by a full detailed technical report published in Dec 2018 in *Pure and Applied Chemistry.*

Finally, we can say with near certainty that this is not the end of the Periodic Table. The frequently asked question "Can we expect more new chemical elements, and if so, when?" will hopefully be answered in the next few years. These questions have been addressed recently in a separate paper in some detail [3].

For now, we are all looking forward to the very many events and activities for IYPT in 2019 worldwide, including the opening ceremony in Paris.

References

1. N. Tarasova, *Chem. Int.* (2018), **40**(2), 2-4
2. S. Hofmann, S.N. Dmitriev, C. Fahlander, J.M. Gates, J.B. Roberto and H. Sakai , *Pure Appl. Chem.* 2018; 90(11), 1773-1832; https://doi.org/10.1515/pac-2018-0918
3. J. Reedijk, *Polyhedron* (2018), **141**, 1-4

Jan Reedijk <reedijk@chem.leidenuniv.nl> has been President of the Inorganic Chemistry Division of IUPAC from 2014-2017, and has been Past President of this Division since January 2018, when he also became co-chair with Natalia Tarasova of the Interunion Management Committee for IYPT 2109. He is a retired professor at Leiden University, The Netherlands, where he held the chair of Inorganic Chemistry between 1979 and 2009. He was the founding Director of the Leiden Institute of Chemistry (1993) and served in this role until 2005.

Natalia Tarasova <tarasnp@muctr.edu.ru> has been Past President of IUPAC since January 2018. She was President in 2016 and 2017 and has been a member of the IUPAC Bureau since 2008, and the Executive Committee since 2010. She is a professor at the D. I. Mendeleev University of Chemical Technology of Russia, a Member of the Russian Academy of Sciences, Director of the Institute of Chemistry and Problems of Sustainable Development, and a Chairholder of the UNESCO Chair of Green Chemistry for Sustainable Development.

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IUPAC and the Periodic Table

by G.J. Leigh

The Periodic Table is now regarded as such a fundamental part of current chemical research and teaching that it is salutary to learn that this prominence is a relatively recent development. IUPAC was established in its present form in 1919, but the roots of the Table go back much further. The general realization of the value of the Periodic Table to rationalize and teach chemistry has only come about since the new flowering of inorganic chemistry, which can be dated to the 1960s. Today the most popular form of the Table and its updating and dissemination owe much to IUPAC, though this was not always the case.

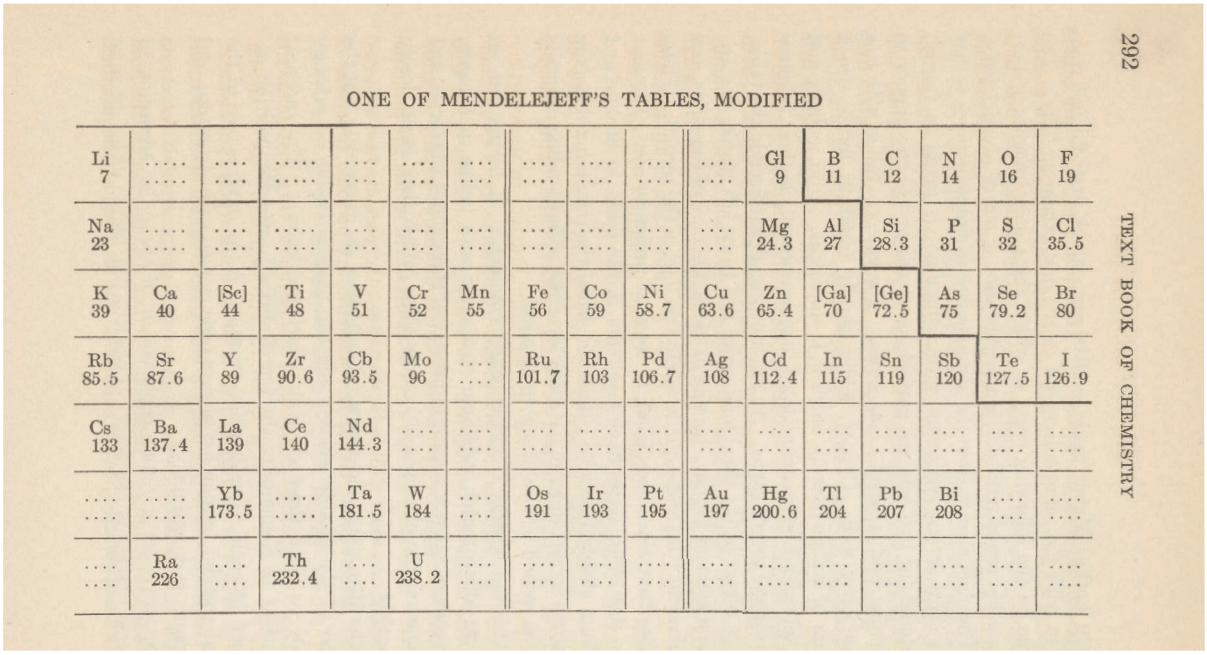
Figure 1 is taken from a Periodic Table of the Elements published by IUPAC on 1 December 2018. It represents the second and third periods, with the lighter elements of Groups 13-18. Each element square contains an atomic number, an atomic name, an atomic symbol and as many as three atomic weights. IUPAC is deeply concerned both with the general form of the Periodic Table and with the contents of each elemental entry. Note that IUPAC always uses a long form to display the Table, but this has not discouraged chemists from devising other arrangements, such as circular, spiral and even three-dimensional.

Attempts to systematize the chemistry of the elements in a logical fashion are more than 200 years

5	6	7	8	9	10
B	**C**	**N**	**O**	**F**	**Ne**
boron	carbon	nitrogen	oxygen	fluorine	neon
10.81 [10.806, 10.821]	12.011 [12.009, 12.012]	14.007 [14.006, 14.008]	15.999 [15.999, 16.000]	18.998	20.180
13	14	15	16	17	18
Al	**Si**	**P**	**S**	**Cl**	**Ar**
aluminium	silicon	phosphorus	sulfur	chlorine	argon
26.982	28.085 [28.084, 28.086]	30.974	32.06 [32.059, 32.076]	35.45 [35.446, 35.457]	39.95 [39.792, 39.963]

Figure 1 *Typical element entries taken from a long form of the Periodic Table, https://iupac.org/what-we-do/periodic-table-of-elements/. See back cover of this issue.*

old. The general acceptance of atomic theory, often ascribed to the influence of Dalton who published his ideas in 1805, was the beginning of the modern scientific systemization of the inorganic chemistry. It encouraged a more quantitative approach to inorganic chemical studies and the appearance of lists of so-called atomic weights. These were then relative combining weights, and are essentially those still used today. They are not related to the real weights of atoms. Döbereiner was an early systematiser who recognised the existence of triads, such as lithium + sodium + potassium, chlorine + bromine + iodine, and calcium + barium + strontium as early as 1817 [1]. In such triads the atomic weight of the middle element is roughly the mean of the atomic weights of the other two members. The recognition of weight relationships was extended further by Newlands [2] who enunciated his Law of Octaves. He noted that



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ONE OF MENDELEJEFF'S TABLES, MODIFIED

TEXT BOOK OF CHEMISTRY

Li 7	....	....	....	....	....	....	....	....	....	....	Gl 9	B 11	C 12	N 14	O 16	F 19
Na 23	....	....	....	....	....	....	....	....	....	....	Mg 24.3	Al 27	Si 28.3	P 31	S 32	Cl 35.5
K 39	Ca 40	[Sc] 44	Ti 48	V 51	Cr 52	Mn 55	Fe 56	Co 59	Ni 58.7	Cu 63.6	Zn 65.4	[Ga] 70	[Ge] 72.5	As 75	Se 79.2	Br 80
Rb 85.5	Sr 87.6	Y 89	Zr 90.6	Cb 93.5	Mo 96	....	Ru 101.7	Rh 103	Pd 106.7	Ag 108	Cd 112.4	In 115	Sn 119	Sb 120	Te 127.5	I 126.9
Cs 133	Ba 137.4	La 139	Ce 140	Nd 144.3	....	....	....	....	....	....	....	....	....	....	....	....
....	....	Yb 173.5	....	Ta 181.5	W 184	....	Os 191	Ir 193	Pt 195	Au 197	Hg 200.6	Tl 204	Pb 207	Bi 208	....	....
....	Ra 226	....	Th 232.4	....	U 238.2	....	....	....	....	....	....	....	....	....	....	....

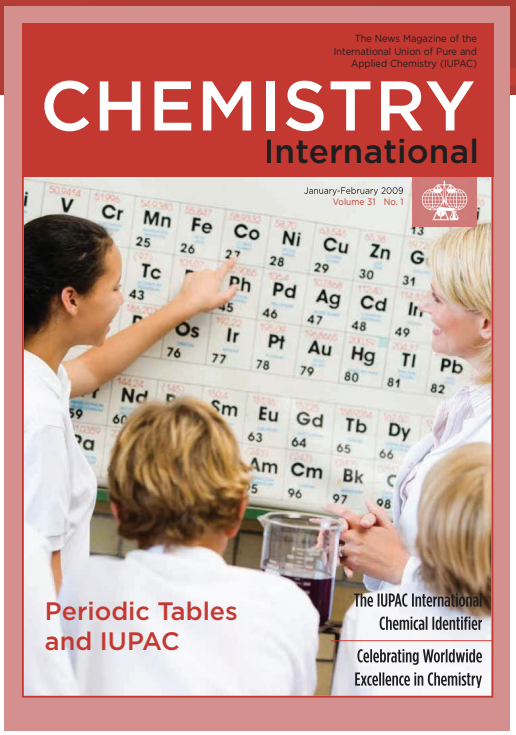
Figure 2. An early text-book example of a periodic table, taken from Alexander Smith, Intermediate Text Book of Chemistry, Century Co., New York, 1919.

groups of related elements are separated in weight order by seven other elements, and he even drafted a form of periodic table, though essentially with periods and groups at right angles to the modern usage. These advances would have been impossible without the wider determination of many atomic weights relative to hydrogen which was assigned the atomic weight of 1 and the recognition that some elements can exhibit more than one combining weight, an expression of what we would now understand is due to variable valency [3]. The first proponent of a modern form Periodic Table was Mendeleev who proposed what we would now regard as a short form [4]. Atomic weights were regarded as a basis for systematization until after 1913, when the significance of atomic number and hence basic elemental electronic structure was described by Moseley [5]. This eventually gave rise to the long form of the Table, and also to the many variants which are in circulation today. A very early and detailed adoption of Moseley's proposals for the employment of atomic numbers is to be found in the text of A Smith (1919), Intermediate Text Book of Chemistry, Century Co., New York. Figure 2, reproduced from page 292 of this book, shows a modified Mendeleev Periodic Table, which still retains atomic weights rather than atomic numbers, but leaves appropriate gaps for missing elements, except for hydrogen which is ignored and but it does include glucinium, which is now known as beryllium. There are no group or period numberings.

All this happened before IUPAC was formally constituted in 1919, and IUPAC still does not have an official format for the Table, though its discussions and recommendations generally use a clear and easily readable long form. However, it does promulgate official formalisms and rules governing the Table content.

The short form of the Table, essentially an extension of Mendeleev's format, was the first to be widely adopted. However, it was developed in contradictory forms on different sides of the Atlantic. For example, in the USA and Chemical Abstracts, the group of elements indicated by the symbols IVA was indicated by the symbols IVB on the European side of the Atlantic. There could have caused considerable confusion in the mind of a reader unaware of the place of origin of a particular paper and of the difference usages. The resolution of this contradiction involved the wider adoption of the long form of the Table and has been clearly and objectively described [6].

It was recognised by Ölander in 1956 [7] that this problem could be avoided by using a long-form numbering scheme for the various Groups. He suggested



See reference 7 in Chem Int *January 2009*

numbering them 1-17, though this was not generally adopted. Although the 1970 IUPAC Red Book [8] made no mention of a Periodic Table, it did list groups of elements designated by numbers and the letters A and B. Thus Group 3A was listed as Sc, Y, La (including the lanthanoids) and Ac (including the actinides), whereas Group 3B included Ga, In, and Tl. The AB confusion still reigned until 1970 when the ACS proposed the current 1-18 Group numbering, which is best appreciated in a long form Periodic Table. There was considerable discussion between the ACS and IUPAC concerning the introduction of the 1-18 numbering and its value. Many older chemists did not see the need to agree to such formalisms, but the IUPAC Commission on the Nomenclature of Inorganic Chemistry eventually accepted and recommended it after some discussion. The next version of the Red Book (1990) [9] contains a long form of the Periodic Table with this numbering, though apparently copyrighted by IUPAC and Kurt Samuelsson! Such a long form is as official as IUPAC recommends, but IUPAC now makes formal recommendations as to how all the contents of the Table in each element square such as those exemplified above should be modified as chemistry develops. Currently IUPAC is sponsoring a detailed discussion upon the preferable formulation for the elements in Group 3 of the Table. This has been a subject of discussion for some years. IUPAC now adjudicates for the international chemistry community on all changes and formalisms likely to affect the detailed presentation of Periodic Tables. That includes names, symbols, and atomic weights.

Atomic number rather than atomic weight now defines the place of a given element in the element

series. This will not change. There are now no "missing elements" such as those which puzzled Mendeleev and his contemporaries, and which led him to suggest where unknown elements might occur in the Table. Before the Inorganic Chemistry Division of IUPAC undertook to consider claims for new elements, there was no obvious public method for the chemical community to assess the reliability of the individual claims or to approve the suggested names and symbols, though the Atomic Weights Commission attempted to do so. For example, element 86, now called radon, Rn, was discovered in 1899. It had originally been identified as "radium emanation", and was designated in early literature as Em and even Ra Em, though no general decision to adopt such symbols was ever made.

Since World War II, new synthetic heavy elements have been synthesized in several different countries, starting with element of atomic number 93, neptunium, Np. When these "new" elements began to appear, they originated in the United States. During the Cold War, the Soviet Union was eager to show the world that it could also synthesize new elements, and meetings of the IUPAC Commission on the Nomenclature of Inorganic Chemistry sometimes provided a battle ground where representatives from each of these two countries made efforts to undermine claims to new elements made by the other. This was an uncomfortable experience for those members of the Commission who were not of Soviet or US nationality [10]. There was also an accepted rule within the Commission that the name of a living scientist should not be used in the name for a new element. This rule has now been superseded, though not without some initial spirited discussion [10]. It became evident that an internationally acceptable procedure was needed for assessing and naming a claim to have prepared a new element. Since these new elements are as much a product of high-energy physics as of chemistry, the procedure now used is one in which IUPAC collaborates with IUPAP in assessing claims.

The current limit of recognised elements concludes with element 118, oganesson, Og. When new elements are claimed, IUPAC and IUPAP jointly consider whether the claim is scientifically satisfactory. If the science is accepted, then the discoverers are asked to suggest a name and symbol, and IUPAC then assesses whether the name would prove acceptable to the international community. This exercise was last undertaken and published in 2016 when the discoveries of the elements with Z = 113, 115, 117, and 118 were confirmed [11] and then the names and symbols for these elements nihonium, moscovium, tennessine, and oganesson were officially recognised and recommended for inclusion in the Periodic Table. For an account of these discoveries see [12]. Criteria for acceptable sources used when proposing new names have also recently been published [13].

In the past, there was considerable literature concerning unprepared elements, and it became necessary to devise a system of provisional element names and symbols to assist such discussions. To this end, Joseph Chatt, then Director of the Unit of Nitrogen Fixation at the University of Sussex, proposed the system of provisional names and symbols based upon atomic number, which IUPAC adopted. In this system, a set of syllables derived from classical sources, but recognizably representing each number from 0 to 9, is sufficient to identify any element of a given atomic number even if the element has not been prepared and has no recognised name and symbol [14]. For example, element 118, designated by IUPAC by the provisional symbol Uuo and the provisional name ununoctium; it is now officially named oganesson. The validity of claims to its initial preparation were the matter of some dispute, but it seems to have been prepared on more than one occasion in different laboratories between the years of 2002 and 2006. The synthesis was officially accepted after assessment in 2015. Oganesson concludes both a Group and a Period in the Periodic Table. If element 119, ununnovium, symbol Uun, ever appears, its position in the Table will have to be decided by the community and IUPAC. It is tempting to suggest it would be a new alkali metal in Group 1, below francium. A discussion of these matters can be found in [15].

Atomic weights have been a concern of IUPAC since the 1920s. The history of the Atomic Weights Commission (now known as the Commission on Isotopic Abundances and Atomic Weights, CIAAW) has been described in detail by Holden, and shows that the need to determine internationally agreed-upon atomic weights was understood long before IUPAC was formally established in 1919 [16]. The formation of the Commission itself was a consequence of the realization that the determined values of atomic weights depended upon the isotopic composition of the samples employed, and these varied with place of origin. In addition, the determination of atomic weights is now based upon physical methods of great accuracy and no longer relies, as it did originally, on simple test-tube chemical analysis. The Commission was first established in 1899 and now operates under the auspices of the Inorganic Chemistry Division of IUPAC. In its early days it was responsible for naming elements, and it was involved in discussions such as whether element 74 should be named tungsten

or wolfram. Its recommendations were not always accepted by all countries, and some national variants in spelling, such as aluminum and aluminium, still persist. Today name recommendations are made only for use in English since it may not be possible to devise names which satisfy all international requirements. For example, recommended names such as tennessine for element 117 may cause discomfort to users of Spanish, which does not normally use combinations of letters such as "ss" and "nn".

CIAAW attempts to keep the chemistry community aware of the latest and best estimates of the atomic weights and isotopic compositions of the elements. It generally reports every second year on the atomic weights of the elements and on their isotopic compositions. Each value is usually cited to five significant figures. For some elements it cites maximum and minimum values which arise from the differing isotopic compositions of the samples studied, which come from sources of different origins. For a recent summary of data see www.sbcs.qmul.ac.uk/iupac/AtWt/. This range is indicated in the IUPAC 2016 Table for most of the lighter elements, where variations may have greater practical significance, such as the study of biological systems. In such cases the Table also gives a satisfactory mean value. Heavier elements are generally given a best mean value, with the exceptions of thallium and bromine, for which ranges are also provided. The 2017 report of the CIAAW also adds a weight range for argon [17].

In conclusion, IUPAC was not involved in the development of the Periodic Table, but once the Union became established in 1919 it has kept notice of the various changes made, and since its widespread adoption for teaching and rationalizing chemistry it has been the prime international authority for developing and adopting changes in its content, including new elements, and their atomic numbers, names, symbols, and atomic weights.

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Criteria for New Element Discovery:

by Sigurd Hofmann

Allure and romance are rarely expected in an article presented under the bulky headline "Criteria that must be satisfied for the discovery of a new chemical element to be recognized." However, the members of the Transfermium Working Group (TWG) worked out a most fascinating publication on a difficult subject during the years from 1988 to 1991 [1].

In order to solve problems related to the discovery of transfermium elements, which included claims up to element 109 at that time, IUPAC and the International Union of Pure and Physics (IUPAP) had jointly launched TWG for working out appropriate criteria and rules so that existing claims for discovery could be settled and that in the future the priority of discovering new elements could be decided timely and unambiguously. As a result, the 1991 article on the criteria for discovery of a new element was prepared by A.H. Wapstra as secretary in the name of the TWG, consisting of:

- D.H. Wilkinson (IUPAP; UK), Chairman
- A.H. Wapstra (IUPAP; Netherlands), Secretary
- I. Ulehla (IUPAP; Czechoslovakia), Secretary
- R.C. Barber (IUPAP; Canada)
- N.N. Greenwood (IUPAC; UK)
- A. Hrynkiewicz (IUPAP; Poland)
- Y.P. Jeannin (IUPAC; France)
- M. Lefort (IUPAP; France)
- M. Sakai (IUPAP; Japan)

It is to the credit of the members of TWG that the article became an exciting lecture on the spirit behind research, in particular on the study of new heavy and superheavy elements and nuclei. Two most impressive extracts of the TWG report are presented in the following:

"The centuries-old history of the definition and discovery of chemical elements has a deep scientific and general fascination. This is because the problem is of an essentially finite scope: there can only be a limited number of species of atomic nuclei containing different numbers of protons that can

Transfermium Working Group visit the Berkeley laboratory, 19-23 June 1989. The photo shows the nine members of TWG and Glenn Seaborg as the host of the group. *Front row: Ivan Ulehla (Czechoslovakia, co-secretary), Denys Wilkinson (UK, chairman), Glenn Seaborg (USA, leader of LBNL), Yves Jeannin (France). Back row: Marc Lefort (France), Norman Greenwood (UK), Andrzej Hrynkiewicz, (Poland), Mitsuo Sakai (Japan), Robert Barber (Canada), Aaldert Wapstra (co-secretary, Netherlands). Jeannin and Greenwood were named by IUPAC, the others by IUPAP. The TWG has held the following meetings, of which the first and last were "private", with the remainder in the laboratories of chief concern: 3-5 February 1988, Nonant (France); 12-17 December 1988, Darmstadt (Germany); 19-23 June 1989, Berkeley (USA); 12-16 February 1990, Dubna (Russia); and 16-20 April 1990, Prague (Czechoslovakia).*

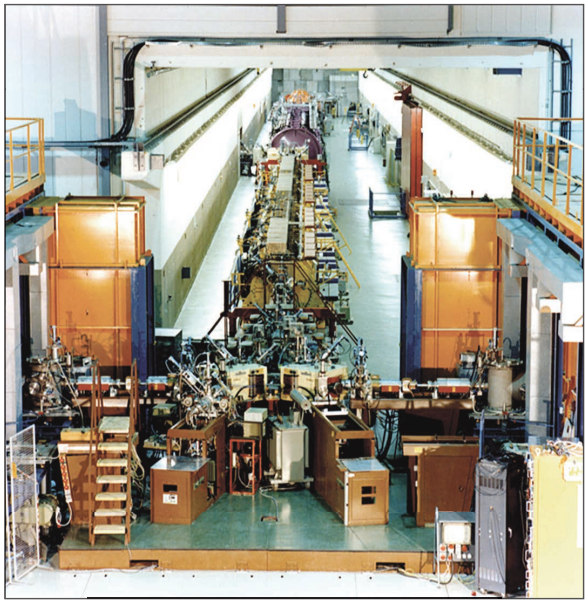
be imagined to have an existence, though perhaps only fleeting, in the chemical sense. But although the problem is of finite scope, we do not know what the scope is: we do not as yet know how many elements await discovery before the disruptive Coulomb force finally overcomes the nuclear attraction. In this sense, the problem is open although of finite scope, unlike the number of continents upon the surface of the earth where we know with certainty that none still awaits discovery. These considerations give to the discovery of new elements an importance, an allure and a romance that does not attach to the discovery of, say, a new comet or a new beetle where many more such discoveries are to be anticipated in the future."

And:

"... the insight that they [the new elements] give into the details of the construction of Nature's most complex nuclear edifices and the laws that govern their construction, explains the great investment of material and, most particularly, human resources into the discovery of new elements. Lives are committed over decades to this enterprise, and this is not surprising. Nor is it then surprising that, although from the point of view of science itself (except that of the "science of history") and the associated advance of human understanding it does not matter who makes the discovery, immense importance is attached, personally, institutionally and nationally, by those engaged in the enterprise, to the public recognition of their discoveries."

Beyond personal, institutional, and even national controversies, scientific work needs clear and unambiguous data and results. Those related to new elements are obtained in big laboratories having adequate instrumental equipment available. These are necessary prerequisites because all new elements beyond uranium were discovered by observation of the nuclear reactions which produced them. The last eighteen elements were discovered in fusion reactions and the more recent ones in fusion with heavy ions. Now, one may ask why ambiguities arise when this research is performed by outstanding scientists working in highly advanced laboratories with the most sophisticated technical equipment?

The answer is related to the complicated matter, and to the fact that only a few atoms are produced, in extreme cases only one, so that statistical fluctuations are huge. Another complication with identification of

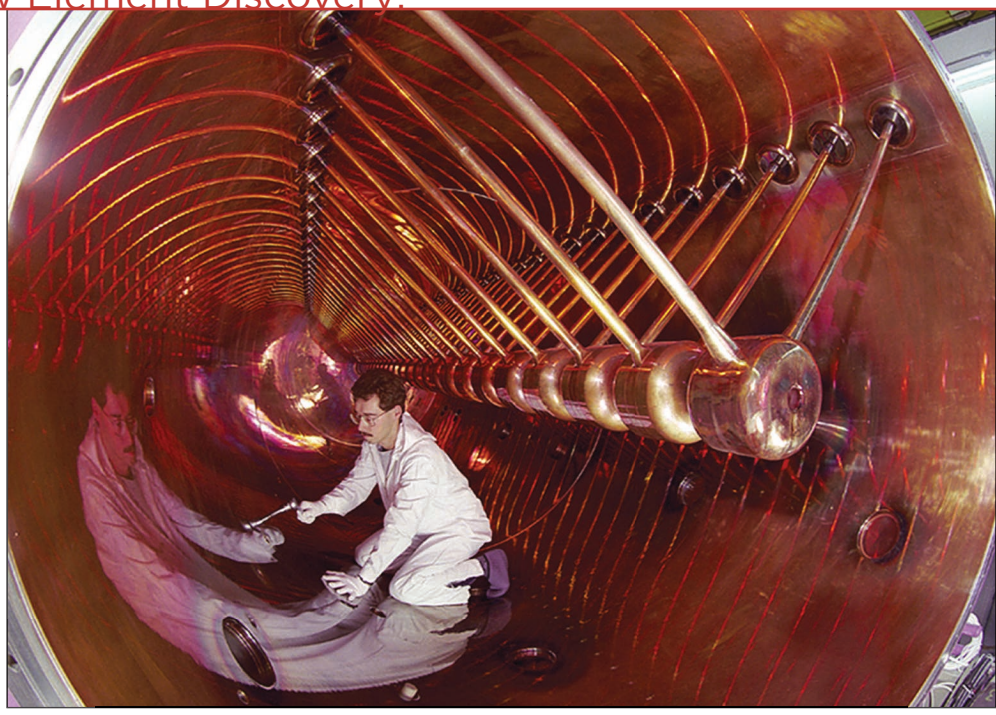


The "UNIversal Linear Accelerator" (UNILAC) setting at the Gesellschaft für Schwerionenforschung, GSI, in Darmstadt, Germany, where the first beam was generated at the end of 1975.

the produced nuclei arises through the variety of decay modes and wide range of possible lifetimes. In principle, all known nuclear decays, except radioactive neutron emission, have to be considered for isotopes in the region of the heaviest elements: β^+ or electron capture, β^- and α decay, radioactive proton emission, and spontaneous fission, as well as decays from the ground-state and from isomeric states. On one hand, this variety of decay modes opens a rich field for experimental research as well as theoretical studies. On the other hand they can be a source for errors and incorrect or misleading interpretations. In addition, all these studies are hampered by relatively high backgrounds from various nuclear reactions other than complete fusion. To make matters worse, energetically possible evaporation of reaction neutrons, protons and/or α particles after fusion contributes additional uncertainty.

Furthermore, experimental deficiencies like beam and target impurities, insufficient detector resolution, and electronic disturbances, together with the large statistical fluctuations and sometimes also the application of uncertain theoretical predictions may result in interpretation of a measurement which later cannot be substantiated. The worst that could happen, and indeed happened more than once in the scientific work of laboratories, is that individuals may not resist the temptation to manipulate data. This may be explained by an obsession for recognition as well as a motivation to satisfy the expectations of sponsors.

Criteria for New Element Discovery:



Inside the UNILAC at the GSI

All these experimental and human imperfections can lead to ambiguities and controversies which do not allow for an immediate recognition of an experimental result as being correct or, in the case of conflicting data, to determine which is correct.

In order to solve the problems related to the assignment of priority of discovery of elements 101 to 109, TWG applied its 1991 criteria to the existing claims of these elements. The result was published in 1993 [2]. The following years saw a number of consultations and exchanging of letters in order to find agreement between IUPAC, IUPAP, and the involved laboratories. At that time this included Lawrence Berkeley Laboratory, (now Lawrence Berkeley National Laboratory (LBNL)), in California, USA, the Joint Institute for Nuclear Research (JINR) in Dubna, Russia, and the Gesellschaft für Schwerionenforschung, (GSI) in Darmstadt, Germany. Eventually, a final IUPAC Recommendations for the names and symbols of these elements were published in 1997 [3]. These names and symbols as they appear now in the Periodic Table of the Elements were also accepted by IUPAP and the involved laboratories.

Discussion on the priority of discovery of elements up to 109 was still ongoing in 1995 and 1996 when discovery of further elements 110, 111, and 112 was claimed by an international collaboration working at the Separator for Heavy Ion Reaction Products (SHIP) at GSI. A review of all the results was presented and published in 2000 [4]. The most recent results of this series of experiments have been published in 2002 [5]. In 1999, discovery of element 114 was announced by international research collaborations working at the energy filter VASSILISSA and the Dubna Gas-Filled Recoil Separator (DGFRS) at JINR. Subsequently, international collaborations working at DGFRS announced claims for discovery of elements 116, 118, 115, 113, and 117 in chronological order in the years up to 2010. The most recent discovery was published in [6]. A summary of all results of the Dubna experiments has been presented in [7]. Another claim on the discovery of element 113 was submitted by a Japanese-Chinese collaboration working at the Gas-filled Recoil Separator (GARIS) at the Institute of Physical and Chemical Research (RIKEN) at Saitama near Tokyo in 2004 [8]. Subsequently, most of the experiments were repeated at the claiming laboratories, in many cases independently at other research centres as well. Most of the results were confirmed.

The claims for discovery of elements from 110 to 118 were investigated by four newly established Joint Working Parties (JWPs) of IUPAC and IUPAP in the years from 2001 to 2016. In six IUPAC Technical Reports, the JWPs assigned priority of discovery of the elements from 110 to 118 on the basis of the criteria published by TWG in 1991. The decisions were accepted by IUPAC, IUPAP, and in particular by the involved laboratories. Discovery of elements 110 to 112 was assigned to the collaboration at GSI, 113 to the collaboration at RIKEN and 114 to 118 to the collaborations at JINR. According to the rules for the 'Naming of New Elements' published as IUPAC Recommendations in 2002 [9] with an update from 2016 [10] these elements received their names as suggested by the discoverers. These names and symbols from darmstadtium, Ds, for element 110 to oganesson, Og, for element 118 are listed in IUPAC's recent Periodic Table of the Elements.

The remarkable growth of research on superheavy nuclei and elements based on the development of

Foundation meeting of the JWG in Egelsbach near Darmstadt, Germany, 20-22 May 2017. Left to right: Sigurd Hofmann (Chair), Sergey Dmitriev, Jacklyn Gates, Natalia Tarasova (2017 President of IUPAC) proudly keeping the Chart of Nuclei in her hands, Bruce McKellar (2017 President of IUPAP), James Roberto, Hideyuki Sakai (Vice Chair), and Claes Fahlander, respectfully holding the Periodic Table of the Elements.

intensive beams of rare but stable isotopes, the use of neutron rich radioactive targets of actinides, and highly sensitive detection methods was difficult to envisage at the time when criteria and rules for assigning priority of discovery of new elements were set up in 1991. Therefore, not all criteria take into account specific advantages or any problems and difficulties adherent to the production and identification methods being in use now.

A new Joint Working Group (JWG) was created by IUPAC and IUPAP at the beginning of 2017 with the task to review the criteria and rules worked out by the 1991 TWG in the light of the experimental and theoretical advances in the field. The new JWG consists of six members:

- Sigurd Hofmann (IUPAC; GSI, Germany), Chairman
- Hideyuki Sakai (IUPAP; RIKEN, Japan), Vice Chairman
- Sergey N. Dmitriev (IUPAC; JINR, Russia)
- Claes Fahlander (IUPAP; Lund University, Sweden)
- Jacklyn M. Gates (IUPAP; LBNL, US)
- James B. Roberto (IUPAC; ORNL, US)

Three members were suggested by IUPAC and three by IUPAP. The restriction excluding the appointment of members from a claimant laboratory which applies to JWPs does not apply to our JWG, which is not evaluating any claims. Two members are nuclear chemists and four nuclear physicists. This reflects that nuclear decay properties are eventually needed for the identification of an isotope, although chemical separation may have been or will be performed. The importance of the mutual dependence of chemistry and physics becomes apparent in cases when radioactive isotopes of actinides are needed for the irradiation. An impressive example is the production and purification of the isotope ^{249}Bk by chemists of the Oak Ridge National Laboratory, Tennessee, USA. This isotope with a half-life of only 327 days was needed for the synthesis of element 117 at JINR. The work of those chemists was honoured with naming this element after the state of their laboratory, tennessine.

Our first meeting with participation of the then respective Presidents Natalia P. Tarasova of IUPAC and Bruce H. J. McKellar of IUPAP took place in Egelsbach near GSI in Darmstadt, Germany, 20-22 May 2017 (see photo). After election of a chairman and a vice chairman, both presidents communicated the Terms of Reference for JWG. A second four-hour meeting was arranged during the 3rd International Symposium on Super-Heavy Elements in Kazimierz Dolny, Poland, on 11 September 2017.

At the first meeting in Egelsbach we exchanged opinions on the subject and discussed a possible layout of our report. Considering the update of the criteria in the context of recent discoveries and expected future search experiments for new elements we felt it also necessary to present a short retrospective on the elaborate work of experimentalists and JWPs according to the Chinese proverb: "*If you want to learn about the future, you have to look into the past.*"

The retrospective research revealed that the task of our JWG differs from that of the TWG functioning during the years 1988 to 1991. At that time, criteria were developed for assigning priority of discovery of

Festive christening of element 112 as copernicium, Cn, at the GSI in Darmstadt, Germany, on 12 July 2010.

elements for which discovery was already claimed up to meitnerium with element number Z = 109. Our present aim was to work out criteria for assigning discovery of new elements beyond oganesson, Z = 118, which may be discovered in the future. Therefore, it was essential to estimate on the basis of known data and theoretical studies which new elements will most likely be searched for, what their decay properties may be, and which methods could be applied for production and identification using present and near-future technology.

The detailed study of the publications claiming discovery of a new element revealed that in general the nature of the experimental data is such that an absolutely secure identification in a first attempt is rarely possible when new regions in the chart of nuclei are explored, where decay chains produced by subsequent α decays are not connected to known nuclei, or the small number of produced nuclei does not allow for a convincing identification by characteristic X-rays. Only the combination of information from various irradiations and measurements results in a secure identification. The term "discovery profile" was already coined for this method of linking results from different obtainable measurements in different laboratories in the 1991 TWG report. This was the procedure from the end of the 1990s and the beginning of the new millennium through which the isotopes of new elements with proton numbers from 114 to 118 could be safely and relatively quickly identified. These isotopes were located in the theoretically predicted and now experimentally confirmed region of spherical superheavy nuclei, also known as the island of stability.

A similar situation may occur in the future when experimentalists will search for new regions of isotopes of new elements beyond the known region of spherical superheavy nuclei at Z = 114 and neutron number N = 184. Such new regions could arise from the stabilizing effect of a next single or double shell closure for spherical nuclei, from a special arrangement of the energy levels for protons and/or neutrons for deformed nuclei, or due to bubble or donut like arrangements of the nucleons.

Identification of new elements is relatively straightforward when the produced isotopes can be identified *via* a sequence of subsequent α decays genetically connected to known daughter products and using known reactions, *e.g.* fusion evaporation reactions, and established identification methods. In this case only one measured decay chain could be sufficient for safely assigning priority of discovery. This is way the first isotopes of the elements from bohrium, Z = 107, to nihonium, Z = 113, were identified.

However, the identification of an isotope using genetic relations is not always straight forward. The assignment of a decay chain genetically linked to a potentially known isotope requires that no other possible candidate with similar properties exists that could be mistaken for the isotope that is believed to be well known. Similarly, in irradiations of a target with heavy ions it is *a priori* not possible to assign a measured decay chain to the product of a fusion reaction and in particular not to an isotope produced by evaporation of only neutrons.

This relatively simple example already reveals the difficulties which can arise with the interpretation of experimental results. In our JWG report we discuss the criteria listed in the 1991 TWG report in the light of the present technical possibilities and improved physical and chemical knowledge obtained from the successful production and identification of isotopes in the region of superheavy nuclei and elements. We discuss in detail various identification methods and point out specifically the experimental problems which can arise and which can hamper the interpretation of the measurements. Also considered are physical properties of the reaction for production and properties of the nuclear decays. All this information is intended as

guidance to be considered by experimentalists and future JWPs. It became obvious that our report cannot present a list for checking fulfilled and failed criteria where the number of fulfilled criteria decides on the discovery. It rather reveals that for each criterion its weight and its applicability to a certain experimental result have to be carefully evaluated and that a number of relevant criteria often need to be combined for elaboration of a discovery profile.

We do not consider our report as a review of all experimental and theoretical studies performed in the field since 1991. This information can be found in various review articles and in the specific publications in *Pure and Applied Chemistry*. Study of the large number of publications and reports needed time. Similar to situations in research or other enterprises, the development of ideas and discussion with an exchange of views also needs time.

To develop rules and criteria for safe and timely decisions on priority of discovery of a new element could not be achieved in a few days of meeting. On the other hand, the long distances between our home institutions made frequent meetings difficult. Therefore, we tried to approach an ideal form of communication using email. This way we could finish our report after one year of work. It was sent for further consideration to the Presidents of IUPAC and IUPAP in May 2018 [11].

Our look into the past led us to reflect with admiration on the obtained results in the field of research on superheavy elements and nuclei during the nearly thirty years since 1991. The publications convey not only the pure physical or chemical results but also the enthusiasm and pride of the authors, with uncertainty usually hidden between the lines. We realized that in complicated situations the best way for solving open problems is communication in addition to the application of rules and criteria. This is similar to situations which happen to us in our everyday life. Communication often helps to overcome apparent injustice and to improve collaboration through the exchange of knowledge.

Although nobody can look into the future we believe that exciting work is still ahead of us. Primarily it is the search for isotopes of new elements near and beyond the presently known region of superheavy nuclei and elements but also the detailed study of nuclear, atomic, and chemical properties of isotopes of the already known ones. Exploring the unknown gives us '*... the insight ... into the details of the construction of Nature's most complex nuclear,* atomic, and chemical *edifices and the laws that govern their construction'.*

Finally, I would like to thank my colleagues in the Joint Working Group for a fruitful period of discussion and sharing thoughts and ideas on an important theme of allure and romance.

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Sigurd Hofmann <S.Hofmann@gsi.de> was leading scientist at the Gesellschaft für Schwerionenforschung (GSI), in Darmstadt, Germany, which is credited with the discovery experiments of several chemical elements, including darmstadtium, roentgenium, and copernicium. He is Honorary Professor at the Goethe-Universität in Frankfurt am Main.

Looking Backwards and Forwards at the Development of the Periodic Table

by Eric Scerri

Since the periodic table has reached the ripe old age of 150 years it may be an appropriate time to look back at the development of this unique scientific icon. It is also an opportunity to look forwards to any changes that the periodic table may undergo in view of the ever-growing list of new elements that continue to be synthesized. The way that the past and future will be examined in this article will be to follow a main thread that focuses on the number of columns in the periodic table at various stages in its development.

MENDELÉEFF'S TABLE I.—1871.

Series.	Group I. R_2O.	Group II. RO.	Group III. R_2O_3.	Group IV. RH_4. RO_2.	Group V. RH_3. R_2O_5.	Group VI. RH_2. RO_3.	Group VII. RH. R_2O_7.	Group VIII. RO_4.
1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Ce=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	? Y=88	Zr=90	Nb=94	Mo=96	—=100	Ru=194, Rh=104 Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	I=127	
8	Cs=133	Ba=137	? Di=138	? Ce=140	....	....	....	....
9	....	....	....	....	....	....	....	....
10	....	....	? Er=178	? La=180	Ta=182	W=184	....	Os=195, In=197 Pt=198, Au=199
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	....	....	
12	....	....	....	Th=231	....	U=240	....	....

Figure 1. Short-form or eight column periodic table as devised by Mendeleev in 1871.

So, let's begin with Mendeleev and the others who discovered chemical periodicity in the 1860s and generally presented their findings in the form of an 8-column table or what has become known as a short-form table (figure 1) [1]. This format has several appealing features which are worth pausing to consider. The first virtue is the simplicity of the short-form. It is based on the notion that chemical and physical properties recur approximately after eight elements and continue to do so. Unfortunately, some of the directness of this presentation is lost on moving to the 18-column format (figure 2) or even wider periodic tables.

A second virtue is that the 8-column table groups together a wide range of elements that share the same highest valency. For examples, beryllium, magnesium, calcium, strontium and cadmium all appear in the second column of the short-form table. Not surprisingly, the 8-column table is still used in certain parts of the world, most importantly in Russia where its most successful version was first discovered by Mendeleev in 1869. The reason why Mendeleev receives the most credit, even though he was the latest among the six independent co-discoverers, has been much debated by historians and philosophers of chemistry.

The usual account is that only Mendeleev made successful predictions of then unknown elements. However, another school of thought disputes the claim that successful predictions are quite so important and proposes that the successful accommodation of already known data is an equally good criterion for the acceptance of scientific theories and concepts [2].

The early periodic tables were required to literally accommodate the 60 or so elements that existed in the 1860s and the relationships between them, which was by no means a trivial task. Today a periodic table must accommodate the presence of about twice that number of elements and their similarity relationships.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	

Fig 2. 18-column or medium-long form table

18-column tables

The expansion of the periodic table from an 8-column format to one with 18-columns is not essential but seems to have been generally made some years after the initial discovery of chemical periodicity. There are several reasons why this change was made, some of them scientific and others pragmatic.

First of all, it must be recognized that the periodic table, an object of enormous utility, is man-made. It is not given to us directly by Nature even though chemical periodicity is a scientific fact. The precise form of the periodic table is a form of compromise that aims to serve the majority of scientists and students of science, but it cannot serve all of them at once. For example, chemists who choose to focus primarily on chemical similarities might wish to favor a particular format; chemical educators or experts focusing on atomic structure may favor a different format. The author does not claim that there is one optimal periodic table and yet he believes that it is worth striving to obtain the best possible compromise version that the scientific community can agree upon.

But let me return to the expansion of the table to an 18-column format. One reason for expanding the table in this way is that upon closer inspection chemical periodicity does not invariably operate with a constant repeat distance of eight elements. If one wants to capture chemical similarities among elements more accurately, one must accept that after two period lengths consisting of eight elements each, the repeat length becomes 18 elements. Consider for example the two metals chromium and molybdenum that are very similar chemically but stand 18 rather than 8 elements apart. The 18-column highlights such similarities more effectively than the 8-column version.

Another motivation for the adoption of the 18-column table was that Mendeleev's table displayed certain awkward looking anomalies. The 8-column table can only truly display chemical periodicity if certain short sequences of elements are excluded from the main body of the table. For example, Mendeleev relegated iron, cobalt and nickel to what he labelled as group VIII (figure 1). He did this again for ruthenium, rhodium and palladium as well as osmium, iridium and platinum, all of which elements he termed as transition elements.

In an 18-column table there is no longer any need to exclude these elements. This feature would seem to suggest that an 18-column format shows some advantages in terms of representing all the elements in an evenhanded manner, although as we will see below, the 18-column table introduces another set of 'relegated' elements.

In historical terms the use of an 18-column format has followed a complicated path. Interestingly, even Mendeleev published some medium-long form tables, although his versions contained 17 rather than 18 columns since the noble gases had not yet been discovered [3]. The advent of quantum mechanics and the notion that electrons can be regarded as being situated in distinct shells also seems to have motivated the widespread adoption of a medium-long or 18-column format. Simply put, the 18 groups arise from the fact that, starting with the 3rd main electron shell, electrons occupy s, p and d-orbitals, numbering 9 in all, each of which can be doubly occupied to make a total of 18 electrons and hence the atoms of 18 successive elements, with each one having an additional electron. Since not all electron shells reach their capacity once they contain 8 electrons, it makes perfect sense to expand the periodic table according to the quantum mechanical explanation of chemical periodicity.

32-column tables

However, from the 4th electron shell 14 more electrons can now be accommodated in addition to the previous 18. In the modern terminology we now have f-orbital electrons in addition to the earlier mentioned s, p and d orbital electrons. So why don't we expand the periodic table further to make it into a 32-column format (fig 3)? In fact, an increasing number of textbooks are beginning to show such a long-form periodic table, which again has some advantages and some disadvantages.

H																														He
Li	Be																							B	C	N	O	F	Ne
Na	Mg																							Al	Si	P	S	Cl	Ar
K	Ca													Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr													Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

Fig. 3. 32-column or long form table

On the plus side, it allows every single element to be incorporated into the main body of the table. The odd-looking footnote to the 18-column table which traditionally houses the f-block elements now disappears. This is an analogous change to the one that occurs on moving from an 8 to an 18-column format that results in the incorporation of certain otherwise excluded elements into the main body of the table. Returning to the 32-column table, this also shows every single element in its correct sequence in terms of increasing atomic numbers as one moves through each period from left to right.

There are some pragmatic downsides, however. Presenting the periodic table in a 32-column format requires that the space for each element must be approximately halved. Worse still, the one or two-letter symbol for each element must now be reduced in size with the risk of rendering them less legible.

What next?

If we continue to follow this line of thinking regarding the progressive expansion of the periodic table we notice that the table may be due for yet a further expansion, at least in principle. Rapid advances have taken place in the synthesis of super-heavy elements in recent years. The f-block of the table has now been completely filled with elements, the most recent additions being nihonium, moscovium, tennessine and oganesson. For the very first time, and also the last time in the foreseeable future, the periodic table has absolutely no missing gaps. At least this state of affairs is true for the current periodic table that houses 118 elements arranged in seven periods.

There is no reason to believe that the periodic table has reached its end point and there are several current initiatives that are aimed at producing elements 119, 120 and beyond. The discovery of elements 119 and 120 will be easily accommodated by tagging two new spaces directly below francium and radium in either the 18 or 32-column formats. However, as soon as element 121 is synthesized, it will become necessary to introduce a new kind of footnote to the table to house what will be formally known as the g-block elements.

On the other hand, if we insist that all elements be placed together in the main body of the table and that all elements are numbered sequentially we will have no choice but to introduce a 50-column wide table! But this will only be the formal beginning of the g-block since theoretical calculations predict that the first element with a true g-orbital electron will be approximately element number 125 [4].

Interesting issues connected with the onset of new blocks of the table

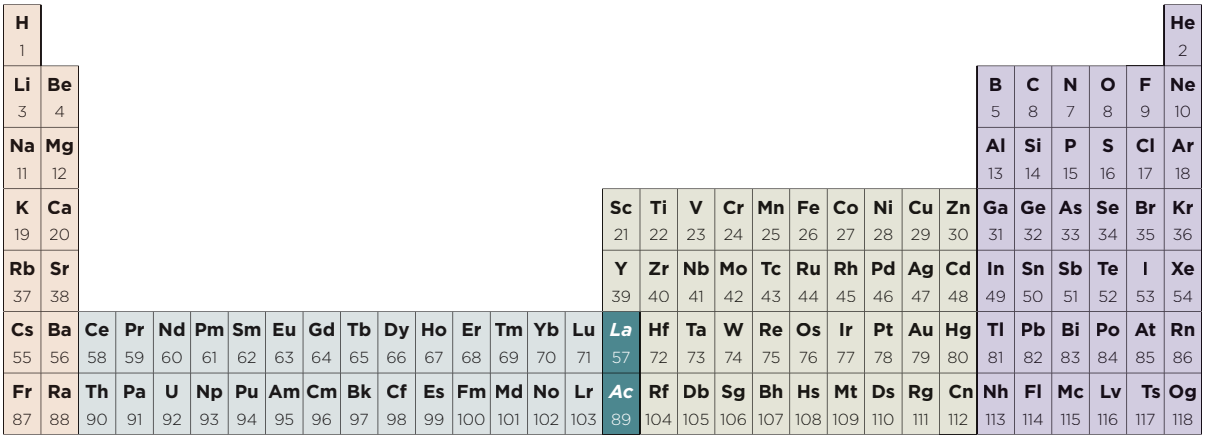
Each time that a new kind of orbital occurs in the Aufbau and the sequence of increasing atomic numbers, a new kind of problem also seems to arise.

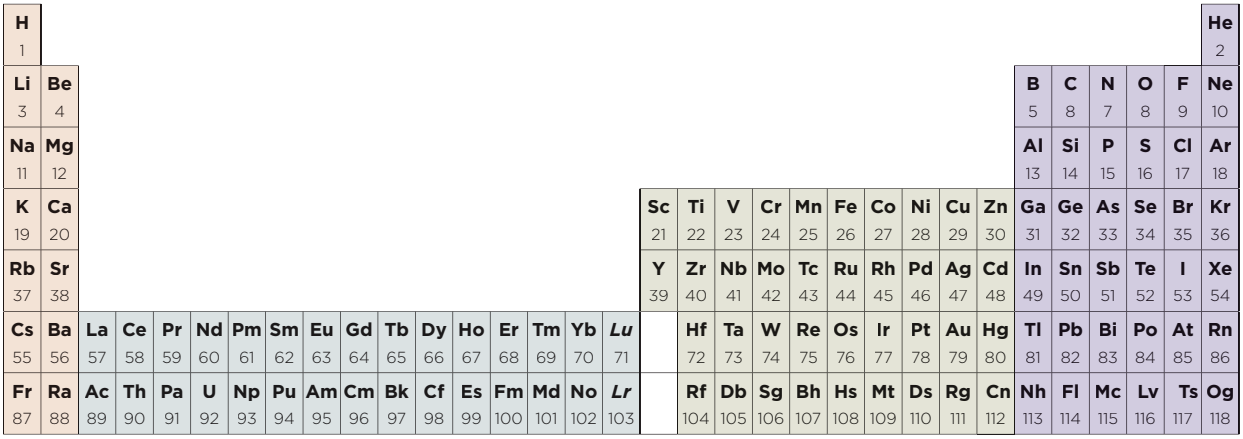
The first time that a d-orbital electron appears is in the atom of scandium, or element 21. In this case the claim that the atom contains a d-electron is not merely formal but is supported by much spectroscopic evidence. The problematical aspect concerns the fact that 3d orbital electrons only begin to appear after the 4s orbital has been occupied in the case of the atoms of potassium and calcium.

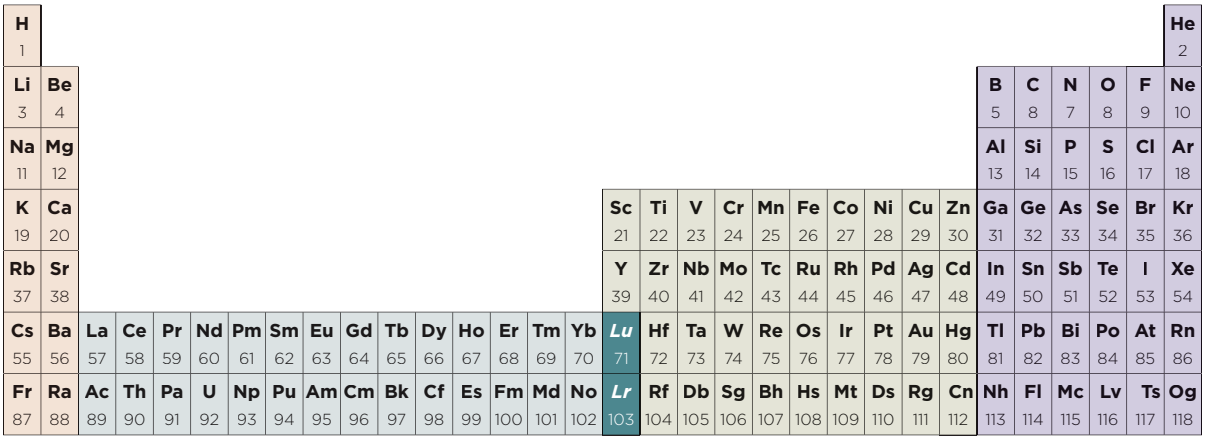
The vast majority of textbooks state that in the case of scandium the final electron to enter the atom, in terms of the fictitious but useful Aufbau scheme, is a 3d electron. This view immediately creates a problem when it comes to explaining the ionization behavior of the scandium atom. Experimental evidence clearly shows that the 4s electrons are preferentially ionized in scandium. If the 3d orbital had really been the final one to enter the atom it ought to be the first to be ionized, which runs contrary to the experimental facts. Almost every textbook proceeds to simply fudge the issue, in order to maintain that 4s electrons enter the atom first but are also the first to depart during the ionization process, something that clearly makes no sense in energetic terms [5].

The problem was clarified relatively recently by the theoretical chemist Eugen Schwarz who pointed out that in fact the 3d orbital electrons are preferentially occupied in scandium, followed by the 4s electrons and thus explaining perfectly why it is that 4s electrons are the first to be ionized [6]. However, it appears that Schwarz wants to throw out the "Aufbau baby with the bathwater." Schwarz correctly points out that the Madelung rule fails for all except the s-block elements. This is the rule that purports to show the relative energies of all the orbitals, and is part of the staple diet of high school and first-year undergraduate chemistry courses. However, any dismissal of this well-known mnemonic would be rather unfortunate since it still succeeds in listing the differentiating electron in all but about 20 atoms in the entire periodic table.

My reason for saying this is that as we move through the periodic table there is no denying that the differentiating electrons in potassium and calcium are 4s electrons while for scandium and most of the following transition metal atoms the differentiating electron is of the 3d variety. The Madelung rule therefore still rules when it comes to discussing the periodic table as a







Figures 4–6 (top to bottom): Three different long-form periodic tables with differences highlighted. Figure 4 (top): Version with group 3 consisting of Sc, Y, La, Ac. The sequence of increasing atomic number is anomalous with this assignment of elements to group 3, e.g., Lu (71), La (57), Hf (72). ***Figure 5 (middle):*** Second option for incorporating the f-block elements into a long-form table. This version adheres to increasing order of atomic number from left to right in all periods, but with lanthanum located at the start of a 15-element block. ***Figure 6 (bottom):*** Third option for incorporating the f-block elements into a long-form table. This version adheres to increasing order of atomic number from left to right in all periods, and groups Sc, Y, Lu and Lr together as group 3.

whole, as opposed to the occupation and ionization behavior of a single element such as scandium as discussed above [7].

First appearance of an f-electron

In principle, or using the Madelung rule, we find that f-orbital electrons begin to appear in the atom of lanthanum or element 57. However, according to experimental evidence this event occurs at the next element cerium (Z = 58). Notice how this delayed onset is analogous to the delayed onset of g-electrons that was described above.

If one consults current versions of the periodic table one finds that there are at least three versions that are on offer. In the majority of textbooks and wall-chart periodic tables we find lanthanum located in the d-block directly below the atom of yttrium (figure 4). In a smaller number of currently available periodic tables one finds lanthanum located at the start of a 15-element wide f-block (figure 5); and yet a third version places lanthanum at the start of a 14-element wide f-block (figure 6).

As a result of these alternative tables there are three different ways of regarding group 3 of the periodic table. According to the first option group 3 consists of scandium, yttrium, lanthanum and actinium (figure 4). In the second option, which features a 15-element wide f-block, group 3 contains a mere 2 elements, namely scandium and yttrium (figure 5). Finally, the third form of the periodic table implies that group 3 should be regarded as containing scandium, yttrium, lutetium and lawrencium (figure 6). What is a student of chemistry, or even a professional chemist to make of all of this?

A further complication is that neither chemical and physical evidence on the elements concerned, nor microscopic evidence in the form of electronic configurations, provide an unambiguous resolution of the question. One possible way to try to resolve the issue is to consider a 32-column table representation, and return to the main theme of this article. It turns out that in a 32-column table that also maintains all the elements in their correct sequence of increasing atomic number, the 3rd option would seem to be the most reasonable choice [8].

Needless to say, it is important for IUPAC to be in a position of recommending a compromise periodic table that most effectively conveys the largest amount of information to the largest group of users. Since the periodic table is a human construct there is no absolutely correct version of the periodic table. My own personal recommendation is that group 3 should be considered as consisting of scandium, yttrium, lutetium and lawrencium and that the f-block should formally begin at lanthanum even though the atom of lanthanum does not actually contain an f-electron. It remains to be seen what the recommendations of the working group will be [9].

What does not seem to be well known, even though Jeffery Leigh has written an article on the subject in this very magazine, is that there is currently no officially recommended IUPAC periodic table even though it regularly publishes one [10]. Now that the periodic table has reached 150 years it may be time for IUPAC to take the plunge and go ahead and recommend one official table.

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History of IUPAC Commission II.1 in the Service of Chemistry*

by John R. De Laeter

Atomic weights are of fundamental importance in science, technology, trade and commerce. In particular, atomic weights relate mass to molar quantities. It is therefore not surprising that the measurement of atomic weights has played a central role in the development of chemistry and continues to be a key component in the progress of discipline.

By the middle of the 19th century the atomic theory and its implications for the chemical elements had taken firm hold. Nature was seen to be using remarkably few types of elementary "building blocks" for all materials. With an understanding of simple-number valencies of these "elements", the stage was set for chemistry to emerge as a science based on measurement of the interactions between "atoms" of the elements in simple mass proportions. Chemical reactions, energies, and products, could now all be represented by simple formulae and equations. With newly developed balances of high precision, the relative mass values of the atoms of the elements could be determined. When scaled to the mass of hydrogen equal to one, or oxygen equal to sixteen, these relative elemental masses became known as "atomic weights."

Quantitative chemical analysis of materials with uncertainties a little better than 1 % became possible and widely practiced. However, there was an increasing need to determine the ratios between these constants with higher reliability than could be achieved by chemical analysis. To determine atomic weights to the highest possible accuracy, Berzelius and others developed the quantitative gravimetric study of the most stoichiometric compounds and the most complete reactions for each known element. Often the compounds and reactions involved oxygen, less frequently hydrogen, chlorine, bromine, or silver. Atomic weights, scaled to hydrogen or oxygen, and the oxygen/hydrogen mass ratio in water, were measured with great skill under carefully controlled conditions of purity and freedom from contaminations. New and better atomic-weight determinations by classical chemical methods also drove progress in chemistry, for instance in purification and recovery methodologies and insight into isotropy. The scientists, among them Richards, Brauner, Urbain, Hönigschmid, and Baxter who measured atomic weights, were rightfully accorded the highest honor among professional scientists.

As early as 1872 Frank W. Clarke, chief chemist at the US Geological Survey, recognized that measurement compatibility between laboratories made uniformly recognized atomic weights desirable. Under his leadership the best contemporary knowledge of the atomic weights became the primary task of the American Chemical Society's Committee on Atomic Weights, formed at the start of the 20th century, and of which the IUPAC Commission on Isotopic Abundances and Atomic Weights [CIAAW or Commisssion II.1] is the direct descendent.

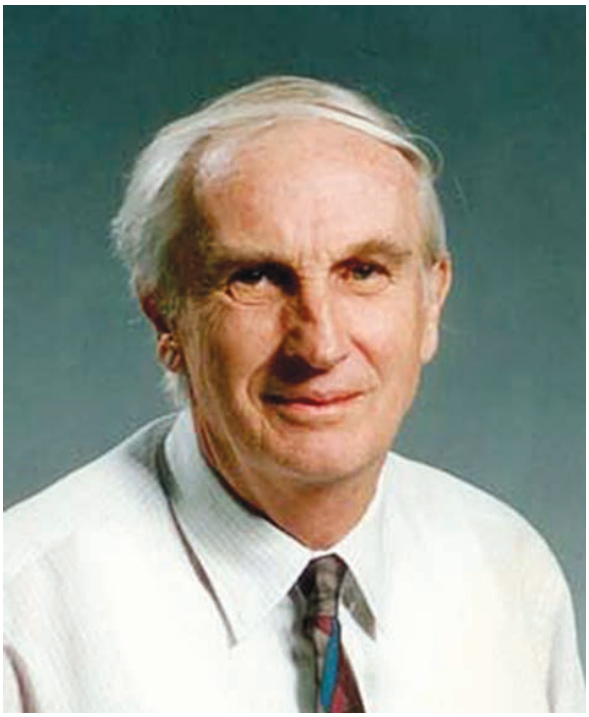
An elaborate international election of 57 chemists from many nations was organized by W. Ostwald, and, as a result, the Commission was initially entrusted to just three members who had obtained the highest number of election votes: F. W. Clarke, K. Siebert from Germany, and T. E. Thorpe from England. There was a strong feeling that France, a leader in the promotion of rational unification in measurement science, had to be represented on the Commission. So first H. Moissan and, after his death, G. Urbain of France joined the Commission. It preserved continuity through World War I despite problems in contacting German colleagues through Switzerland, as is documented in our Commission archives.

Nevertheless, after World War I the Commission flourished. It subordinated itself to the International Union of Pure and Applied Chemistry when that organization was established (in 1919). IUPAC saw the Commission's mandate at the heart of its own responsibilities to the world's science community. Indeed, no data set of science and technology has been or is now used more extensively or in as many disciplines, technologies, and commercial transactions, as is the IUPAC table of recommended atomic weights, now called the standard atomic weights. Reproduction of the table is encouraged by IUPAC and all cognate data are freely available in print or online.

In 1921 it was decided to reorganize and enlarge this Commission by giving it the responsibility of advising on the existence of radioactive and stable isotopes, as well as on atomic weights. It was renamed the

* This article is reproduced from the CIAAW Technical Booklet (5th edition, 1999) and has been edited slightly before online publication in April 2017, as http://www.ciaaw.org/history.htm.

Committee on Chemical Elements. Two members of the Committee were Francis Aston and Frederick Soddy, both of whom had received Nobel Prizes for their work on isotopes. Altogether six Nobel Prize laureates have served on the Commission and two of them have chemical elements named after them (Curie and Flerov). In 1930 the Committee on Chemical Elements was subdivided into three parts, one of which became the Atomic Weights Committee. In 1979 this Committee became the Commission of Atomic Weights and Isotopic Abundances (CAWIA), which has the role of evaluating new isotope abundance and other relevant data and providing the outcome of such investigations to the scientific community on a regular basis.



John Robert de Laeter (1933-2010) served as the 11th Chairman of the CIAAW from 1988-1991, prior to which he also served as the CIAAW Secretary from 1983-1987. He remained active member of the CIAAW and attended his last CIAAW meeting in 2009 (Vienna).

In the second half of the 20th century, the Commission has not only evaluated and reported best knowledge of atomic weights on a biennial basis, but has also made wider retrospective evaluations of improvements achieved in the data set and in the reliability of the data. The precision and reliability of the tabulated values of atomic weights show considerable improvements during all periods of this century. The objective is for users to be confidently assured that the atomic weight of an element from any source, be it taken from laboratory shelves, from a manufacturing process, or from nature, will truly be in the quoted interval. The Commission in its reports highlights the causes for exceptional atomic-weight values. When in future years the precision of tabulated values improves further, the Commission will need to expand the statements on exceptions. At all times during the 20th century, atomic weights have been of adequate precision for the vast majority of concurrent relevant applications. Among the memorable events was Mattauch's and Wichers' persuasion of the physics and chemistry communities respectively to use the mass of carbon-12 isotope for the atomic weights scale. In addition, in 1971 the international community, under the Metre Convention, defined the number of carbon-12 atoms in 12 g of carbon-12 as the unit of amount of substance of any chemical entity. That new unit was called the mole, a well-known term in chemistry, though previously it carried a slightly differing definition.

Two major reviews of the atomic weights of the elements have been published. The first was published in 1962, in which the existing chemical and physical determinations of the atomic weights of all the elements were reviewed in the light of the new reference nuclide carbon-12 (Wichers and Cameron, 1962). A second element-by-element review, which critically examined the changes that had occurred in the atomic weights of each element since the first report, was published in 1984 (Peiser *et al.*, 1984). A third review, which evaluated all the changes that have taken place in atomic weight in the 20th century was published in 2003 (de Laeter *et al.,* 2003).

Most of the determinations of atomic weights in the first half of this century were based on gravimetric procedures in which the mass ratio of the chloride or bromide of the elements to the chemically equivalent amount of silver or the corresponding silver halide was measured. The relationship of silver to the primary oxygen standard was established by accurately measuring the silver-silver nitrate ratio. This technique became known as the "Harvard Method". The discovery of isotopes led to an alternative "physical" method of determining atomic weights, and since the 1940s very few chemical determinations have been carried out. The predominant method for determining atomic weights is now based on the isotopic composition of the element combined with the relevant atomic masses. CIAAW uses published tabulations of the atomic masses in determining atomic weights by the Atomic Mass Evaluation Group.

In 1969 there was a serious move within IUPAC to eliminate the Atomic Weights Commission. Not that atomic weights were not needed—not that the Commission had performed badly—no, it was because atomic weights were then thought to be so accurate that any further improvement was at most an 'academic' exercise of no interest or relevance to professional chemists, or chemical technology, and certainly not to commerce. The physical method of determining atomic weights was so successful, that chemists were not fully able to utilize the accuracy which had so painstakingly been achieved.

In the 1980s it became clear that the very techniques that gave more accurate atomic weights could be employed to do chemical analyses and other chemical measurements to equal accuracies. New applications sprang into prominence, among them the ability to use subtle differences in sample atomic weights for identifying sources of materials, influences from manufacturing processes, and mechanisms of biological reactions. So in atomic-weight measurements we have come around full circle. From the classical emphasis on better atomic weights, higher and no longer needed accuracies were achieved, that in turn are being applied to novel, practically important measurements that now drive us once again to aim at values that have significantly better accuracies than can now be achieved from the best modem analytical measurements.

While the Commission made such progress in atomic weight determinations and assessments, the more universal art of measurement at the highest achievable accuracy also advanced. That field, called metrology, received wide recognition especially in physics and engineering. A world-wide agreement came into use on an international system of units of measurements (SI). The previously mentioned mole is an SI base unit, namely that for quantities of amount-of-substance. Other new insights and conventions of metrology are actively disseminated by the International Organization for Standardization with participation by IUPAC. Some of these may be found applicable to the work of the Commission. Among these is the concept that the estimated uncertainty of a measurement is its sole quantitative measure of quality. With only a slight problem with the definition, the Commission has in fact pioneered uncertainty estimates since 1969.

The metrological importance of reference standards with certified values has equally been recognized by the Commission as playing a key role in the determination of the atomic weights in specific samples. Reference materials enabled laboratories with sensitive instruments to make 'traceable' (accurate, absolute) determinations from relative measurements of similar uncertainty without a reference value. The Commission in the years ahead may find itself involved with uncertainties, reference materials, and other concepts of metrology, such as statistical evaluations and choices in nomenclature in cooperation with IUPAC Interdivisional Committee on Terminology, Nomenclature and Symbols.

In more recent years, the Commission has undertaken additional responsibilities. Most important is that of publishing tables of isotopic compositions of the elements consistent with the standard atomic weights, if not necessarily with their respective uncertainties. The Commission also makes a substantial effort in abstracting and summarizing literature information on the isotopic compositions of non-terrestrial materials. The rapidly increasing knowledge and diversity of available information might eventually outgrow the Commission's ability to fulfill this function. At the present time (1999) the Commission has a Subcommittee for Natural Isotopic Fractionation, which is charged with the responsibility of investigating the impact of naturally occurring fractionation processes on the isotopic abundances and atomic weights of the elements—particularly with respect to the uncertainties which these processes impose.

However, the primary work of the Commission is to continually evaluate the literature on isotopic abundances and atomic weights so as to provide accurate information to the scientific community on a regular basis. This data is accepted as the authoritative information in the field and is used for many purposes—including the refinement of fundamental constants.

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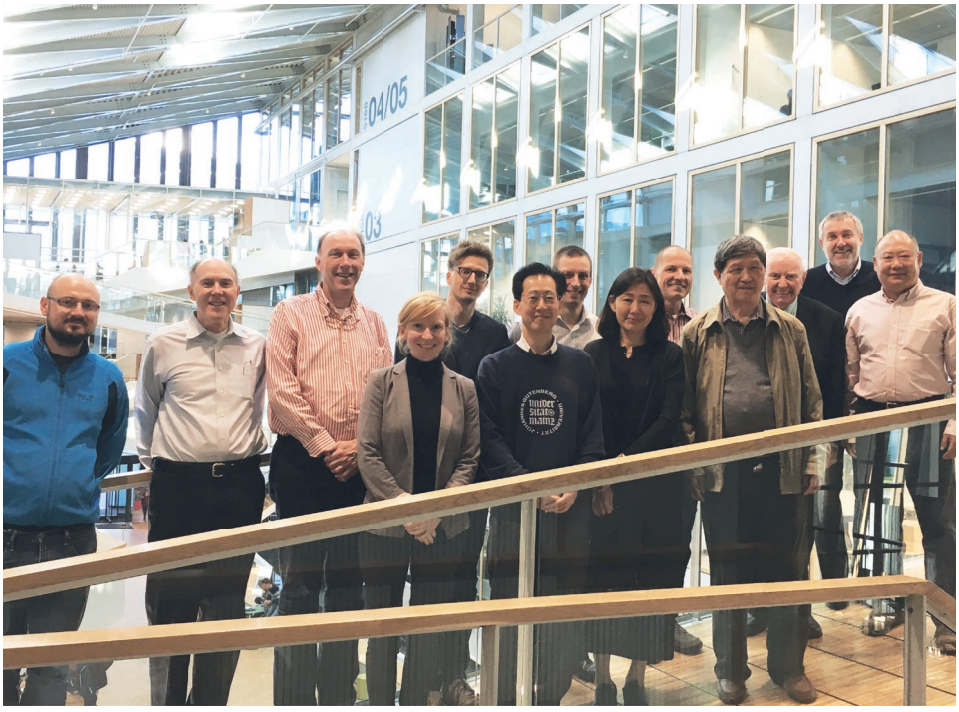
IUPAC Commission II.1 Today

by Juris Meija

It is hard to imagine IUPAC without the Periodic Table, and in turn, without atomic weights. As IUPAC celebrates its centennial, its oldest body, the Commission on Isotopic Abundances and Atomic Weights (CIAAW) turns 120. The parent Commission was formed in March 1899 and its inaugural task was to decide the atomic weight standard: should it be based on hydrogen or oxygen? Although the issue was settled in favor of oxygen, when the CIAAW formally joined the IUPAC in 1919, the question of the atomic weight scale was back for debate suggesting that many issues before this Commission transcend their scientific merit. In fact, many view the Periodic Table and changes therein as a part of larger cultural fabric of science so any changes are likely to be debated for a long time.

Atomic weights have a history that spans two centuries. Kepler and Newton taught us how to weigh planets and stars, and Dalton and with his contemporaries taught us how to weigh atoms. Atomic weights lay the foundations for many scientific measurements, many of which go largely unnoticed. For example, the 2007 definition of the kelvin (the SI unit of thermodynamic temperature) refers to a triple point of water with specific isotopic composition. Likewise, atomic weight of silicon played a special role in the recent efforts to redefine the kilogram and the mole. Most recently, the CIAAW was recognized in the International Vocabulary of Metrology, and its recommendations have been endorsed by the International Committee on Weights and Measures (of BIPM, the *Bureau International des Poids et Mesures).*

The CIAAW has changed significantly over the last several decades. One of the biggest impacts to its work has undoubtedly been the rise of digital communications. The CIAAW has recognized the value of disseminating its outcomes on the World Wide Web as early as 1995. Championed by Robert D. Loss, the first CIAAW website was setup in 1997 on servers at the Curtin University of Technology in Perth, Western Australia. In 2007, the ciaaw.org domain was registered, and the CIAAW website was redesigned to its current form in 2014. Recognizing that formal paper-based publication of standard reference data is a time-consuming process,



The 2017 Atomic Weights Commission biennial meeting in the Netherlands (from left): Heiko Moossen, Tyler Coplen, Harro A.J. Meijer, Johanna Irrgeher (acting Secretary), Juris Meija (Chair), Shigekazu Yoneda, Philip J.H. Dunn, Jun Wang, Jochen Vogl, Tiping Ding, Norman Holden, Manfred Gröning, Xiang-Kun Zhu

recent revisions to the standard atomic weights have been first disseminated through iupac.org and ciaaw.org well before they appear in the pages of the IUPAC official journal *Pure and Applied Chemistry*. Note that atomic weights are summary outcomes derived from the isotope amount ratios. The CIAAW has not yet disseminated the isotope ratios in its publications but the online platform seems more appropriate than paper. In addition, online platform offers searchable data and interactive calculators.

The work of the CIAAW relies on the volunteers who are willing to engage in evaluation of isotope ratio measurements for the benefit of broader goals. Since 1902, the International Committee has been shaped by 120+ expert volunteers. A major change of the CIAAW in the recent decades has been the gradual increase in the youth of its members. In 1947, the average age of the CIAAW was at its peak—72—whereas today it is nearly at its lowest—just under 50. In addition, the gender diversity has improved significantly over the last decades. Marie Curie was the first woman elected member of the CIAAW in 1930 and of the eight women ever to serve to the CIAAW, half are from the last decade alone. These are all positive changes which will position the CIAAW to be more responsive in the upcoming years.

Although the issue that comes up most frequently is the name "weight," which many find inappropriate, the CIAAW has plenty of technical issues at hand. Evaluation of atomic weight data is a complex endeavour. Here, one often faces mutually inconsistent measurement results which are separated in time by several decades. Given that scientific norms and standards evolve, it is not trivial to evaluate such results. Nearly one in ten revisions of the standard atomic weights, in fact, result in 'less precise' values. This is due to the fact that new measurements might reveal biases in the past measurements. The most recent example of this was the atomic weight of ytterbium with two available contemporary measurements more than ten standard uncertainties apart. Alternatively, standard atomic weights of other elements become 'less precise' as we learn the true extent of natural variations, as happened most recently for argon.

Whereas the 19th century chemists set out to determine the atomic-weight values with highest precision, culminating with the 1914 Nobel Prize in Chemistry for Theodore W. Richards, the 20th century was largely shaped by the quest to understand these values which lead to the discovery of isotopes and the realization that the atomic-weight values of many elements do vary in nature. Our drive to measure atomic weights and isotope ratios with ever-increasing precision is bound to reveal new phenomena.

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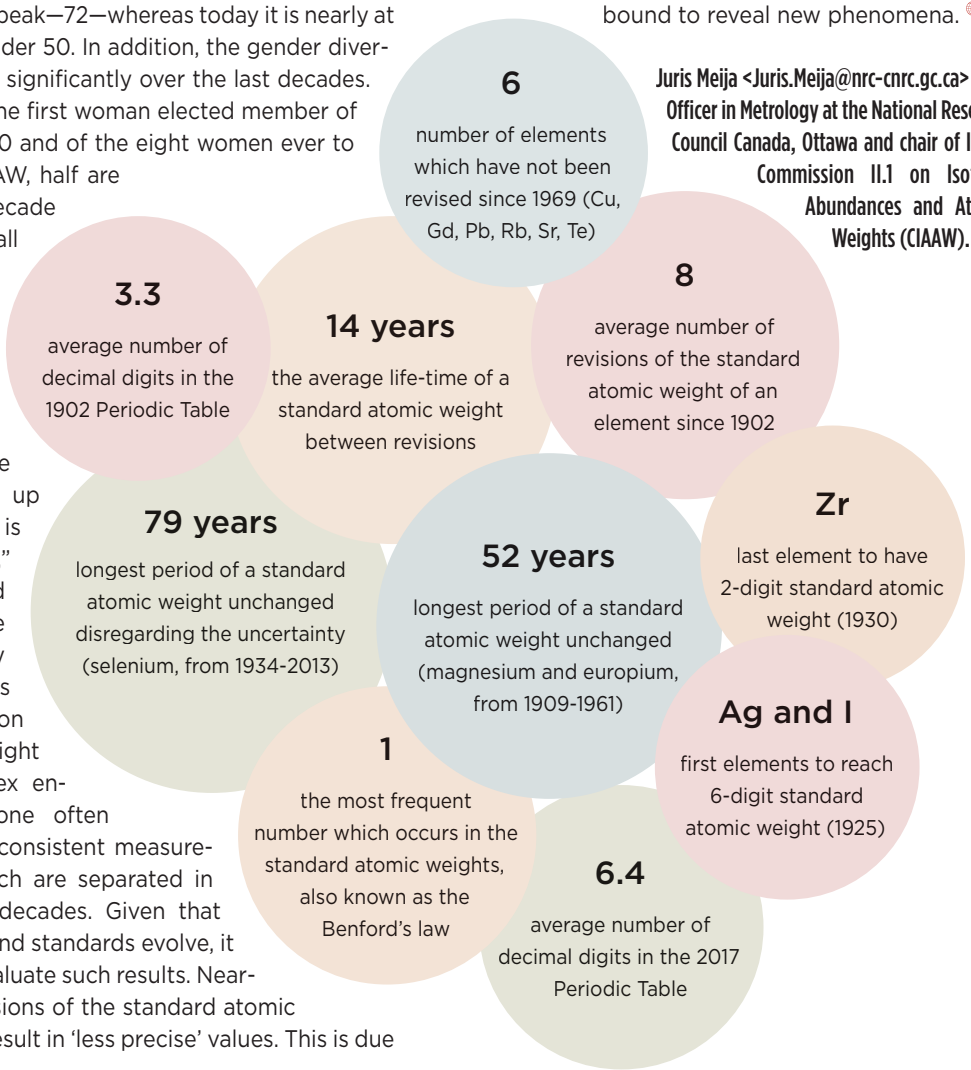

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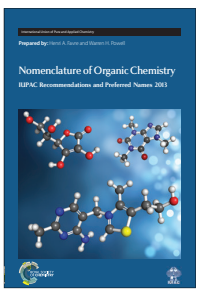

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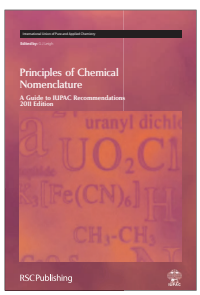

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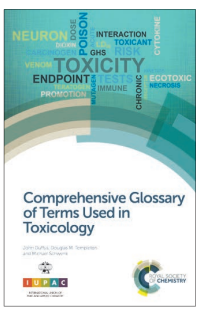

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Isotopes Matter

Norman E. Holden, Tyler B. Coplen, and Peter Mahaffy

Two years ago, the King's Centre for Visualization in Science (KCVS) at The King's University, Edmonton released a new digital interactive version of the IUPAC Periodic Table of the Elements and Isotopes with accompanying educational resources at an International Conference on Chemistry Education. It can be found at www.isotopesmatter.com. The effort was part of an IUPAC project [1]. The science behind this new table was developed by Inorganic Chemistry Division scientists working for over a decade on an earlier IUPAC project [2]. These projects were joint efforts between the IUPAC Committee on Chemistry Education (CCE) and the Inorganic Chemistry Division.

The atomic weight of an element is not a constant [3] nor is it a fundamental property of an element, but can be determined from the product of the atomic mass of each stable or long-lived radioactive isotope of an element in naturally occurring materials and the corresponding mole fraction (isotope abundance) of that isotope in the element. However, the atomic-weight value of an element is still the fundamental link between the mass and the amount of substance of a chemical element.

For any element that has two or more stable isotopes, there is the possibility that the relative amounts of the stable isotopes may not be the same in all samples of that element in naturally occurring materials. This variation of the fraction of each isotope in an element can cause a variation in the element's atomic weight. With time, improvements in instrumentation for measurement of isotopic abundances has caused this variation in atomic-weight values of some elements to have a larger span than the improved, lower uncertainty measurement in a single material. In lieu of the previously accepted value and uncertainty for an element, if an IUPAC evaluation of variability in isotopic composition has been completed, the atomic weight of the element can be listed as an interval, which includes an upper and lower bounds. The best estimate for the atomic weight is a value somewhere within these upper and lower bounds, but not the average of the upper and lower bounds [3].

For the education community and the public to understand fully (1) how atomic-weight values can be determined from the product of the isotopic abundance and atomic-mass values of the stable isotopes of an element, (2) why atomic weights are no longer considered to be constants of nature, and (3) why the atomic-weight values of some elements are listed with intervals, people will need to become more aware of the abundances and applications of isotopes.

Figure 1 displays the IUPAC Periodic Table of the Elements and Isotopes (IPTEI) that was developed to help users better understand the concept of isotopes. Currently, 253 stable isotopes and 3092 unstable isotopes have been identified for the 118 chemical elements. There are 289 isotopes that determine the standard atomic weights of the 84 elements that are assigned a standard atomic weight. Of these, 36 are radioactive isotopes that have a half-life value sufficiently long and an isotopic abundance value in naturally occurring substances that is sufficiently large that they contribute to the determination of the atomic weight of elements. The IPTEI is based on the design of the original Mendeleev Periodic Table. However, instead of a display of chemical and physical properties of each element, the IPTEI lists all stable and long-lived radioactive isotopes for each element, which contribute to the atomic weight for that element. This Periodic Table lists these isotopes and a pie chart for each element indicates the mole fraction of each isotope (the isotopic abundance in nature) in the element by the relative size of its pie slice for that element. The isotope mass number is listed around the pie chart in black for stable and in red for long-lived radioactive isotopes. Atomic-weight values and associated uncertainties are provided for 71 elements, and atomic-weight intervals are provided for 13 elements having a standard atomic weight expressed as an interval. Elements with a standard atomic weight expressed as an interval also have a conventional atomic-weight value listed for users who may need it in industry, trade, commerce, or education (*e.g.* for molecular-weight calculations).

An element-by-element review [4] is soon to be published and will accompany the IPTEI. Its information can also be readily accessed through the interactive digital version of the IPTEI [5]. This review includes additional information not shown on the print version of the Periodic Table itself for each element, including a chart of all known stable and radioactive isotopes of each of the 118 elements, with the radioactive isotopes listed in one of three half-life ranges. It should be noted that, on average, there are more than an order of magnitude as many radioactive isotopes (3092) as there are stable isotopes (253). To aid in the calculation of the atomic weight of each element, a table of stable and long-lived radioactive isotopes having characteristic terrestrial isotopic compositions that determine the standard atomic weight of that element

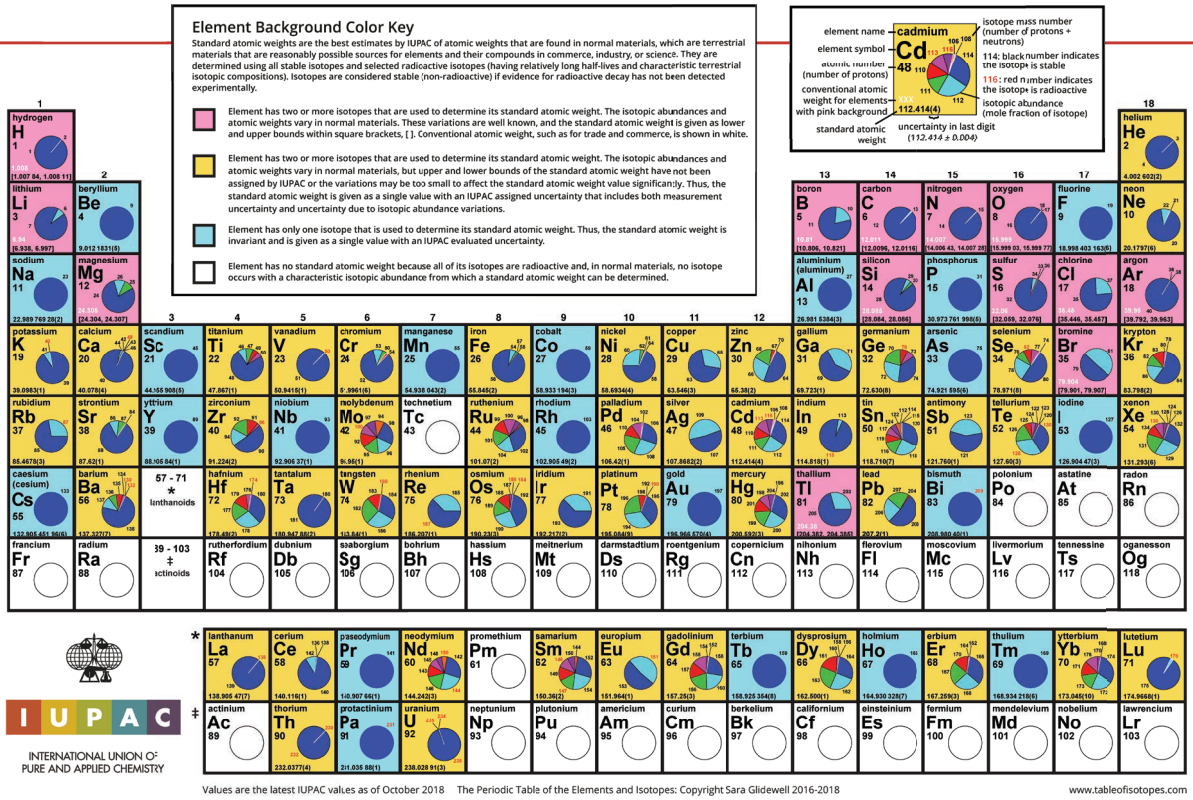

Fig. 1. IUPAC Periodic Table of the Elements and Isotopes [kindly modified by Sara Glidewell from The Periodic Table of Elements and Isotopes©, copyright by Sara Glidewell (www.tableofisotopes.com), and used with permission].
A background color scheme is associated with each element cell. A white cell indicates an element that has no stable or long-lived radioactive isotopes that contribute to a standard atomic weight. Blue is the background color of a cell for an element that has only one stable or long-lived radioactive isotope that contributes to its standard atomic weight. The standard atomic weight of elements having a blue background is given as a single value with a measurement uncertainty. Yellow is the background color if an element has two or more isotopes that are used to determine its atomic weight. The standard atomic weight of an element having a yellow background is given as a single value with an uncertainty that includes both measurement uncertainty and uncertainty due to isotope-abundance variation. The variation in isotopic abundances may be too small to exceed the measurement uncertainty and affect the atomic-weight value. Pink is the background color if an element has two or more isotopes that are used to determine its atomic weight and the variation in isotopic abundances and atomic weights in normal materials exceeds measurement uncertainty and is well known. The standard atomic weight is given as lower and upper bounds within square brackets. Figure 2 displays an example of an element cell for each of the four background color schemes, with the element's pie chart of stable and long-lived radioactive isotopes and the mass numbers of the isotopes.

are listed in the IPTEI IUPAC report [4], along with the relative atomic mass and the mole fraction (isotopic abundance) of each of these isotopes of the element. An example of some of the additional information that does not appear on the IPTEI itself, but does appear in the IPTEI IUPAC report [4] and on the electronic IPTEI [5], is shown in Figure 3. It includes the element cell from the IPTEI, the previously described table of relevant isotopes, and a chart that contains all of the stable and radioactive isotopes of the element.

To emphasize the everyday importance of isotopes, applications of both the stable and radioactive isotopes for each element are highlighted for their practical uses in science and in everyday life in one or more of seven different categories in the element-by-element review section of the soon to be published IPTEI IUPAC report [4]:

- for biology, there are 24 different isotopes from 18 different elements,
- for Earth and planetary science, there are 86 different isotopes from 54 different elements,
- for forensic science and anthropology, there are 27 different isotopes from 13 different elements,
- for geochronology (including isotopic dating of materials), there are 57 different isotopes from 39 different elements,
- for industry, there are 70 different isotopes from 34 different elements,
- for medicine, there are 110 different isotopes from 58 different elements,

- for isotopes used to produce other radioactive isotopes, there are 58 isotopes from 35 different elements.

These applications provided for each element are exemplary and are not intended to encompass all isotope applications for an element. Overall, the IPTEI IUPAC report [4], also available in the electronic IPTEI [5], presents 432 applications from 96 different elements. For example, in the case of a radioactive isotope, consider that the human body contains the element potassium and one of its isotopes, potassium-40, ^{40}K, which is radioactive. ^{40}K is part of the naturally occurring isotopic composition of potassium; thus, the human body is naturally radioactive. In the case of stable isotopes, consider that the amount ratio, $n(^{13}C)/n(^{12}C)$, in testosterone in the human body varies from that ratio in synthetic testosterone. This fact can be used to detect performance enhancing drug use (doping) in sports.

In biochemical analysis, it is easy to detect (even at low concentrations) the presence or absence of radioactive materials. Radioisotopes are used to label molecules of biological samples to determine constituents of blood, serum, urine, hormones, antigens, and many drugs. The findings from these procedures are used to diagnose diseases, such as diabetes, thyroid disorders, hypertension and reproductive problems. The tagging of cells with a therapeutic dose of radiation may lead to regression, or even cure, of some diseases.

In industry, radioisotopes are used in gamma sterilization for medical supplies and food preservation. Gamma radiography is used to scan luggage at airports. Gamma rays show flaws in metal castings or welded joints. Critical components can be inspected for internal defects without damaging the component or making it radioactive. Unlike X-ray generators, radioactive sources are small and do not require power, so they can be transported easily to remote areas where there is no power. Smoke detectors use americium-241, ^{241}Am, to ionize atoms of air (knock out electrons from the atom) and create a small electric current. When smoke or steam enters the ionization chamber, it disrupts the current. The detector senses the drop in current and sets off the alarm. Smoke detectors are the most abundant radioisotope-based devices used around the world.

Rapidly dividing cells are particularly sensitive to damage by radiation. Some cancerous growths can be controlled or eliminated by irradiating the area with radioactive isotopes. This is called radiotherapy. Internal radioisotope therapy is accomplished by administrating or planting a small radiation source in the target

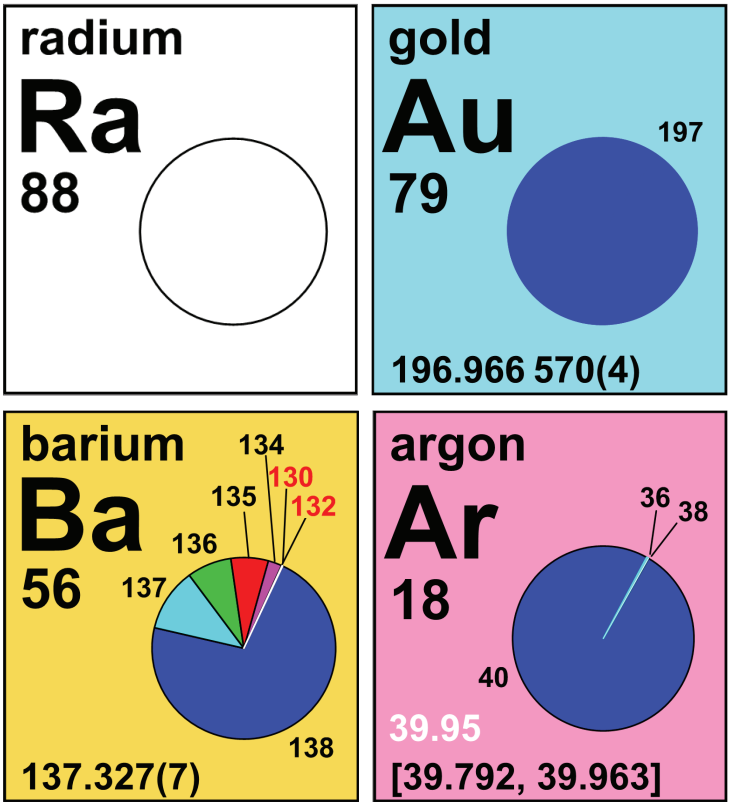

Fig. 2. Examples of the four classifications of element cells in the IPTEI. Radium, with white background, illustrates elements that have no standard atomic weight because their isotopes are all radioactive and no isotope occurs with a characteristic terrestrial isotopic abundance. The element gold, with blue background, is an example of elements having a single isotope used to determine their standard atomic weights. Barium, with yellow background, is an example of elements having two or more isotopes used to determine their standard atomic weights. Argon, with pink background, exemplifies elements having two or more isotopes that are used to determine their standard atomic weights; the isotopic abundances and atomic weights vary in normal materials, and these variations exceed measurement uncertainty, are well known, and standard atomic-weight values are given as lower and upper bounds within square brackets, [ ]; the conventional atomic weights, such as for trade, commerce, and education are shown in white.

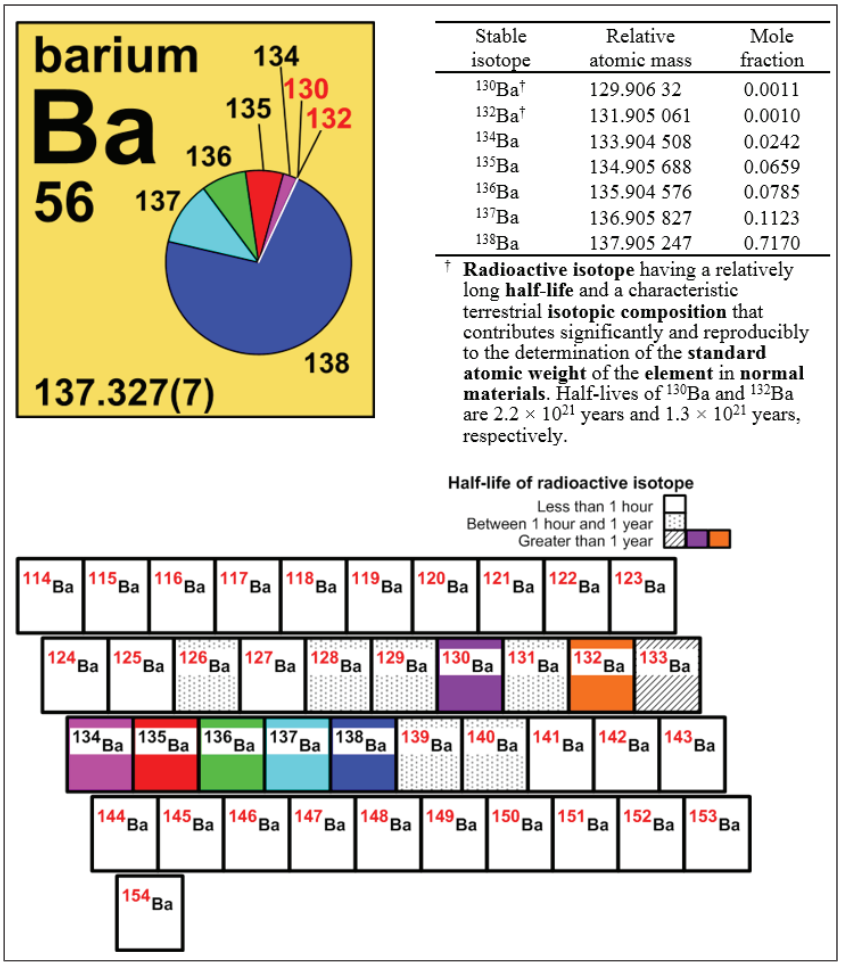

Fig. 3. Example of auxiliary information appearing in the IPTEI element-by-element review [4,5], including a table of isotopes contributing to the standard atomic weight and a chart of the stable and radioactive isotopes of the selected element (barium in this example having 41 isotopes). The background colors of stable isotopes in the chart reflect those of isotopic-abundance fraction in the pie diagram. Mass numbers of stable isotopes are shown in black and those of radioactive isotopes are displayed in red. Two isotopes (^{130}Ba and ^{132}Ba) have sufficiently long half-lives resulting in characteristic isotopic abundances that they are used to determine the standard atomic weight.

area. Short-range radiation therapy (called brachytherapy) is becoming the main means of treatment for cancer. Many radiation therapeutic procedures are palliative, usually to relieve pain, such as cancer-induced bone pain. These radiation procedures are preferable to traditional pain killers, such as morphine, because they improve the patient's quality of life, allowing them to be more lucid during time spent with family.

Radioactive products used in medicine are referred to as radiopharmaceuticals. Every organ in our body acts differently from a chemical point of view. Certain chemical elements are preferentially absorbed by specific organs, called targeting agents, such as iodine in the thyroid and glucose in the brain. Once a radioactive form of one of these substances enters the body, it is incorporated into the normal biological processes and excreted in the usual ways. Radiopharmaceuticals can be used for examining blood flow to the brain, functioning of the liver, heart or kidneys, assessing bone growth, predicting effects of surgery, and assessing changes since a treatment has begun. In sports medicine, radiopharmaceuticals are used to diagnose stress fractures in bones, which are not generally visible in X-rays. The non-invasive nature of this technology, with its ability to reveal organ function from outside the body, makes this technique a powerful diagnostic tool.

Radioisotopes are used to estimate the age of groundwater from wells using the activity of naturally occurring radioisotopes in the water. Airborne testing of nuclear weapons during the late 1940s to the early 1960s doubled the amount of radioactive carbon-14, ^{14}C, in the atmosphere. The increased number of ^{14}C atoms in the environment acts as a radioactive tracer (substances containing a radioisotope and used to measure the speed of chemical processes or to track the movement of a substance through a natural system), enabling measurement of soil movement and land degradation. Levels of certain radioisotopes in environmental samples can be measured to check if nations are complying with agreements limiting the development of nuclear weaponry. Radioactive tracers

can be used to trace small leaks in complex systems, such as power station heat exchangers. Flow rates of liquids and gases in pipelines, as well as large rivers, can be measured accurately with the assistance of radioisotopes. These are only a few of more than 400 applications of isotopes discussed in the soon to be published IPTEI IUPAC report [4] and the electronic IPTEI [5] for the education community. Hopefully, this comprehensive set of resources on isotopes will not only act as a compendium and ode to the 100 years of knowledge and discovery that have been witnessed and documented by IUPAC, but also impart a deeper and better understanding to the public about why isotopes matter.

To assist users who may not be familiar with some of the technical terms used in the applications phase of the element-by-element review, a glossary of terms is included at the end of the review to explain these terms in non-technical language.

Acknowledgements

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- the Avogadro constant N_A is exactly 6.022 140 76 × 10^{23} mol^{-1},
- the luminous efficacy K_{cd} of monochromatic radiation of frequency 540 × 10^{12} Hz is exactly 683 lm/W.

where the hertz, joule, coulomb, lumen, and watt, with unit symbols Hz, J, C, lm, and W, respectively, are related to the units second, metre, kilogram, ampere, kelvin, mole, and candela, with unit symbols s, m, kg, A, K, mol, and cd, respectively, according to Hz = s^{-1}, J = m^2 kg s^{-2}, C = A s, lm = cd sr, and W = m^2 kg s^{-3}.

Defining constant	*Symbol*	*Numerical value*	*Unit*
hyperfine transition frequency of caesium	$\Delta\nu_{Cs}$	9 192 631 770	Hz
speed of light in vacuum	c	299 792 458	m s^{-1}
Planck constant	h	6.626 070 15 × 10^{-34}	J s
elementary charge	e	1.602 176 634 × 10^{-19}	C
Boltzmann constant	k	1.380 649 × 10^{-23}	J K^{-1}
Avogadro constant	N_A	6.022 140 76 × 10^{23}	mol^{-1}
luminous efficacy	K_{cd}	683	lm W^{-1}

Table 1: The seven defining constants of the SI, and the seven corresponding symbols, numerical values, and units

The numerical values of the seven defining constants have zero uncertainty. They are summarized in Table 1 on this page. Definitions based on defining constants are called explicit-constant definitions; they are based on the fundamental constants of nature, in contrast to explicit-unit definitions which are based on particular experimental procedures.

Defining a unit by specifying the numerical value of a fundamental constant may be understood as follows. The value of any quantity Q may always be represented as the product of its numerical value $\{Q\}$ and a unit $[Q]$, so that we may write $Q = \{Q\}\,[Q]$ (for example c = 299 792 458 m/s for the speed of light in vacuum). If the quantity Q is itself a unit that we wish to define, this may be done **either** by specifying some convenient reference (such as the length of the prototype metre bar that was used to define the SI unit of length prior to 1980) or by specifying the numerical value $\{Q\}$ when expressed in terms of the desired SI unit (such as the numerical value of the speed of light 299 792 458 expressed in the unit m/s used to define the metre since 1980). It is this second method of using defining constants that is now being adopted for all the seven base units of the SI.

For chemists, the definition of the mole has an important conceptual consequence. It is namely equivalent to stating that "One mole contains exactly 6.022 140 76 × 10^{23} elementary entities," quite in the spirit of William Shakespeare in *As You Like It: "It is as easy to count atomies as to resolve the propositions of a lover."* In addition, the exact and fixed number of elementary entities defining a mole finally receives the name that has been used for it for decades without proper definition: the Avogadro number.

In general, the changes associated with the new SI will lead to reduced uncertainties in our knowledge of most of the fundamental constants of physics and chemistry in the new SI.

The changes in the new SI will strengthen the philosophical foundation of our system of units in relation to our present understanding of theoretical and quantum physics. However, they will not affect the daily work in the laboratory in any sizeable manner.

What are the direct consequences of these changes to a chemist working in the laboratory? For example, the equation

$$C_2H_4O = CH_4 + CO$$

has the meaning that one mole of oxirane (C_2H_4O) decomposes to yield one mole of methane (CH_4) and one mole of carbon monoxide (CO). The new definition of

constant	*current SI*	*new SI*	*constant*	*current SI*	*new SI*
$m(K)$	0.0	5.0	α	0.068	0.068
h	5.0	0.0	K_J	2.5	0.0
e	2.5	0.0	R_K	0.068	0.0
k	170	0.0	μ_0	0.0	0.068
N_A	5.0	0.0	ε_0	0.0	0.068
R	170	0.0	Z_0	0.0	0.068
F	2.5	0.0	N_Ah	0.14	0.0
σ	700	0.0	J↔kg	0.0	0.0
m_e	5.0	0.14	J↔m^{-1}	5.0	0.0
m_u	5.0	0.14	J↔Hz	5.0	0.0
$m(^{12}C)$	5.0	0.14	J↔K	170	0.0
$M(^{12}C)$	0.0	0.14	J↔eV	2.5	0.0

Table 2: Relative standard uncertainties for a selection of fundamental constants in the current SI and the new SI, multiplied by 10^8 (i.e. in parts per hundred million)
Note: in this table the symbols denote the following constants: R: the molar gas constant; F: the Faraday constant; σ: the Stefan-Boltzmann constant; m_e: the electron mass; m_u: the unified atomic mass constant; $m(^{12}C)$: the mass of a carbon 12 atom; $M(^{12}C)$: the molar mass of carbon 12; α: the fine structure constant; K_J and R_K: the Josephson and von Klitzing constants; μ_0 and ε_0: the magnetic and electric constants; Z_0: the impedance of vacuum; N_Ah: the molar Planck constant; and $U_a \leftrightarrow U_b$: the conversion factor between unit a and unit b.

the mole will not change this meaning. A chemist in the laboratory will continue to determine the amount of a chemical entity B, n(B), by weighing the corresponding mass m(B) and setting n(B) = m(B)/M(B), where M(B) is the molar mass of B. He/she will continue to state that 44.053 g of oxirane decomposes to yield 16.043 g methane and 28.010 g carbon monoxide. Truly, the molar mass M(B) = M_r(B) M_u will acquire an uncertainty component of less than 1 part in 10^9 due to the new uncertainty of the molar mass constant M_u = M(^{12}C)/12 (see Table 2; the relative molar mass M_r(B) of any atom B is unchanged in the new SI). However, balances in chemistry laboratories will continue to yield masses (*e.g.* in the SI unit kg) with uncertainties that far exceed the uncertainty of the molar mass of any given chemical entity by orders of magnitude, so that the change in the new definition of the mole will never influence the result of the determinations of amount of substance in practice.

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Ian Mills <i.m.mills@reading.ac.uk> is emeritus professor of chemistry at the University of Reading, UK and an elected Fellow of the Royal Society. He was the President of Consultative Committee on Units of the International Bureau of Weights and Measures (BIPM) and retired from this role in 2013 after 18 years of service. In IUPAC, he served as chair of the Commission on Physicochemical Symbols, Terminology, and Units (Commission I.1), and also as chair of the Interdivisional Committee on Nomenclature and Symbols (IDCNS, preceding the current ICTNS) until 1999.

Roberto Marquardt <roberto.marquardt@unistra.fr> was President of the Physical and Biophysical Chemistry Division of IUPAC in 2014-15.

The Seven Base Units of the new SI are defined as in the table below*

Quantity	SI unit
time	The **second**, symbol s, is the SI unit of time. It is defined by taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9 192 631 770 when expressed in the unit Hz, which is equal to s^{-1}.
length	The **metre**, symbol m, is the SI unit of length. It is defined by taking the fixed numerical value of the speed of light in vacuum *c* to be 299 792 458 when expressed in the unit m s^{-1}, where the second is defined in terms of the caesium frequency $\Delta\nu_{Cs}$.
mass	The **kilogram**, symbol kg, is the SI unit of mass. It is defined by taking the fixed numerical value of the Planck constant *h* to be $6.626\ 070\ 15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of *c* and $\Delta\nu_{Cs}$.
electric current	The **ampere**, symbol A, is the SI unit of electric current. It is defined by taking the fixed numerical value of the elementary charge *e* to be $1.602\ 176\ 634 \times 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\Delta\nu_{Cs}$.
thermodynamic temperature	The **kelvin**, symbol K, is the SI unit of thermodynamic temperature. It is defined by taking the fixed numerical value of the Boltzmann constant *k* to be $1.380\ 649 \times 10^{-23}$ when expressed in the unit J K^{-1}, which is equal to kg m^2 s^{-2} K^{-1}, where the kilogram, metre and second are defined in terms of *h*, *c* and $\Delta\nu_{Cs}$.
amount of substance	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 the unit mol^{-1} and is called the Avogadro number. The amount of substance, symbol *n*, of a system is a measure of the number of specified elementary entities. An elementary entity may be an atom, a molecule, an ion, an electron, any other particle or specified group of particles.
luminous intensity	The **candela**, symbol cd, is the SI unit of luminous intensity in a given direction. It is defined by taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit lm W^{-1}, which is equal to cd sr W^{-1}, or cd sr kg^{-1} m^{-2} s^3, where the kilogram, metre and second are defined in terms of *h*, *c* and $\Delta\nu_{Cs}$.

*Table reproduced from https://www.bipm.org/utils/en/pdf/si-revised-brochure/Draft-SI-Brochure-2018.pdf (accessed 31 Oct 2018). The concept of base units and derived units was used to define the SI until 2018. These categories, although not essential in the new SI, are maintained in view of their convenience and widespread use.

Election of IUPAC Officers and Bureau Members—Call for Nominations

At its General Assembly in Paris, France, on 10-11 July 2019, the IUPAC Council will be asked to elect a Vice President, a Secretary General, a Treasurer, and members of the Bureau to fulfill the vacancies created by retiring members. IUPAC National Adhering Organizations are invited to submit nominations no later than 31 March 2019.

On 1 January 2020 Christopher Brett (Portugal), Vice President and President-Elect of IUPAC, will become President. Qi-Feng Zhou (China), current President, will become Past President and remain an officer and a member of the Bureau for a period of two years, while Natalia Tarasova (Russia), current Past President, will retire. Secretary General Richard Hartshorn (New Zealand) and Treasurer Colin Humphris (UK) were both elected by the Council in August 2015 for a four-year term and are eligible to be nominated for an additional four-year term commencing in 2020. Nominations are invited.

In addition, there are this year five vacancies for Elected Members of the Bureau. Elected Members are elected to a four-year term, and are eligible for re-election to a second four-year term. No National Adhering Organization shall have more than one Elected Member on the Bureau, and the principle of fair geographical representation of Members shall be taken into account, as stipulated in the IUPAC Statutes.

Elected Members whose terms expire at the end of 2019 are:

- Prof. Mei-Hung Chiu* (China/Taipei) (2016-2019)
- Prof. Hemda Garelick* (UK) (2016-2019)
- Prof. Ehud Keinan* (Israel) (2016-2019)
- Prof. Kew-Ho Lee* (Korea) (2016-2019)
- Prof. Pietro Tundo* (Italy) (2016-2019)

*eligible for nomination

The following are Members whose terms continue to the end of 2021

- Prof. Russell J. Boyd (Canada) (2014-2017, 2018-2021)
- Prof. Javier García-Martínez (Spain) (2018-2021)
- Prof. Mary Garson (Australia) (2018-2021)
- Prof. Christopher K. Ober (USA) (2014-2017, 2018-2021)
- Prof. Ken Sakai (Japan) (2018-2021)

In addition to the five officers and the ten Elected Members, the Bureau also includes the eight Division Presidents (each elected by each individual Division), and five members representing the following Standing Committees, *i.e.* the Committee on Chemistry Education (CCE), the Committee on Chemistry and Industry (COCI), CHEMRAWN (the Committee on CHEMical Research Applied to World Needs), the Interdivisional Committee on Terminology, Nomenclature and Symbols (ICTNS), and the Committee on Publications and Cheminformatics Data Standards (CPCDS).

IUPAC National Adhering Organizations are invited to submit nominations to the Secretary General via the Executive Director at <executivedirector@iupac.org> no later than 31 March 2019.

It is important for a vibrant organization that all vacant positions are filled after a fair and vigorous election process, so all nominations are encouraged. So, to make your voice heard, contact your National Adhering Organization and get involved.

A call for the general elections for the 2020-21 term was released earlier on 2 October 2018 and published in CI Oct 2018.

What Does the Bureau Do?

The Bureau is established by the Council to act for the Union during intervals between meetings of the Council; it therefore fulfills important functions by ensuring continuity. The Bureau normally meets once a year. It consists of the officers (president, vice president, secretary general, treasurer, and immediate past president), the division presidents, the chairs of the operational standing committees, and 10 other members elected by the Council. The elections should also allow for a fair geographical representation. In principle, no member country should have more than one elected member on the Bureau. The principal duties of the Bureau—as quoted in the statutes—are as follows:

- to ensure the strict observance of statutes and bylaws
- to prepare the agenda for meetings of the Council and in particular
- to make provision for elections
- to make recommendations thereon to the Council
- to attend the meetings of the Council
- to implement the decisions of the Council and execute the program of the Union as directed by the Council
- to take steps to ensure that international congresses of pure and applied chemistry are held

- to take decisions about the holding of scientific meetings as proposed by the division committees
- to take all other steps necessary for the good conduct of the affairs of the Union

See the Bylaws for more details: https://iupac.org/who-we-are/organizational-guidelines/

https://iupac.org/2019-election-iupac-officers-bureau-members-call-nominations/

Juris Meija Made the Top 40 Under 40

On 16 Oct 2018, *The Analytical Scientist* released their Top 40 Under 40 Power List celebrating the gifted young scientists making waves in analytical science. Among them is Juris Meija, the current Chair of the IUPAC Commission on Isotopic Abundances and Atomic Weights (CIAAW).

In his own words, Dr. Meija claimed that his greatest achievement has been his election as Chair of the Commission at age 33 and being part of the team to draft the new definition of the mole. As part of his research as an Officer in Metrology at National Research Council Canada, Ottawa, he explores the reliability of analytical data with a focus on isotope-based methods of quantitation. As Meija stated "it is all about the attention to detail in chemical measurements."

His prediction: We live in the era of big data, which often favors quantity over quality. This has undesirable effects on the reliability of chemical testing results. I believe that metrology will guide us away from the reproducibility crisis in analytical chemistry.

His advice: Nurture your social skills and be someone others will want to work with.

Juris Meija, Research Officer, Metrology, National Research Council Canada, Ottawa, Canada.

All rising stars were nominated by *The Analytical Scientist* readers and shortlisted by an independent judging panel.

https://theanalyticalscientist.com/power-list/2018/

C. Oliver Kappe is Awarded the 2018 IUPAC-ThalesNano Prize for Flow Chemistry

C. Oliver Kappe

The 2018 IUPAC-ThalesNano prize has been awarded to Professor C. Oliver Kappe. The prize will be presented at the 15th International Conference on Microreaction Technology (IMRET15) in Karlsruhe on 21 October 2018. The award address will be delivered at the Flow Chemistry Europe Conference in Cambridge, UK on 26 February 2019. The prize consists of an award of 10 000 USD.

Professor Kappe is Professor of Chemistry at the University of Graz (Austria) and Scientific Director for Continuous Flow Synthesis and Processing (CC Flow) at the Research Center Pharmaceutical Engineering GmbH (RCPE). Professor Kappe has over 400 publications in the areas of continuous flow chemistry, application of microreactors, process intensification, and microwave-assisted reactions. He and his team have published syntheses with challenging systems and chemistry. He has served as an Ambassador for Flow Chemistry through his teaching, interdisciplinary work, and collaborations.

Professor Kappe holds a PhD in Organic Chemistry from the University of Graz. He completed postdoctoral research at the University of Queensland (Australia) and Emory University (United States). He has served as visiting scientist/professor at the Scripps Institute, Tokyo Institute of Technology, Sanford-Burnham Institute for Medical Research, and the Federal University of Rio de Janeiro. He is the founding editor and Editor-in-Chief of the *Journal of Flow Chemistry*.

Previous Awardees: Professor Volker Hessel (TU/e – Eindhoven University of Technology) received the award in 2016, for his outstanding contributions to the methodology of organic syntheses, including homogeneous catalysis, photochemistry, plasma catalysis, and multiphase flow, setting new standards for flow chemistry.

The recipient of the 2014 Prize was Professor Steven V. Ley (University of Cambridge, UK) for his outstanding contribution and creative work in methodologies for organic synthesis, especially in multi-step synthesis in continuous flow chemistry reactor systems.

In 2012 the first IUPAC-ThalesNano Prize in Flow Chemistry was awarded to Professor Klavs F. Jensen (MIT, USA) for his outstanding contribution to the field of flow chemistry both in academia and industry. He is considered one of the pioneers of flow chemistry.

https://iupac.org/c-oliver-kappe-is-awarded-the-2018-iupac-thalesnano-prize-for-flow-chemistry/

OPCW to Further Enhance Contributions to United Nations' Sustainable Development Goals

During the 3rd edition of the OPCW Forum on the Peaceful Uses of Chemistry, held at the OPCW Headquarters in The Hague on 23 October, Professor Pietro Tundo, Chair of IUPAC's Interdivisional Committee on Green Chemistry for Sustainable Development, provided insights into the approaches of supporting sustainable development through peaceful uses of chemistry. With that Forum, and in a bid to strengthen international security through development, the Member States of the Organisation for the Prohibition of Chemical Weapons (OPCW) identified activities to help achieve the United Nation's (UN) Sustainable Development Goals (SDGs).

The Forum convened over 30 professionals including chemists, chemical engineers, academics, as well as government and industry officials from the following OPCW Member States: Algeria, Argentina, Azerbaijan, Belgium, Belize, Bhutan, Burkina Faso, China, Colombia, Ecuador, Germany, Indonesia, Italy, Kenya, Malaysia, Morocco, Myanmar, Pakistan, Panama, the Philippines, Poland, Sao Tome and Principe, Saudi Arabia, South Africa, Sri Lanka, Sudan, Switzerland, and the United States of America. The attendees participated in panel discussions on a range of topics including: an overview of the SDGs; peaceful application of chemistry; chemical safety, security and sustainability; gender mainstreaming; and building institutional synergies to promote international cooperation on SDGs.

https://iupac.org/opcw-to-further-enhance-contributions-to-united-nations-sustainable-development-goals/

1001 Inventions: Journeys from Alchemy to Chemistry

UNESCO and 1001 Inventions will launch a new educational initiative celebrating the 8th century polymath Jabir ibn Hayyan as part of the 2019 International Year of the Periodic Table of Chemical Elements. The new multimedia initiative, titled "1001 Inventions: Journeys from Alchemy to Chemistry", focuses on contributions to the foundations of modern chemistry by ancient cultures and civilizations, in particular the remarkable work of the pioneering polymath Jabir ibn Hayyan, also known as Geber, in the 8th century.

Jabir ibn Hayyan spent most of his life in Kufa, Iraq, where he devised and perfected sublimation, liquefaction, crystallization, distillation, purification, amalgamation, oxidation, evaporation, and filtration. He developed precise measuring equipment, and discovered sulfuric, nitric, and nitromuriatic acids, all now vitally important in the chemical industry. His research and publications, including the *Great Book of Chemical Properties, The Weights and Measures, The Chemical Combination,* and *The Dyes*, opened the way for modern chemistry and guided scientists during the following centuries.

Through a series of international events, combining experiments, live shows, digital content, and teaching resources, this new initiative will promote basic sciences education to all, including youth, teachers and families to inspire inquisitiveness and curiosity. It will be launched during the opening ceremony of the International Year of the Periodic Table of Chemical Elements on 29 January 2019 at UNESCO Headquarters in Paris, France.

"*The International Year of Periodic Table of Chemical Elements is a great opportunity to reflect upon many aspects of the periodic table, including its evolution, the role of women in research, global trends and perspectives on basic science for sustainable societies*" explained Martiale

Zebaze Kana, Executive Secretary of UNESCO's International Basic Sciences Programme (IBSP). "*UNESCO is delighted to collaborate with 1001 Inventions to further promote innovative ways in teaching basic sciences with special emphasis in hands-on approach.*"

"*1001 Inventions is delighted to continue to partner with UNESCO and support IYPT2019 public engagement efforts*" said Ahmed Salim, 1001 Inventions Co-Founder and Managing Director. "*We are very excited to launch a new global educational initiative presenting fascinating journeys of discovery in Chemistry. Through exciting learning experiences, we aim to help inspire a new generation to learn more about basic sciences and its importance for sustainable development while recognising humanity's shared scientific heritage.*"

The launch will include an event organized for schools and youth, and the initiative will be rolled out around the world in partnership with science centres, science festivals, museums, educational institutions, digital and social media platforms.

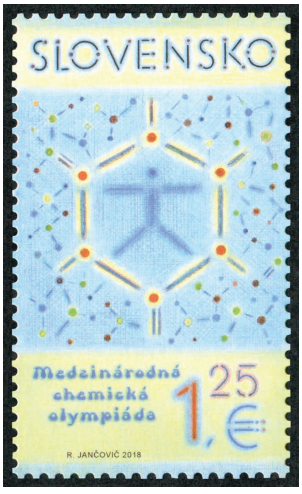
About 1001 Inventions - 1001 Inventions is an award-winning, British based organization that creates international educational campaigns and engaging transmedia productions aiming to raise awareness of the contributions to science, technology and culture from the Golden Age of Muslim Civilization. 1001 Inventions has engaged with over 350 million people across the globe working with a network of international partners, including UNESCO, National Geographic and leading academics to produce interactive exhibits, short films, live shows, books and classroom learning materials that are being used by hundreds of thousands of educators around the world. <http://www.1001inventions.com/>

https://www.iypt2019.org/2018/10/29/unesco-and-1001-inventions-join-forces-for-iypt2019

Stamps International

See also www.iupac.org/publications/ci/indexes/stamps.html

Olympic Gold



The International Chemistry Olympiad (IChO) is an annual worldwide competition for high school students in which their chemical knowledge and skills are tested through a series of theoretical and practical problems. The first IChO was held in Prague in 1968 with three teams of six students representing Czechoslovakia, Hungary, and Poland. Humble beginnings perhaps, but interest in the IChO rose quickly and, by 1980, a total of 52 competitors from 13 countries attended the 12th IChO, held for the first time outside Eastern Europe, in Linz, Austria. Participation expanded steadily in the ensuing years and 186 students from 47 countries were present at the 30th IChO in Melbourne, Australia, in 1998.

The postage stamp illustrated in this note, the first ever issued to honor a Chemistry Olympiad, was released on 15 June 2018 to commemorate the 50th IChO, which was jointly hosted for the first time by two countries, Slovakia and the Czech Republic. It took place on 19-29 July 2018, organized by Comenius University in Bratislava and the University of Chemistry and Technology in Prague, institutions that shared the management of both technical sessions and social events. Significantly, the 50th IChO had a record attendance of 300 students from 76 countries, a fitting milestone for the golden anniversary of the International Chemistry Olympiads.

The 51st IChO will take place in Paris on 21-30 July 2019, just a few days after the IUPAC World Congress and General Assembly, yet another reason to celebrate chemistry during the International Year of the Periodic Table. Dmitri Mendeleev, 150 years after introducing the first version of the modern periodic table, would be so proud of the students competing at the IChO!

Written by Daniel Rabinovich <drabinov@uncc.edu>.

Critical Evaluation of Homogeneous Equilibrium and Solubility Constants of Gadolinium in Environmental and Biological-Relevant Conditions

There are a number of trace elements that until recently were only considered to be laboratory curiosities but which have now become essential components in a variety of applications ranging from information and communication technologies, semiconductors, electronic displays and optic/photonic applications, and "green energy" related technologies. Their current strategic importance is such that these elements have now been labeled as "energy-critical elements" or "technology-critical elements" (TCEs) and initiatives at national levels are underway to secure their availability in the coming years. TCEs have diverse chemistries and uses. The degree of the current knowledge on their environmental fate and (eco)toxicity is not uniform, ranging from relatively well studied elements, such as the platinum group, to essentially unknown ones, such as tellurium. But for all of them, fundamental thermodynamic data are lacking.

This project will compile and critically evaluate existing data for gadolinium. This will allow a "best set" to be immediately used by stakeholders and sound identification of the systems that require urgent data acquisition. Gadolinium is an element of increasing concern because its concentration is steadily increasing in surface waters world-wide.

For more information and comments, contact Task Group Chair Montserrat Filella <montserrat.filella@unige.ch>.

https://iupac.org/project/2018-025-1-500

23rd UNESCO/IUPAC Postgraduate Course in Polymer Science

The UNESCO/IUPAC Postgraduate Course in Polymer Science has been organized annually since the academic year 1996–1997 by the Institute of Macromolecular Chemistry of the Czech Academy of Sciences (Prague, Czech Republic)—with financial support of the Czech Academy of Sciences and under the auspices of IUPAC and the Czech Commission for UNESCO.

The Institute has more than 60 years of experience in postgraduate polymer science education and offers up-to-date facilities for polymer science. The course lasts 10 months and comprises primarily experimental work on research projects under supervision of institute scientists, compulsory lectures and laboratory demonstrations in modern polymer science, and access to all educational activities within the Institute. At the end of each run of the Course, all of the participants report on their project results in a public meeting, where a certificate bearing the logos of UNESCO and IUPAC is awarded to the participants—new graduates.

The Course is now a global activity with graduates from all continents except Australia and North America, represents a major educational activity within Polymer Division, and contributes to a positive image of IUPAC even outside the professional community. Reports on the courses have been presented annually and favorably accepted at the meetings of the IUPAC Polymer Division. The 22nd run (the year 2017-18) was completed by 10 participants at the end of July 2018. The 23rd Course started in October 2018 and covers the 2018-19 academic calendar. The Course was awarded the IUPAC-Samsung Education Prize for 2005, and received support from the Hanwha-Total fund once again this year.

For more information and comments, contact Task Group Chair Pavel Kratochvíl <krat@imc.cas.cz>

https://iupac.org/project/2018-031-1-400

Guidance for the Compilation, Critical Evaluation and Dissemination of Chemical Data

Critical evaluation of chemical data has long been an important activity within IUPAC. Thus the current "Guidelines for IUPAC Projects" states: "The core activity of IUPAC is to provide critical evaluations of methods and data and to make recommendations for nomenclature, terminology, metrology, and measurement standards." Members of the Analytical Chemistry Division's Subcommittee on Solubility and Equilibrium Data, wanting to learn more about activities related to critical evaluation in other divisions and committees, organized an *ad hoc* interdivisional discussion on critical evaluation during the 2017 General Assembly (project 2016-043-1-500). This half-day meeting was attended by interested individuals from the Inorganic Chemistry Division (Div II), the Polymer Division (IV), the Analytical Chemistry Division (V), and the Committee on Publications and Cheminformatics Data Standards (CPCDS). From this meeting and subsequent conversations (which have included the Physical and Biophysical Chemistry Division (I)

and the Chemistry and the Environment Division (VI) as well as those listed above) two ideas emerged: that the exchange of information and experience among groups and individuals in IUPAC concerned with critical evaluation should continue, and that an important first project would be to develop guidance or best practices for critical evaluation of chemical data. This project addresses that second idea.

Currently active critical evaluation projects within IUPAC are highly varied treating both equilibrium and kinetic data; properties measured with either high and low relative uncertainty; and outputs ranging from monographs to databases. Given this range in the data sets evaluated and the rapidly evolving needs for cheminformatic documentation, guidance is needed to focus on best practices and provide flexibility while at the same time embodying high scientific standards. The Task Group that has been assembled for this project reflects the breadth of IUPAC's experience in critical evaluation.

The Task Group will consider the three aspects of the critical evaluation process—compilation, evaluation, and dissemination—and develop best practice recommendations for each. Because of the wide variation in the data types that are evaluated, detailed protocols for the work are not considered appropriate. Rather the guidance will consider the qualities that are inherent in a good evaluation (completeness, clarity, traceability, *etc.*) and how those qualities can be achieved.

For more information and comments, contact Task Group Chair David Shaw <shaw02110@gmail.com>.

https://iupac.org/project/2018-009-2-500

IUPAC Periodic Table of the Elements and Isotopes (IPTEI) for the Education Community (IUPAC Technical Report)

Norman E. Holden, Tyler B. Coplen, John K. Böhlke, Lauren V. Tarbox, Jacqueline Benefield, John R. de Laetera, Peter G. Mahaffy, Glenda O'Connorb, Etienne Rotha, Dorothy H. Tepper, Thomas Walczyk, Michael E. Wieser and Shigekazu Yoneda

***Pure and Applied Chemistry* 2018**
Volume 90, Issue 12, pp. 1833-2092

The IUPAC Periodic Table of the Elements and Isotopes (IPTEI) was created to familiarize students, teachers, and non-professionals with the existence and importance of isotopes of the chemical elements. The IPTEI is modeled on the familiar Periodic Table of the Chemical Elements. The IPTEI is intended to hang on the walls of chemistry laboratories and classrooms. Each cell of the IPTEI provides the chemical name, symbol, atomic number, and standard atomic weight of an element. Color-coded pie charts in each element cell display the stable isotopes and the relatively long-lived radioactive isotopes having characteristic terrestrial isotopic compositions that determine the standard atomic weight of each element. The background color scheme of cells categorizes the 118 elements into four groups: (1) white indicates the element has no standard atomic weight, (2) blue indicates the element has only one isotope that is used to determine its standard atomic weight, which is given as a single value with an uncertainty, (3) yellow indicates the element has two or more isotopes that are used to determine its standard atomic weight, which is given as a single value with an uncertainty, and (4) pink indicates the element has a well-documented variation in its atomic weight, and the standard atomic weight is expressed as an interval. An element-by-element review accompanies the IPTEI and includes a chart of all known stable and radioactive isotopes for each element. Practical applications of isotopic measurements and technologies are included for the following fields: forensic science, geochronology, Earth-system sciences, environmental science, and human health sciences, including medical diagnosis and treatment.

https://doi.org/10.1515/pac-2015-0703

On the Discovery of New Elements (IUPAC/IUPAP Provisional Report)

Sigurd Hofmann, Sergey N. Dmitriev, Claes Fahlander, Jacklyn M. Gates, James B. Roberto and Hideyuki Sakai

***Pure and Applied Chemistry* 2018**
Volume 90, Issue 11, pp. 1773-1832

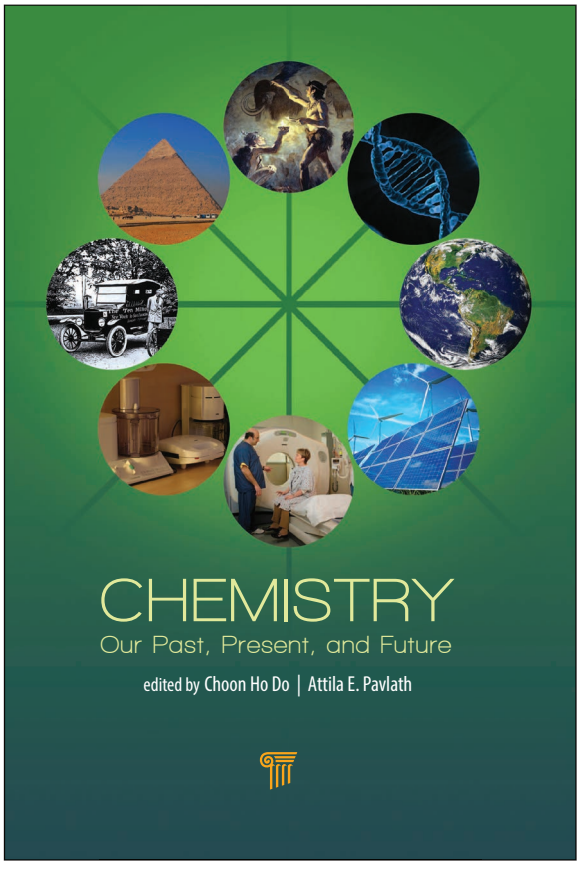
Almost thirty years ago the criteria that are currently used to verify claims for the discovery of a new element were set down by the comprehensive work of a Transfermium Working Group, TWG, jointly established by IUPAC and the International Union of Pure and Applied Physics (IUPAP). The recent completion of the naming of the 118 elements in the first seven periods of the Periodic Table of the Elements was considered as an opportunity for a review of these criteria in the light of the experimental and theoretical advances in the field. In late 2016 the Unions decided to establish a new Joint Working Group, JWG, consisting of six members determined by the Unions. A first meeting of the JWG was in May 2017. One year later this report was finished. In a first part the works and conclusions of the TWG and the Joint Working Parties, JWP, decisions on the discovery of the now named elements are summarized. Possible experimental developments for production and identification of new elements beyond the presently known ones are estimated. Criteria and guidelines for establishing priority of discovery of these potential new elements are presented. Special emphasis is given to a description for the application of the criteria and the limits for their applicability.

In accordance with the Terms of Reference under which the JWG was established, this report has been provisionally accepted by IUPAC and IUPAP, and is open for comment for 5 months. Comments should be directed to Zhou Qifeng <qfzhou@iupac.org>, President of IUPAC and to Kennedy Reed <reed5@llnl.gov>, President of IUPAP, and will be accepted up to 31 March 2019.

https://doi.org/10.1515/pac-2018-0918

Chemistry: Our Past, Present, and Future

CRC Press 2017, ISBN 9789814774086
Reviewed by Richard J Sundberg



This is a multi-authored book edited by Choon Ho Do and Attila E. Pavlath, who have served as presidents of their respective national chemical societies and been active in promoting public interest in chemistry and chemical education. The book is organized into three sections: Chemistry Inherited from the Universe; Contributions of Chemistry; and Chemistry and Activities. Chapter 1 by Sunney I. Chan and Andrew P. Yeh is a broad overview of the origin of molecules, their organization into life forms and the crucial role of DNA, RNA, and protein in life processes. The central point is that chemistry, the understanding of substances at the molecular level, has provided deeper insight and enabled science-based progress. In Chapter 2, Mary V. Orna describes the origins of substances such as gunpowder, salt, dyes, metals, and glass. This chapter also provides examples of chemicals used in medicine. In Chapter 3, Dr. Pavlath emphasizes the role of chemically-modified materials—such as metals, alloys, textiles, glass, and ceramics—have had in changing daily life over the course of human history.

The second section of the book addresses specific areas of chemical impact in agriculture, nutrition, energy, medicine, transportation, and communication. For example, in Chapter 6, James Wei describes the chemical aspects of energy use including petroleum refining, combustion processes, pollution control, biomass conversion, and nuclear energy. In Chapter 7, Veronica Nemeth considers chemical aspects of clinical assays and imaging in diagnosis. In Chapter 8, Etrika and Dorottya Godor adopt a more anecdotal approach than most of the other chapters in discussing pain management, steroidal anti-inflammatories, psychotherapeutic agents, contraceptives, and insulin. This approach gives more emphasis to the circumstance of discovery than most of the other chapters. Chemist Carl Djerassi gets slightly less than top billing in the contraceptive section, not because his contribution was less critical, but because he did not need to step so far out of existing boundaries as the four "stars" (Margaret Sanger, George Pincus, Katherine McCormick and John Rock) of the chapter. Chapter 9 by Young Ha Kim describes implantable medical devices and regenerative medicine. In Chapter 10, James Wei discusses the materials used for vehicles, roads, and fuels in ground transportation. In Chapter 11, Dr. Pavlath considers materials used for communication. Examples include batteries, vacuum tubes, transistors, computer chips, liquid crystal displays, optical fibers, compact disks, ink, and photographic film. If I had edited this book, I would have split this section into two parts emphasizing the more biological (Chaps. 4, 5, 7, 8, 9) and physical aspects (Chaps. 6, 10, 11), and in particular bringing together the closely related chapters on energy and transportation.

In Chapters 12 and 13, at the beginning of the third section, the editors discuss the future. Dr. Pavlath's chapter addresses perceived needs for improvement in chemical education and the public's appreciation of chemistry. The pronoun "we" is used frequently in this chapter, meaning professional chemists, as Dr. Pavlath urges his colleagues to address the problems he has noted. In Chapter 13, Dr. Do seeks to identify ways in which chemistry might be used to achieve advances and sustainability in the future. Among the topics are artificial photosynthesis, renewable energy sources, and new materials. Climate change, in particular CO_2 management, is addressed. The conversion of deserts to livable environments by massive water redistribution is considered. The final chapter looks at Africa,

the part of the world that has received the smallest share of the benefits extolled in the rest of the book. It envisions improved education, research, and "green" chemistry as means of progress.

So far as I could tell, this book is factually solid, although I noted two curious time warps. On page 115, the wrong Isaac Newton (1642-1727) is said to have been the first US Commissioner of Agriculture, beginning in 1862. On page 390, the Wright brothers first flight is dated as Dec 17, 1953, exactly 50 years off the mark.

There is no mistaking that this book is "pro-chemistry." That is its avowed purpose. On page 375 Dr. Pavlath estimates that the benefits of chemistry outweighs its problems by 100:1. This is probably conservative, if the units are human life-years multiplied by some quality factor. Some of the problems get brief mention. Automobile emission control by catalytic converters is described on pages 152-154 and on 321-322. But there is no mention of the 50-year battle by geochemists and environmental chemists against the offending tetraethyllead. On page 370 the success of chemists in finding substitutes for ozone-destroying chlorofluorocarbons is described, but not the role of atmospheric chemists in predicting and verifying the problem.

What will readers get from this book? The dust jacket includes professionals, teachers, students, and the general public as potential readers. For professional chemists the book will be a relatively easy read and a reminder of the chemical aspects of many everyday activities. Teachers and students can appreciate the broad scope of chemistry but will not find close connections between the beneficial results and the fundamental chemistry they are addressing. It is hard for me to judge the situation for the general public. Professional chemists have a broad technical language that is relatively unfamiliar to the public. This books makes an effort to keep the message understandable, but general readers will probably encounter some unfamiliar language.

https://www.crcpress.com/Chemistry-Our-Past-Present-and-Future/Do-Pavlath/p/book/9789814774086

Richard J Sundberg <rjs1d@virginia.edu> is Prof Emeritus of Chemistry at The University of Virginia, Charlottesville, USA .

Solution Chemistry

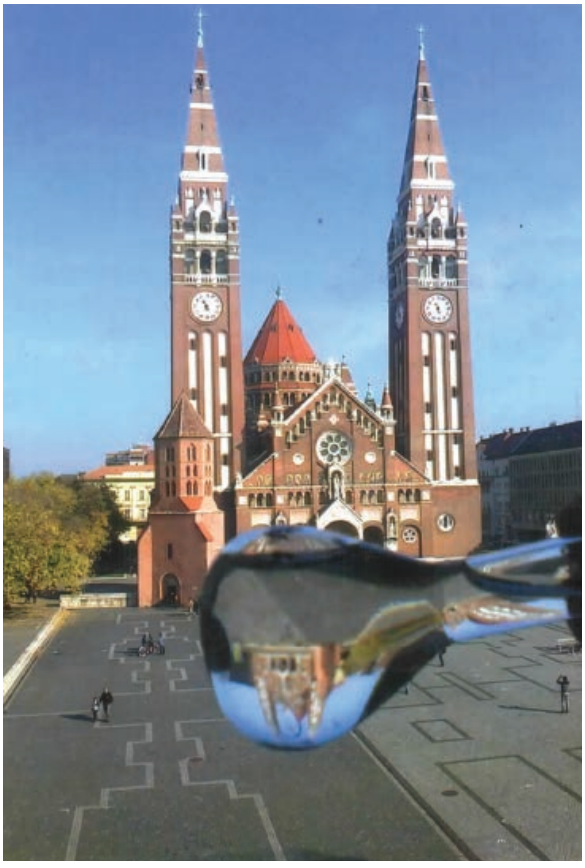
by Pal Sipos

The **35th International Conference on Solution Chemistry (ICSC2018)** was organized by the Hungarian Chemical Society and was held in the Hunguest Hotel Forrás in Szeged, Hungary, **26–30 August 2018**. The ICSC2018 is a continuation of the successful IUPAC conference series that began in Lund, Sweden in 1988. The conference brought together scientists from all branches of solution chemistry, including both fundamental and applied sciences. The topics of the conference included many themes associated with modern applications of solutions: in the medical sciences; for practical/industrial purposes; radioactive waste management; spectroscopy; (bio)coordination chemistry; supercritical fluids; colloids and interfaces; ionic liquids; and computational studies, as well as more traditional work in thermodynamics and solubility phenomena.

The Conference had more than a hundred registered participants, with every continent represented. The 12 invited lecturers gave 6 plenary and 6 keynote talks, all of a very high standard. They were as follows:

- K. N. Raymond, University of California, Berkeley, USA; *Solution thermodynamic and kinetic studies of host/guest supramolecular clusters*
- I. Persson, Swedish University of Agricultural Sciences, Uppsala, Sweden; *Solution chemistry in the surface region of aqueous solutions*
- A. Skerencak-Frech, Karlsruhe Institute of Technology, Institute of Nuclear Waste Disposal, Karlsruhe, Germany; *Radionuclide chemistry in Nuclear Waste Disposal—application of modern spectroscopy for molecular process understanding and actinide thermodynamics*
- S. Hirofumi, Kyoto University, Kyoto, Japan; *Theoretical study of chemical reactions in solution phase using a variety of theoretical approaches*
- S. P. Rosenberg, Emirates Global Alumina, Dubai, United Arab Emirates; *The importance of solution chemistry in industrial hydrometallurgy*
- P. Tremaine, University of Guelph, Guelph, Canada; *Formation constants and transport properties of aqueous complexes in hydrothermal solutions by Raman spectroscopy and AC conductivity methods*
- É. A. Enyedy, University of Szeged, Szeged, Hungary; *Solution chemistry of anticancer metallodrugs and their interaction with proteins*
- Z. Yu, Tsinghua University, Beijing, People's Republic of China, *Excess spectroscopy, a new approach to study the structures of liquid mixtures*
- J. Hunger, Max Planck Institute for Polymer Research, Mainz, Germany; *Interaction and dynamics of organo-catalysts in solution*
- M. Kanakubo, National Institute of Advanced Industrial Science and Technology, Sendai, Japan; *Supercritical fluids, ionic liquids, and their applications*
- G. Laurenczy, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland; *Practical applications of solution chemistry in energy storage and CO_2 utilization*
- Gy. Tircsó, University of Debrecen, Debrecen, Hungary; *MRI imaging and solution chemistry.*

In addition, 40 section lectures and 40 posters were presented. Glenn Hefter, the IUPAC representative to ICSC2018, gave a 10-minute talk detailing the various activities of IUPAC. Following the poster session, Earle Waghorne presented two poster prizes, sponsored by SPRINGER, to Sándor Nagy (University of Debrecen, Hungary) and to Kazuyoshi Kaneko (Soka University,



A view of the Votive Church in Szeged through a volumetric flask containing a solution, the official logo of the ICSC2018. (Photo by G. Kiss)

Japan). Four further posters were given Honorable Mention certificates, reflecting the high standard of the presentations.

During the conference, Ingmar Persson retired from the chairmanship of the International Steering Committee. To honor his chairmanship (2001–2018), he was presented with a bottle of Tokaji wine, vintage 2001, at the conference banquet. Professor Persson is replaced by Toshio Yamaguchi, whose mandate will expire in 2025. The next ICSC, the 36th, will be held in 2019 in Xining, China. The organizers gave a presentation and demonstrated that all the necessary preparations are well underway. The International Steering Committee selected Cartagena, Columbia to organize the 37th ICSC in 2021, which will see the ICSC return to its customary biennial timing.

Beyond the busy scientific schedule, the conference was rich in social events. The opening ceremony was held in the Szeged Town Hall, sponsored by the City Council. An organ concert was organized at the famous Votive Church one evening. Conference excursions included a visit to the National Memorial Park and outdoor village museum in Ópusztaszer. The closing banquet included a wine tasting, featuring local winemaker, Sándor Somodi.

Thus, the 35th ICSC was successful on several fronts: high quality science and interesting social programs. Special thanks go to the organisers from the Hungarian Chemical Society (especially Beáta Androsits, Beatrix Schenker, and Eszter Körtvélyessy) and to the contributing members of the Materials and Solution Structure Research Group (MASOST) at Szeged: Csilla Dudás, Eszter Orbán, Dr. Bence Kutus, Szilveszter Ziegenheim, and Ákos Buckó.

We look forward to meeting again in Xining, in 2019!

Pal Sipos <sipos@chem.u-szeged.hu> is chairman of the Local Organizing Committee.

Organometallic Chemistry and Challenges in CO_2 Activation and Utilization

by Luca Gonsalvi, Alessandro Mordini, and Maurizio Peruzzini

The **XXVIII International Conference on Organometallic Chemistry** (ICOMC 2018) was held in Florence, Italy, from 15-20 July 2018. ICOMC 2018 is the 28th edition of a series biennial events that came back to Italy after exactly 30 years (Torino 1988), and was organized by the Institute of Chemistry of Organometallic Compounds (ICCOM) of the National Research Council of Italy (CNR). The Organizing Committee was formed by the Chair Dr. Maurizio Peruzzini (CNR Research Director), the Co-chair Dr. Alessandro Mordini (CNR Research Director), and the Scientific Secretary, Dr. Luca Gonsalvi (CNR Senior Researcher). A Professional Conference Organizer (PCO), Adria Congrex s.r.l., was in charge of the overall management and logistics of the event, including the official ICOMC 2018 website (www.icomc2018.com). More than 30 ICCOM students and staff personnel, including full-time researchers, also gave valuable contributions before and during the event.

Ben L. Feringa's Plenary Lecture, Thursday 19 July 2018

The Conference venue was the Florence Congress & Exhibition Center, located in a beautiful park in the historical city center; the venue was in close proximity to Santa Maria Novella church and a nearby railway station. The ambitious goal of the 2018 edition was to be one of the main meeting points for scientists active in various fields of organometallic chemistry worldwide for the year, attracting both inorganic and organic chemists due to the interdisciplinary nature of this research area. The scientific program was organized as lecture and poster parallel sessions, focusing on the most recent scientific advances in key and emerging areas of organometallic chemistry including:

- asymmetrics synthesis by organometallics
- bio-organometallic and medicinal chemistry
- clusters, coordination polymers, and metal-organic frameworks (MOFs)

Venue park and welcome cocktail on Sunday 15 July 2018

- early, late transition metal and f-block organometallics
- green chemistry and catalysis
- main group organometallic synthesis
- mechanisms, structure and bonding, calculations
- polymerisations, materials, and nanomaterials
- supramolecular chemistry and molecular machines

One of the parallel lecture sessions was reserved on Thursday and Friday to the works of the XIII Conference of the Interdivisional Group of Organometallic Chemistry of The Italian Chemical Society (Co.G.I.C.O. 2018).

Congress and Exhibition Centre Auditorium during ICOMC 2018.

ICOMC 2018 saw the participation of more than 950 attendees from 45 countries worldwide. The audience included staff academics (475), industrial and commercial participants (23), student participants (381), retired academics (7), accompanying persons (33), and Local Organizing Committee (> 30). A significant overall female participation was reached (26 %). The largest delegations came from Japan, Germany, UK, China, South Korea, Spain, and France.

During the five full days of scientific works, 10 plenary, 36 keynote and 72 invited lectures were presented, together with 203 oral communications and 60 flash presentations. Ben L. Feringa of the University of Groningen, Netherlands, Nobel Laureate in Chemistry for 2016, gave an inspiring plenary lecture, one of the many presentations on research activity from distinguished scientists. The other Plenary Lecture speakers, who kindly accepted our invitation, were chosen as the most outstanding experts in various fields of organometallic chemistry, such as Matthias Beller (LIKAT Rostock, Germany), Christian Bruneau (CNRS-University Rennes I, France), Luisa De Cola (University of Strasbourg, France), Paul J. Dyson (EPFL Lausanne, Switzerland), John F. Hartwig (UC Berkeley, USA), Zhaomin Hou (RIKEN Tokyo, Japan), David Milstein (Weizmann Institute Rehovot, Israel), Roberta Sessoli (University of Florence, Italy), and Shuli You (State Key Laboratory of Organometallic Chemistry Shanghai, PRC).

The two posters sessions also gathered a large interest and participation, especially from the young scientists and students attending, with a total of more than 500 posters being shown. The Symposium **Challenges**

in CO_2 Activation and Utilization, supported by IUPAC under the New Directions in Chemistry (NDC) scheme, was organized as a full-day session of ICOMC 2018 on Monday, receiving good interest and attendance. The Session focused on the latest developments in CO_2 utilization by reduction and addition processes, and many state-of-the-art results were shown by the invited and selected speakers. Keynote lectures were given by Thibault Cantat (CEA Saclay, France) and Yuichiro Himeda (AIST Tsukuba, Japan). This area of research was also well represented in the poster sessions. Similarly, a symposium was organized on Tuesday addressing the area of *Photovoltaics and Photoactivated Chemical Processes*. For this event, a keynote lecture was delivered by Curtis Berlinguette (UBC Vancouver, Canada). During the breaks, the organizers often received enthusiastic comments by many participants on the choice and variety of the scientific program and research areas represented during ICOMC 2018.

IUPAC support included the participation of a Young Lecturer and four Young Scientists showing either poster or flash presentations. On the opening day, Pietro Tundo (IUPAC Representative, Italy) gave an overview talk on the structure and current activities of IUPAC.

To make the Florence experience memorable from more than just a scientific point of view, a welcome cocktail was offered in the venue park on the opening day and a banquet was organized on Thursday evening in the adjacent Fortezza da Basso, the old Medici family fortress now used as tourist site and exhibition center. Accompanying persons were offered a choice of guided tours in Florence taking place during three of the five days of conference works. As is tradition, Wednesday afternoon was kept free from programming to allow the participants either to enjoy Florence at their own leisure or to join an excursion to the towns of San Gimignano or Chianti Area and Monteriggioni walled town. All these side events were highly praised by the participants.

The next edition of ICOMC will be held in Shanghai, China, in July 2020, co-chaired by Shuli You and Yong Tang, Shanghai Institute of Organic Chemistry, Chinese Academy of Sciences. This will certainly be another milestone event and an occasion to meet colleagues and establish new collaborations and friendships, as we trust happened during ICOMC 2018 in Florence.

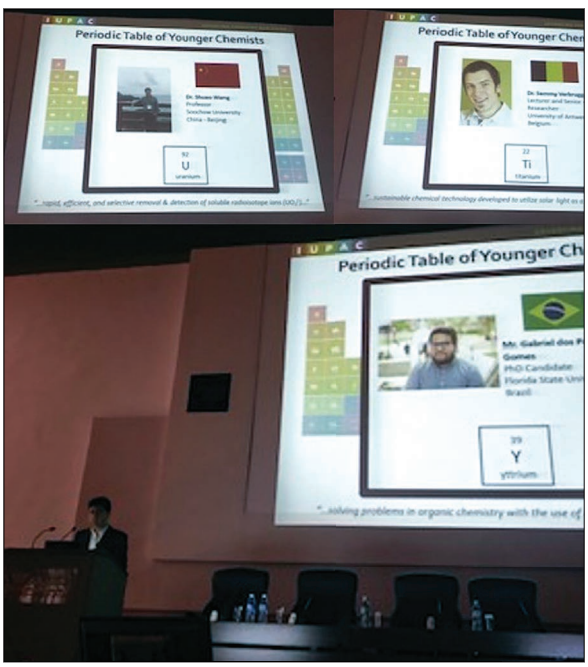
Luca Gonsalvi <l.gonsalvi@iccom.cnr.it> was Scientific Secretary ICOMC 2018 and Symposium Chair. He and his co-authors are affiliated with the Consiglio Nazionale delle Ricerche, Istituto di Chimica dei Composti Organometallici in Firenze, Italy, and Maurizio Peruzzini is also affiliated with the Consiglio Nazionale delle Ricerche, Dipartimento di Scienze Chimiche e Tecnologie dei Materiali, in Roma, Italy.

Congreso Latino Americano de Química

by Javier Garcia Martinez

CLAQ (Congreso Latino Americano de Química) is the main chemistry meeting in Latin America. It is held every two years, in combination with the General Assembly of the Federation of the American Chemistry Societies. The most recent one was held in La Habana, Cuba, 8-12 October 2018. Over 1 000 people attended this major meeting in the Palacio de Congresos de La Habana. There was a significant participation of young people from the region, especially Cuba, and the scientific program was very good with outstanding plenary speakers, including Jean-Pierre Sauvage (Nobel Laurate, University of Strasbourg, France), Benjamin G. Davis (University of Oxford, UK), Wolfram Sander (Ruhr-University Bochum, Germany) and Alessandro Gandini (Universidade de São Paulo, Brazil).

IUPAC was present in the Opening Ceremony and was given the opportunity to address all the participants. I had the honor, as its representative to Latin America, to present IUPAC mission, structure, and activities, focusing on what we are organizing for the IUPAC centenary and the 2019 International Year of the Periodic Table (IYPT). I also announced the next four winners of the Periodic Table of Younger Chemists



Javier Garcia Martinez announces four new additions to The Periodic Table of Younger Chemists during his address to the conference participants at the Congreso Latino Americano de Química.

(see box below). This activity is giving IUPAC a lot of visibility as it is recognizing young chemists in some of the major chemistry events. I used this opportunity to encourage nominations from nearby regions. The impact of this activity is clear as evidenced by how social media is responding to our posts, and by the number of nominations received for each element. Other activities like the Global Breakfast, IUPAC Stories, and the Periodic Table Challenge also got a lot of attention and I had several questions from representatives from universities and chemical societies about these activities.

One important meeting I attended was with the Presidents of the Latin American Chemical Societies. After the CLAQ General Assembly was concluded, the representatives from the ACS, RSC and IUPAC were invited to address the Assembly, and a good discussion continued after our presentations. I encouraged the different chemical societies represented there to organize their own activities at local, national, and regional levels and to keep us informed. Brazil is organizing a major educational activity regarding the periodic table through their Ministry of Education for high school students. This meeting was an excellent opportunity to respond to any questions and concerns and to invite the different chemical societies from the region to engage in our activities and organize their own.

During these four days, I had the opportunity to meet numerous people and coordinate actions to increase their participation in IUPAC, to extend our membership, and to find potential sponsors. I also had several informal meetings with Bonnie Charpentier (President Elect of ACS) and Alejandra Palermo (representative from RSC). I thanked them for everything their organizations are doing to promote and complement what IUPAC is doing regarding IUPAC100 and IYPT. They asked me how they can further help and I indicated that by spreading the word about the activities we are organizing, and letting us know what they are doing, we can better use our resources and communication tools to support each other.

I believe that attending these regional meetings is critical to engage with our stakeholders, promote IUPAC activities and potentially increase our membership. As always, please do not hesitate to contact me if you have any questions. I would like to use this opportunity, on behalf of IUPAC, to thank the organizers of the CLAQ, the Cuban Society of Chemistry, for their kind invitation and for organizing such a nice conference, which will, no doubt, contribute to the development of chemistry in the region.

Javier García Martinez <j.garcia@ua.es> is an IUPAC Executive Committee Member and Professor of Chemistry at the University of Alicante, Spain.

#PTChemists

- **Zr, Dr. Claudia Bonfio, Italy**
  Bonfio is a Postdoctoral Research Fellow at MRC Laboratory of Molecular Biology focusing on identification of key molecular pathways in prebiotic chemistry.
- **U, Dr. Shuao Wang, China**
  Wang is a Professor at Soochow University focusing on rapid, efficient, and selective removal & detection of soluble radioisotope ions.
- **Ti, Dr. Sammy Verbruggen, Belgium**
  Verbruggen is a Lecturer and Senior Researcher at the University of Antwerpen focusing on sustainable chemical technology developed to utilize solar light as a clean source of energy.
- **Y, Mr. Gabriel dos Passos Gomes, Brazil**
  Gomes is a PhD Candidate at Florida State University focusing on solving problems in organic chemistry with the use of computational tools.

Energetic Materials

by Reşat Apak

The "**International Workshop on Energetic Materials**," associated with the Analytical Chemistry Division Project entitled "Critical Evaluation and Vocabulary of Chemo-sensing and Determination Methods for Explosive Residues On-Site and in the Field" (project 2015-008-2-500), was held in Istanbul University, Istanbul, between 18-19 October 2018. Though the project focuses on the analytical chemistry of energetic compounds, the workshop aimed to gather scientists dealing with all aspects of energetic compounds, including synthesis, characterization, stability, physical chemistry, biochemistry and environmental chemistry of explosives, and finally the engineering aspects of ammunition. The workshop brought together world experts, including invited speakers from Australia, USA, U.K., France, Spain, and Turkey, and provided a forum among energetic materials researchers.

Aside from the rich scientific content of the workshop which enabled all the participants to share project achievements, the workshop organizers, as well as the energetics research group in Istanbul University, welcomed participants to the historical city of Istanbul, which unites two continents and comprises many civilizations.

The opening ceremony of the workshop was held by Rector Prof. Nuri Aydin and Vice Rector of Istanbul University-Cerrahpaşa Prof. Mehmet Bİlgİn. As IUPAC project partners, Prof. Jean Claude-Tabet (Sorbonne University, France), Prof. Wujian Miao (University of Southern Mississippi, USA), Assoc. Prof. Manel Del Valle (Autonomous University of Barcelona, Spain), Assoc. Prof. Jose Gonzalez-Rodriquez (University of Lincoln, UK) and Prof. İbrahim DİNÇER from University of Ontario-Canada, and Head of TUBITAK-SAVTAG (Turkish Scientific Technological Research Council-Defense Technological Research & Development Division) Colonel Dr. Mustafa CİVELEK participated. Additionally, experts from the Presidency of Turkish General Staff, TUBITAK-SAGE, TUBITAK-MAM, ROKETSAN AS, ALTINAY Aviation and Advanced Technologies Inc., Istanbul University-Cerrahpasa, Baskent University, Kirikkale University, Ondokuz Mayis University, Hacettepe University and Gazi University actively took part in the Workshop with mostly oral and poster presentations.

IWEM2018 started with the opening speeches of the Rector of Istanbul University-Cerrahpaşa, Prof Dr. Nuri Aydın, and the Co-Chairman of IWEM2018 Prof. Dr. Reşat Apak. Then Assoc. Prof. Sevil Ulucan Weinstein and her team from Istanbul University-State Conservatory performed a violin concert.

During IWEM2018, the following presentations were made: Studies on the detection energetic materials in the environment were reported by Prof. Reşat Apak, Assoc. Prof. Ayşem Arda and research team (orally presented by Prof. Apak) under the title "Examples of Colorimetric and Electrochemical Sensors/Nanoprobes (Devised in Istanbul Univ.) for Determination of Energetic Materials"; "Overview of Novel Hydrogen and Ammonia Production Research at CERL" by Prof. İbrahim DİNÇER as Plenary Lecturer; "Mass spectrometry detection of nitro explosives" by Prof. Jean Claude-Tabet as a keynote lecturer; "Trace detection of explosives based on electrochemical, chemiluminescent, and electrogenerated chemiluminescent techniques" by Prof. Wujian Miao as a keynote lecturer; "Development of molecularly imprinted polymers for the sensor-based detection of explosives" by Assoc. Prof. Manel Del Valle as a keynote lecturer, "Identification and detection of home-made and most common improvised explosives used in terrorist attacks by chromatographic and spectroscopic techniques" by Assoc. Prof. Jose Gonzalez-Rodriquez as a keynote lecturer.

A total of 55 researchers attended IWEM2018; the workshop was successfully completed with the oral presentations of 15 invited speakers from different universities and organizations, totaling 20 oral and 9 poster presentations with positive feedback from the attendees in the closing panel. The workshop hosted scientific discussions with the potential for further cooperation possibilities among heterogenous research groups.

The IUPAC Project 2015-008-2-500 meeting was held just after the workshop with participants Prof. Reşat Apak, Assoc. Prof. Ayşem Arda, Prof. Jean Claude-Tabet, Prof. Wujian Miao, Assoc. Prof. Manel Del Valle, and Assoc. Prof. Jose Gonzalez-Rodriquez. Ultimately, the outcome of this project will constitute a technical report to be published in *Pure and Applied Chemistry.* The participants either brought their draft contribution or promised to submit within a short time following the meeting.

For further information, contact the Task Group Chair Professor Reşat Apak <rapak@istanbul.edu.tr,> or visit https://iupac.org/project/2015-008-2-500 or http://iwem2018.istanbul.edu.tr

Setting their Table: Women and the Periodic Table of Elements

Murcia, Spain, 11-12 February 2019

In the history of the discovery and establishment of the Periodic Table, it seems there are hardly any women scientists involved. However, they are more numerous when it comes to filling the table, and discovering elements, their properties, and their use. Unfortunately, even those women are often forgotten or overlooked. This symposium will specifically address the contribution of women to the Periodic Table and the knowledge of its elements, by demonstrating the presence of women and girls in the history of the development and filling of the PT, by reviewing the present situation and achievement of women in chemistry today and setting the table for the future.

The symposium is organized under the auspices of UNESCO and through the cooperation of IUPAC, IUHPST, EuChemS (European Chemical Society) as well as the Real Sociedad Española de Química and the University of Murcia. This international conference is set against the backdrop of the International Year of the Periodic Table of the Elements and will start on the International Day for Women and Girls in Science. The program includes plenary lectures, key notes, oral communications and posters, and a round table.

Scientific Topics

While the Periodic Table has been established for a while now, and the number of available elements is finite, the progress of chemistry continues to enable researchers to find new ways to use these elements for the benefit of men and women, and meet the challenges faced by humanity in the 21st century. The focus of this symposium is on the contribution of women, and how these contributions have been implemented by the scientific community.

The Symposium sessions will cover a variety of advanced topics on following subjects:

- history of women, the elements and the Periodic Table
- the Periodic Table and chemical education, past, present and future (with a special attention to secondary school teachers and pedagogy)
- the elements and the Periodic Table for sustainable chemistry
- beyond the elements: building nano- and biomaterials
- old elements, new technologies: how to improve the quality of life
- women in the chemical sciences, engineering and technologies
- endangered elements: how to face the scarcity of resources

For more information on the symposium, the venue, the associated events and how to register, see the website: http://www.iypt2019women.es/ or send an email to <congresos@verticesur.es>

For the installation in 2017 of the most likely largest mural Periodic Table (see this CI issue cover), 118 75×75cm metal squares were fastened on the facade of the chemistry building at the University of Murcia, Spain, representing all the known elements and covering approximately 150m² in total. This was hard work. In February 2019, Murcia will be the site of IYPT2019 event reflecting on the contribution of women to the Periodic Table and the knowledge of its elements.

FAIR Publishing Guidelines for Spectral Data and Chemical Structures

29-30 March 2019, Orlando, Fl, USA

Spectral data and chemical structures are most often published as static figures embedded within publisher formatted documents (*e.g.* PDF). This practice has greatly limited both reuse and discovery of chemical data. The chemical community has recognized this limitation and, as a result, there is wide interest in enhanced sharing of spectral data and chemical structures in the form of machine-readable files. However, there is a lack of guidance for authors specifying how to create, describe, and package machine-readable chemical data alongside publication submissions. This workshop brings together a wide variety of stakeholders including researchers, database providers, publishers, and librarians to map workflow models for preparing and publishing FAIR chemical spectral data and chemical structures. Attendees will consider re-use needs for these data within the chemistry community and other disciplines and formulate value propositions to further engage researchers and other stakeholders. As part of the workflow development, attendees will review existing supporting resources, standards and tools, and identify gaps for further development. The focus will be on designing and implementing what can be accomplished with current resources. Outputs will include documentation for sharing FAIR machine-readable spectral and chemical structure data, and strategies for scaling and sustaining community practice.

Organizers: Leah McEwen and Vincent Scalfani. This workshop is an activity of the IUPAC Subcommittee on Cheminformatics Data Standards (SCDS).

https://iupac.org/event/fair-publishing-guidelines-for-spectral-data-and-chemical-structures/

Croatian Meeting of Chemists and Chemical Engineers and 4th Vladimir Prelog Symposium

9-12 April 2019, Šibenik, Croatia

The 26th Croatian Meeting of Chemists and Chemical Engineers (26HSKIKI, www.26hskiki.org) with international participation and 4th Vladimir Prelog Symposium, will be held in Šibenik, Amadria Park (Solaris) from 9-12 April 2019.

The meeting has been organized jointly by the Croatian Society of Chemical Engineers and the Croatian Chemical Society on a biannual basis since 1969. It gathers scientists and experts from Croatia and neighboring countries from academia and industry that will contribute to the Meeting through five sections: Chemistry, Chemical and Biochemical Engineering, Material Science, Environmental Protection, and Education. New knowledge, ideas and technologies within the fields of engineering and economical development is spread through posters and oral presentations, exchanging experiences and accomplishments. The official languages of the Meeting are English and Croatian. As an associated event in this gathering, the 100th anniversary of the Faculty of Chemical Engineering and Technology of the University of Zagreb will be celebrated as well. During last forty-six years, we were honoured by talks given by Nobel laureates Vladimir Prelog, Harold Kroto, Robert Huber, Jean-Marie Lehn, Richard Ernst, Ada Yonath and Dan Shechtman, as well as many other world known chemists.

Deadline for registration and abstract submission is **15 January 2019** and early bird registration is **1 February 2019.**

IUPAC enabled financial support for conference participation for young scientists and advanced students.

IUPAC For Africa—Postgraduate Summer School on Green Chemistry

12-19 May 2019, Dar es Salaam, Tanzania

Inspired by IUPAC Centenary and the International Year of the Periodic Table Celebrations, the 2019 IUPAC Summer School on Green Chemistry will be held in Tanzania, 12-19 May 2019. This will be the first time this event is being held in Africa. It's managed by the IUPAC Interdivisional Committee on Green Chemistry for Sustainable Development (ICGCSD). The Summer School will be hosted by the University of Dar es Salaam (UDSM), University of Dodoma (UDOM), the Tanzania Bureau of Standards (TBS) and the Government Chemist Laboratory Authority (GCLA) in collaboration with the Tanzania Chemical Society (TCS).

The event will provide the participants with an understanding of the latest developments of the concepts and management of green/sustainable chemistry. Basic materials on green chemistry will be covered including state of art topics not limited to: exploitation of natural resources, green methodologies chemistry, green analysis, green synthesis of materials, and industrial green technologies.

Students attending the summer school will be required to present posters. The abstracts for the posters should be submitted through the online registration system; the deadline for submission of abstracts is 14 April 2019. There will be awards for the best posters at the end of the summer school. The registration fee is USD 200 covering lecture materials, local transport, as well as meals and refreshments during the sessions. Partial or full sponsorship will be available from IUPAC and other institutions depending on qualification of applicants and the coverage of the scholarship. Prospective participants are, however, encouraged to seek their own sources of sponsorship.

The Deadline for registration **30 April 2019.**

Contact: Chairman of Organizing Committee: Prof. Egid B. Mubofu, <ebmubofu@gmail.com> Tel: +255 784 538 344

http://www.tcs-tz.org/iupac_summer_school_2019.htm
http://www.tcs-tz.org/iupac2019/
https://iupac.org/event/iupac-for-africa-postgraduate-summer-school-on-green-chemistry/

In Honor of IUPAC's 100th Anniversary

31 March 2019 (exact date to be confirmed), Orlando, USA

A symposium entitled **Creating a Common Language for Chemistry: IUPAC's Role—Past, Present, and Future,** will be held during the 2019 spring National Meeting of the American Chemical Society (ACS) that is scheduled to take place in Orlando, FL during the week of 31 March 2019. Jointly organized by the IUPAC Committee on Publications and Cheminformatics Data Standards (CPCDS) and the ACS Division of Chemical Information (CINF), the symposium will provide a glimpse of IUPAC's illustrious past and its many contributions—from the creation of a common language for chemistry to the development of standards and standardized methods for measurement, atomic weights, and the naming of new elements in the Periodic Table.

Among others, the topics that will be addressed include the history and work of the IUPAC Commission on Isotopic Abundances and Atomic Weights, the development and current status of the InChI code for the digital distribution of molecular structures, the development of a new digital version of IUPAC's Gold Book, IUPAC's efforts to enhance the role of chemistry around the globe and to help ground public policy in sound science, IUPAC's activities that encourage and recognize the role of women in chemistry, and the role that the IUPAC archives play in showcasing and preserving the history of science.

But more importantly, the symposium will take a look at how IUPAC is taking a leadership role in shaping a promising future for chemical information in today's global digital environment. Through its engagement with organizations around the globe, IUPAC is actively participating in the development of standards for creating, sharing, communicating, and preserving digital information that is FAIR (Findable, Accessible, Interoperable, and Reusable), working to ensure the rapid advancement of science and continuing its role as the world authority on chemical nomenclature as it moves into its next centenary.

Organizers: Bonnie Lawlor <chescot@aol.com> and Leah McEwen <lrm1@cornell.edu>. The exact date and time for the symposium has not be set so look for updated news on the IUPAC website.

Mark Your Calendar

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

2019

9-11 January 2019 • Bonding C to Shining C • Mumbai, India

Transitioning Ideas from Mind to Market: Global Collaborations for health, Wellness and Sustainability
Mukund Chorghade <mukundchorghade@fas.harvard.edu> or <chorghad@mit.edu>, www.bc2sc.online

21 January 2019 • Quality of Test Results • Tel Aviv, Israel

International workshop on Quality of Test Results for Conformity Assessment of a Chemical Composition – What is Good and What is Bad? in conjunction with the Isranalytica conference and exhibition (22-23 Jan 2019, http://www.isranalytica.org.il)
Dr. Ilya Kuselman, E-mail: ilya.kuselman@gmail.com, www.iupac.org/event/quality-test-results

22-23 January 2019 • Technology-Critical Elements (TCEs) • Bielystok, Poland

Advanced Workshop on Solution Chemistry of Technology-Critical Elements (TCEs)
Montserrat Filella, University of Geneva, Switzerland, chair of IUPAC project 2008-025-1-500, E-mail: montserrat.filella@unige.ch, http://solchem.costnotice.eu/

29 January 2019 • IYPT2019 Opening Ceremony • UNESCO, Paris, France
www.iypt2019.org

United Nations Educational, Scientific and Cultural Organization
2019 IYPT International Year of the Periodic Table of Chemical Elements

8 February 2019 • Dmitri Ivanovich Mendeleev's Birthday
https://en.wikipedia.org/wiki/Dmitri_Mendeleev

11-12 February 2019 • Setting their Table • Murcia, Spain

International Symposium on Women and the Periodic Table of Elements
The Symposium is set in the frame of the International Year of the Periodic Table and will start on the International Day for Women and Girls in Sciences. Co-chairs: Pedro Lozano, University of Murcia, E-mail: plozanor@um.es and Brigitte Van Tiggelen, EuCheMS-WPHCh / IUHPST-CHCMS, E-mail: vantiggelen@memosciences.be; http://www.iypt2019women.es/

12 February 2019 • Empowering Women in Chemistry: A Global Networking Event • anywhere
Mary Garson, E-mail: globalbreakfast@iupac.org, https://iupac.org/100/global-breakfast/

100 IUPAC

6 March 2019 • On this day in 1869, Dmitri Mendeleev made a presentation to the Russian Chemical Society in which he presented the first version of his periodic table of the elements.
https://www.lapl.org/collections-resources/blogs/lapl/week-remember-mendeleevs-periodic-table

29-30 March 2019 • FAIR Publishing Guidelines for Spectral Data and Chemical Structures • Orlando, Florida
This workshop will brings together a wide variety of stakeholders including researchers, database providers, publishers, and librarians to map workflow models for preparing and publishing FAIR chemical spectral data and chemical structures. Contact: Leah McEwen, IUPAC Subcommittee on Cheminformatics Data Standards (SCDS), E-mail: lrm1@cornell.edu

9-12 April 2019 • Croatian Meeting of Chemists • Šibenik, Croatia

26th Croatian Meeting of Chemists and Chemical Engineers (26HSKIKI)
Prof. Dr Aleksandra Sander, Chair of Scientific and Organizing Committee, E-mail: hskiki@fkit.hr, http://www.26hskiki.org

15-18 April 2019 • Macromolecular Engineering • Stellenbosch, South Africa

13th International Conference on Advanced Polymers via Macromolecular Engineering (APME)
Bert Klumperman, Conference Chair, <bklump@sun.ac.za>, Aneli Fourie, Conference Secretary, <aef2@sun.ac.za >, http://academic.sun.ac.za/apme

12-19 May 2019 • IUPAC for Africa • Dar es Salaam, Tanzania

IUPAC for Africa: Postgraduate Summer School on Green Chemistry
Prof. Egid Mubofu – Chair of the Organizing Committee, Vice Chancellor of the University of Dodoma (UDOM), E-mail: ebmubofu@gmail.com • http://www.tcs-tz.org/iupac_summer_school_2019.htm

19-24 May 2019 • Crop Protection • Ghent, Belgium

14th IUPAC International Congress of Crop Protection Chemistry
Prof. ir. Pieter Spanoghe; E-mail: Pieter.Spanoghe@UGent.be, Onderzoeksgroep Fytofarmacie/Crop Protection Chemistry, Campus Coupure, 9000 Ghent, Belgium, www.iupac2019.be

20 May 2019 • World Metrology Day • The day celebrates the signing of the Metre Convention on that day in 1875 in Paris by 17 nations attending. In 2019, it will coincide with the implementation of the new SI.

2-6 June 2019 • Supramolecular Chemistry • Lecce, Italy

14th International Symposium on Macrocyclic and Supramolecular Chemistry (ISMSC2019)
Pierangelo Metrangolo, Chair of Program Committee, Laboratory of Supramolecular and BioNano Materials (SupraBioNanoLab), Department of Chemistry, Materials, and Chemical Engineering "Giulio Natta," Politecnico di Milano, Italy, E-mail: pierangelo.metrangolo@polimi.it, https://ismsc2019.eu/

10-13 June 2019 • Macromolecule–Metal Complexes • Moscow, Russian Federation

18th International Symposium on Macromolecule–Metal Complexes (MMC-18)
Chair/contact: Prof. Eduard Karakhanov, Lomonosov Moscow State University, Russia
Faculty of Chemistry, Russia, 119991, Moscow 1; E-mail: kar@petrol.chem.msu.ru or mmc-18@yandex.ru
http://mmc-18.org/

3-5 July 2019 • ISOTOPCAT2019 • Poitiers, France

International Symposium on Isotopic studies in Catalysis and Electrocatalysis
Co-chairs: Nicolas Bion, E-mail: nicolas.bion@univ-poitiers.fr and Daniel Duprez,
E-mail: daniel.duprez@univ-poitiers.fr, IC2MP, 4 rue Michel Brunet – TSA 51106
F-86073 Poitiers, France, https://isotopcat2019.sciencesconf.org/

5-12 July 2019 • IUPAC Congress/General Assembly • Paris, France

contact@iupac2019.org, www.iupac2019.org

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

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/

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/

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. web tba

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, President of RAS, Full Member of RAS and M.M. Kotyukov, Minister of Science and Higher Education of the Russian Federation. 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/

14-16 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

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/

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