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

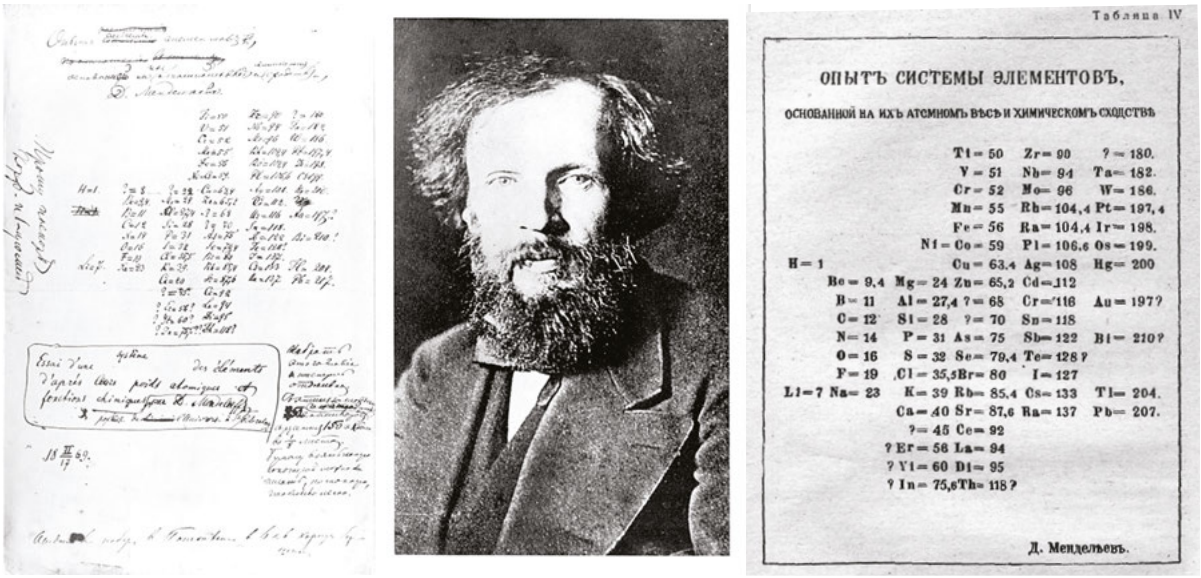

Таблица IV

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	-	189 Er=170	-173	Ta=182	W=184	- Pt=194, Os=195(?) Ir=193, Au=196
11	(Au=196)	Hg=200	Tl=204	Pb=208	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
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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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