

The Periodic Table of the Elements of Mendeleev 150 years after its discovery

In December 2017, the United Nations Assembly proclaimed 2019 the International Year of the Periodic Table of the Elements: one hundred and fifty years ago, on March 6, 1869, the Russian chemist Vladimir Mendeleev presented the first Periodic Table to the Russian Chemical Society, already structurally clear and predictive.

The celebrations of the discovery of the Periodic Table, which led to the understanding of the inherent order of the matter as we know it, are taking place in Paris, 29th January 2019. They will see the participation of the General Secretary of the United Nations, the General Director of UNESCO, Heads of Government, Ministers, as well as scientists, researchers and exponents of the entire scientific community.

The chemical elements play a primary role in everyday life, and the event will bring together the cultural, economic and political aspects of humanity through the common language of the Periodic Table, whose simplicity and elegance still does not cease to attract the attention of young and brilliant minds.

The Periodic Table of the Elements is one of the most significant achievements in science: it initiated modern chemistry and physics, allowed scientists to understand and predict the properties of matter, and brought together the fundamental sciences towards common goals of study and application. The chemical elements are the bricks with which the whole Universe is built, and the chemical and physical properties of Earth are the same as we find them up to the borders of the remote galaxies.

Mendeleev was the last of 17 children. He achieved his academic training in St. Petersburg, at that time a European centre of primary importance in chemistry. In Crimea, he reached the highest grade possible among the academic staff, and then in St. Petersburg, in 1857, he began to do scientific research. In 1863, he became professor of chemistry at the State University of St. Petersburg, and then senior academic with tenure in 1867. Since then, his project was to record all the information on the chemical elements known at the time. In 1893, he was appointed Director of the St. Petersburg Bureau of Weights and Measures.

He was the first to discover the periodicity of the properties of the chemical elements. Subsequently, this made possible to understand that these properties are due to atoms being made up of electrons, protons and neutrons. These particles were unknown at the time.

Mendeleev was the first to place chemical elements according to a precise order, their atomic weight, on a table, discovering that their properties regularly repeated: he was also able to predict the existence and the properties of some elements not known, yet. Scandium, Gallium and Germanium were discovered later, and it was observed that they shared those physical and chemical properties theoretically conceived by Mendeleev thanks to his model. At the time, analytical knowledge was not accurate enough to determine the atomic weights precisely, and the purification of the elements was conducted with very primitive methods. A model is recognized to have scientific validity when it is able to foresee properties and functions of the elements: the Periodic Table gained an immediate success. Thanks to it, it was possible to understand the structure of the atom, composed of electrons, neutrons and protons.

The number of elements of the Table (originally 64) has increased over time with the entry of those belonging to the Earth's crust, and of those that have been synthesized only recently, because of their instability. Thus, with the increase in the number of protons in the nucleus of atoms, the Periodic Table of the Elements was completed last year: the last four elements whose existence was proved

are the elements n. 113 (Nihonium), n. 115 (Moscovium), n. 116 (Livermorium), n. 118 (Oganesson). In total, 118 chemical elements are known today.

The Periodic Table here below (Source IUPAC: International Union of Pure and Applied Chemistry *), starting from the initial hydrogen and helium, consists of two periods of 8 chemical elements each, followed by two periods of 18 and finally two periods of 32 elements. This means, for example, that the elements n. 3, n. 11, n. 19, n. 37, n. 55 and n. 87 (alkali metals), the elements n. 6, n. 14, n. 32, n. 50, n. 82 and n. 114 (alkaloids), as well as the elements n. 2, n. 10, n. 18, n. 36, n. 54, n. 86 and n. 118 (unreactive), share common properties with the elements of their series.

IUPAC Periodic Table of the Elements

1 H hydrogen 1.00784, 1.0082																	2 He helium 4.0026
3 Li lithium 6.941	4 Be beryllium 9.0122											5 B boron 10.81	6 C carbon 12.011	7 N nitrogen 14.007	8 O oxygen 15.999	9 F fluorine 18.998	10 Ne neon 20.180
11 Na sodium 22.990	12 Mg magnesium 24.304, 24.307											13 Al aluminum 26.982	14 Si silicon 28.086	15 P phosphorus 30.974	16 S sulfur 32.06	17 Cl chlorine 35.45	18 Ar argon 39.948
19 K potassium 39.098	20 Ca calcium 40.078(4)	21 Sc scandium 44.956	22 Ti titanium 47.867	23 V vanadium 50.942	24 Cr chromium 51.996	25 Mn manganese 54.938	26 Fe iron 55.845(2)	27 Co cobalt 58.933	28 Ni nickel 58.693	29 Cu copper 63.546(3)	30 Zn zinc 65.38(2)	31 Ga gallium 69.723	32 Ge germanium 72.630(8)	33 As arsenic 74.922	34 Se selenium 78.971(8)	35 Br bromine 79.904	36 Kr krypton 83.798(2)
37 Rb rubidium 85.468	38 Sr strontium 87.62	39 Y yttrium 88.906	40 Zr zirconium 91.224(2)	41 Nb niobium 92.906	42 Mo molybdenum 95.94	43 Tc technetium 98	44 Ru ruthenium 101.07(2)	45 Rh rhodium 102.91	46 Pd palladium 106.42	47 Ag silver 107.87	48 Cd cadmium 112.41	49 In indium 114.82	50 Sn tin 118.71	51 Sb antimony 121.76	52 Te tellurium 127.60(3)	53 I iodine 126.90	54 Xe xenon 131.29
55 Cs cesium 132.91	56 Ba barium 137.33	57-71 lanthanoids	72 Hf hafnium 178.49(2)	73 Ta tantalum 180.95	74 W tungsten 183.84	75 Re rhenium 186.21	76 Os osmium 190.23(3)	77 Ir iridium 192.22	78 Pt platinum 195.08	79 Au gold 196.97	80 Hg mercury 200.59	81 Tl thallium 204.38, 204.38(1)	82 Pb lead 207.2	83 Bi bismuth 208.98	84 Po polonium 209	85 At astatine 210	86 Rn radon 222
87 Fr francium	88 Ra radium	89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganeson



57 La lanthanum 138.91	58 Ce cerium 140.12	59 Pr praseodymium 140.91	60 Nd neodymium 144.24	61 Pm promethium 145	62 Sm samarium 150.36(2)	63 Eu europium 151.96	64 Gd gadolinium 157.25(3)	65 Tb terbium 158.93	66 Dy dysprosium 162.50	67 Ho holmium 164.93	68 Er erbium 167.26	69 Tm thulium 168.93	70 Yb ytterbium 173.05	71 Lu lutetium 174.967
89 Ac actinium 227.03	90 Th thorium 232.04	91 Pa protactinium 231.04	92 U uranium 238.03	93 Np neptunium 237	94 Pu plutonium 244	95 Am americium 243	96 Cm curium 247	97 Bk berkelium 247	98 Cf californium 251	99 Es einsteinium 252	100 Fm fermium 257	101 Md mendelevium 258	102 No nobelium 259	103 Lr lawrencium 260

For notes and updates to this table, see www.iupac.org. This version is dated 1 December 2018. Copyright © 2018 IUPAC, the International Union of Pure and Applied Chemistry.



The observable world is composed of these chemical elements; in fact, those that are mostly important to us may be summarily listed in: hydrogen, oxygen, carbon, nitrogen, sulphur, chlorine, phosphorus.

The chemical elements only correspond to a small part of the Universe. According to the most recent hypotheses, what we know only represents 5% of the total mass of the Universe. The majority of it consists of dark energy (69%) and dark matter (26%), whose nature is still unknown. Alone, this 5% form stars, planets, asteroids, comets, and so on.

Fusion processes have formed all the chemical elements over billions of years, starting from the primary Big Bang, where hydrogen and helium were initially originated. Starting from these two, how have the other elements with higher mass formed? The melting of the nuclei of the atoms was allowed by incredibly high temperatures: several synthetic processes, such as the fusion of neutron stars, the explosion of supernovae, the explosion of white dwarf stars, the death of small-mass stars and the fission of part of cosmic rays.

The formation of all these elements involves one or more singular facts; a striking example is the formation of the atom of carbon, which originates life, as we know it on Earth. The synthesis of the

atom of carbon results after a particularly difficult and atypical process, which involves three atoms of helium going through a very narrow “gateway”, identified only recently (year 2011). Starting from the atom of carbon, all the other heavier elements were generated. In the constitution of the Universe, strange coincidences occurred and allowed its existence. Their unlikely sequence gave rise to different versions of the anthropic principle, currently under discussion among philosophers and scientists.

Next to the chemical elements of the Periodic Table, nowadays about 150 different molecules have been identified, constituted by the aggregation of several atoms. One third of these are complex molecules, at the base of which there is the atom of carbon. Current knowledge of interstellar space organic compounds may suggest that life, as it was generated on Earth, deeply maintains its cosmic roots in these primordial, organic molecules found in interstellar space.

In spite of the size of the Universe (whether it is expanding or not), the number of atoms is immense, but finite. On the contrary, the possibilities atoms have in combining with each other – even considering only the simplest ones on which the current life on Earth is based: carbon, oxygen, hydrogen, nitrogen –, give rise to an infinite number of different molecules, whose number exceeds our comprehension.

Humanity has therefore the power to create an unimaginable and impressive infinity of aggregations of atoms and molecular structures, both organic and inorganic: the problem of choosing what is best to do, among the various and infinite possibilities, here rises.

Thanks to the discovery of the periodicity of the properties of the elements, it is possible to synthesize molecules and materials with the desired properties and characteristics: we have the opportunity to move towards the most different directions possible, with complete freedom.

The awareness of this freedom realizes in sustainable development. The United Nations, proclaiming 2019 the International Year of the Periodic Table of the Chemical Elements, indicates that the future choice of humanity is sustainable development. The celebration of the Mendeleev’s Periodic Table will be an excellent opportunity to reflect on the close correlation between the UN 17 Goals on Sustainable Development and the means humanity has in choosing its future direction.

The major problems to be highlighted are the following: climate change, conservation of natural resources, superconductivity, new magnets and materials used at very high pressures and temperatures, which will allow a more clever use of energy – such as, for example, nuclear fusion.

The Periodic Table will continue to have a revolutionary impact on many fields: the nuclear medicine, the study of compounds and molecules in space, the prediction of new materials. The simple and easily intuitive tool of the Periodic Table will enable an easy access to sustainable development in schools and universities, promoting science as a primary vehicle for a virtuous development and global solutions on energy, agriculture, education and health.

Pietro Tundo

Venice, 16th January 2019

* The International Union of Pure and Applied Chemistry (IUPAC) is the world authority on chemical nomenclature and terminology, including the naming of new elements in the periodic table, on standardized methods for measurement, and on atomic weights.

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