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.

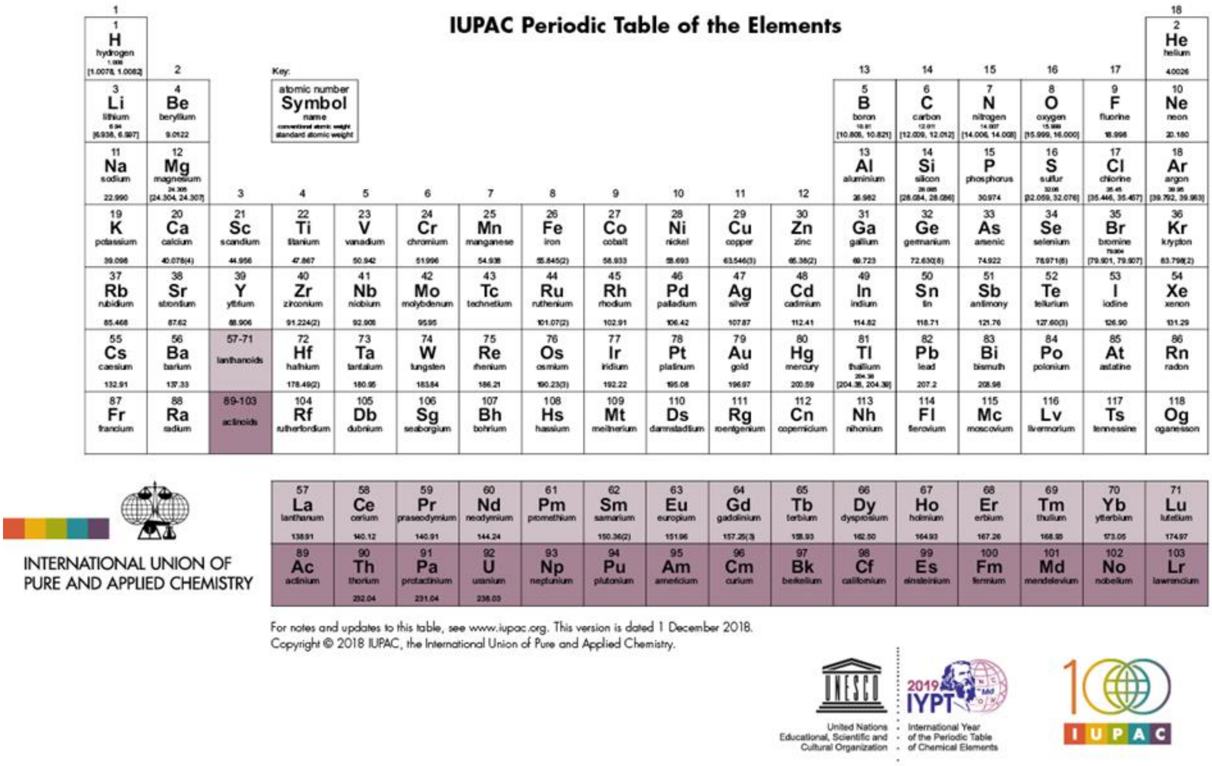
Mendeleev was the last of 17 children. He achieved his academic training in St. Petersburg, at that time a European centre of primary importance in chemistry. In Crimea, he reached the highest grade possible among the academic staff, and then in St. Petersburg, in 1857, he began to do scientific research. 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.



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 synthetize 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

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* 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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