On the Origin of the Elements

Celebrating *150 Years of the Periodic Table* in a joint special session of SCNAT and SPS

Friday, 30 August 2019, 11:15 - 13:30, Room G 30

What Physics has to say about the Periodic Table

On 6 March 1869, Dmitry Mendeleev presented *The Dependence between the Properties of the Atomic Weights of the Elements* to the Russian Chemical Society, where for the first time all then known elements have been placed in a table. This table has grown in what is known today as the Periodic Table of Elements. Hundred fifty years later, the United Nations General Assembly and UNESCO proclaim 2019 as the *International Year of the Periodic Table of Chemical Elements* (IYPT2019, https://www.iypt2019.org) with activities, talks and events organized around the globe (for events in Switzerland see https://www.iypt2019.ch/en/switzerland). Mostly such events highlight the chemical properties of elements, their discovery or their relevance in the environment or in various applications as of today.

United Nations Educational, Scientific and Cultural Organization

International Year of the Periodic Table of Chemical Elements

On the other hand, it is *Physics* that has lots to say about the origin of all the elements, about the understanding of the atomic shell structure, the structure of atomic nuclei, the inner structure of the protons and neutrons that make up the nuclei and that directly leads us to the physics of elementary particles. Particle beams come into play, when heavy ions are carefully shot on heavy nuclei to create previously unknown transuranium elements up to Oganesson with an atomic number of 118.

Time	ID	**ON THE ORIGIN OF THE ELEMENTS - 150 YEARS OF THE PERIODIC TABLE** *Chair: Hans Peter Beck, Uni Bern*
11:15	31	**Celebrating 150 years Periodic Table, historical remarks and current situation** *Heinz W. Gäggeler, Paul Scherrer Institut, 5232 Villigen and Dept. of Chemistry and Biochemistry, University of Bern, 3012 Bern* The first periodic table published by D. I. Mendelejeev in 1869 based on atomic masses and had empty positions that paved the way for the discovery of several new elements. With the discovery of Pu by Glenn Seaborg as a transuranium element a worldwide race for synthesis of new elements started, mostly at LBNL (Berkeley, USA) and JINR (Dubna, Russia), later also at GSI (Darmstadt, Germany) and at RIKEN (Japan). Currently, 118 elements are known and approved by IUPAC. The heaviest is Oganesson completing the 7th period of the periodic table. While all element up to Md have been discovered by chemists, heavier ones were found in physics experiments. Chemical experiments have so far reached atomic number 114 (Fl). Efforts are actually made to extend the periodic table into the 8th period starting with element 119. The ultimate limit of the periodic table is predicted at atomic number 172 being the heaviest element with a stable electron shell structure.
12:00	32	**Big Bang and stars, two hot environments for making elements** *Georges Meynet, Geneva Observatory, 51 chemin des Maillettes, CH-1290 Versoix* The question of the origin of the elements of the Mendeleev table has triggered many lively discussions in the first part of the twentieth century. Some researchers thought that all the elements were produced during the early phase of the evolution of the Universe, while others had the opinion that the stars were the cauldrons in which all the nuclear cooking occurred. I shall explain why neither of these views was correct and how it was possible to make progresses in our understanding. I shall then continue by reviewing the physical principles that govern the evolution of stars and by describing the main nucleosynthetic events at the origin of the elements up to iron. I shall then illustrate the whole process of studying the origin of one element by focussing on the case of oxygen. I shall remind the first ideas about the nuclear processes involved, the astrophysical sites, how this knowledge can be used to make models for the chemical evolution of galaxies and how the predictions of these models can be compared with observational constraints. I shall conclude by describing a present-day highly debated question concerning this element: what is the abundance of oxygen in the Sun?
12:45	33	**Stellar Explosions and the Heavy Elements** *Friedrich-Karl Thielemann, Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel* The build-up of elements up to Fe in stars is governed by fusion reactions in stellar burning stages. The sequence of burning stages is led by the principle that ashes of the previous stage become the fuel of the following one. After the depletion of one fuel, not permitting anymore to make up for the continuing radiation losses which make stars shining, contraction sets in, leading to a temperature increase via the gain of gravitational binding energy. This continues until temperatures pass a threshold, permitting the fusion of reacting charged particles and nuclei via velocities (kinetic energies) which can overcome the repelling Coulomb forces. This stabilizes the star for the next burning stage until its fuel is also depleted. This sequence of events continues until nuclei with the highest binding energy per nucleon are reached, i.e. isotopes of Fe and Ni. What options remain to produce heavier nuclei ? Neutrons do not experience repelling Coulomb forces and neutron capture on nuclei can take place for any temperature. With sufficient amounts of neutrons available, heavy nuclei can be produced by a sequence of neutron captures and beta-decays up to the heaviest nuclei known in nature. The question is how such amounts of unstable neutrons can be provided in stellar environments. The answer is, either (a) via neutron-producing reaction in stellar evolution, or (b) in explosive events originating under conditions of highest densities, where capture of electrons (with high Fermi energies) on protons produced ample amounts of free neutrons. We will connect this to He-burning in stars, as well as neutron star mergers (only observed recently) and a rare class of supernovae.
13:30		***END***