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In the Footsteps of Alfred Werner: The Institute of Inorganic Chemistry at the University of Zurich

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Abstract: Inorganic chemistry has a long-standing tradition at the University of Zurich starting with Carl Jacob Löwig, the first professor of chemistry. The influence of Nobel Prize winner Alfred Werner in coordination, organo-metallic, and bioinorganic chemistry extends right up to the present day as can be seen in many of the research fields of the current professors and young research scientists. With all due respect for the long tradition in inorganic chemistry the Institute of Inorganic Chemistry is also looking forwards to define its role to meet the challenges of the future.

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175 years of Inorganic Chemistry at the University of Zurich

Inorganic Chemistry has a long-standing tradition at the University of Zurich. Surveying its history one has to begin with *Carl Jacob Löwig* who was the first chemistry professor at the University of Zurich starting at its foundation in 1833. In those early years of chemistry the distinction between 'inorganic' and 'organic' chemistry was not yet in common use. ('Unorganische Chemie' denoting inorganic chemistry was coined by *Friedrich Wöhler* only in 1828.)



Carl Jacob Löwig (1803–1890), the first Chemistry Professor at the University of Zurich worked on tetraethyl lead

Carl Jacob Löwig's work covered all chemistry. Nevertheless he is one of the co-discoverers of bromine, an inorganic chemical element, and he worked on tetraethyl lead, one of the first organometallic compounds ever prepared.

After Carl Jacob Löwig, inorganic chemistry at the University of Zurich was somewhat neglected until the coordination chemist *Alfred Werner* entered the stage as Professor of Chemistry of the University of Zurich in 1889. Coming from the ETH Zurich and trained as an organic chemist, Alfred Werner switched research directions to eventually revolutionize coordination chemistry by introducing stereochemical views of organic chemistry, views in three dimensions, to this principal field of inorganic chemistry. He was the first chemist to deal with a correct chemical picture of co-

ordination compounds and by doing so laid the foundations for a persistent theory of the major area of transition metal chemistry. He thus may not only be considered the founder of coordination chemistry honored with the Nobel Prize in 1913, but also as the father of many related chemical disciplines, such as organometallic chemistry, the fields of coordination polymers and bioinorganic coordination chemistry as they are still nowadays present as research disciplines of the Institute of Inorganic Chemistry of the University of Zurich.

After Werner's death in 1919 and with the appointment of *Paul Karrer* in 1920,



Alfred Werner (1866–1919), Nobel Prize Laureate 1913 for coordination chemistry theory

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there was again no specialist for inorganic chemistry in the Chemistry Institute. Unfortunately, the opportunity was not taken at that time to establish a separate Institute of Inorganic Chemistry alongside the newly created Institute of Physical Chemistry. The main lecture courses in inorganic chemistry were given by Karrer until his retirement in 1959. However, in 1931 *Gerold Schwarzenbach* was appointed as 'Abteilungsvorsteher'. Although Gerold Schwarzenbach became one of the leading inorganic chemists of his generation, during his tenure at the University he was never given the responsibility for the main inorganic lecture course. He was appointed Associate Professor in 1943 and Full Professor in 1947. His reputation grew in particular from 1945 on, through his contributions to the modern acid–base theory, and in particular for his studies on metal complexes using potentiometric methods, the quantitative measurement of metal complex association constants, and the discovery of metal-indicators such as eriochrome black. In 1955, however, Gerold Schwarzenbach, who can be denoted as a true successor of Alfred Werner, received an offer from the ETH Zurich following his earlier teacher *William Dupré Treadwell*, and so resigned his position at the University. Had he remained until the retirement of Paul Karrer, his patience would certainly have been rewarded with the creation of an independent Institute of Inorganic Chemistry, and most likely also the mantle of Paul Karrer himself.

In the year following Gerold Schwarzenbach's move to the ETH, *Ernst Schumacher* completed his habilitation in inorganic and analytical chemistry at the University. He was subsequently made Associate Professor (in 1957) and, after the retirement of Paul Karrer, Full Professor and Director of the newly established Institute of Inorganic Chemistry (1959). Under Ernst Schumacher's leadership, the research direction of the new Institute changed more towards problems in physical-inorganic chemistry. The instrumentation within the Institute also improved markedly. However, Ernst Schumacher became frustrated by delays in the refurbishment and extension of the Institute, and in 1964 he accepted an offer from CIBA to become a Director of Research. In 1966 *Hans R. Oswald* was appointed as successor to Ernst Schumacher, and director of the Institute of Inorganic Chemistry. In 1968 *Helmut Werner*, coming from the famous group of *Ernst O. Fischer* at the Technical University, was appointed Professor of Chemistry to fill the newly established second Chair at the Inorganic Chemistry Institute. Helmut Werner was essentially an organometallic chemist building bridges between the classical disciplines of organic and inorganic chemistry. Helmut Werner left the Institute to take up a professorship at the

University of Würzburg in 1975. In 1978 *John Ammeter* was appointed as Associate Professor, but quit his position in 1985. *John Günter* then joined the Institute as Assistant Professor in 1981, became Associate Professor in 1990 and retired in 1999.

After some paucity in the second chaired position *Heinz Berke* came to the University as Full Professor in 1988, and took over as Chairman of the Inorganic Chemistry Institute in 1991. Heinz Berke's major research field concerns organometallic chemistry mainly related to the exploration and exploitation of physical properties of organometallic compounds as molecular materials and metal catalysis of organic reactions. A special field he has recently acquired deals with the archaeometry of ancient blue pigments. After retirement of Hans R. Oswald in 1998, *Roger Alberto*, from the Paul Scherer Institute (PSI) in Würenlingen, was appointed Associate Professor in 1999. Working in the fields of coordination and organometallic transition metal compounds and their application to radiopharmacy, Roger Alberto's research is on very close tracks to that of Alfred Werner. In 2006 he was promoted to Full Professor. Also along the lines of Alfred Werner, links of coordination chemistry to biology were established when *Roland Sigel* entered the Institute as an Assistant Professor in 2003 characterizing the interaction of metal ions with RNA, their respective switching and role in catalytic functions. In 2007 the Institute was supplemented by *Greta Patzke* as an Assistant Professor for solid-state chemistry. Also demonstrating strong ties with the fundamental accomplishments of Alfred Werner, Greta Patzke utilizes coordination compounds to build in controlled ways solids on the nanometer scale. Most recently in 2008, *Eva Freisinger* was promoted to an Assistant Professor, working in the area of bioinorganic chemistry of metallothioneins. The Institute of Inorganic Chemistry presently also hosts very active and ambitious young scientists heading their own research groups: Dr. *Venkatesan Koushik*, Dr. *Christian Frech*, Dr. *Dominik Brühwiler*, Dr. *Bernhard Spingler* and Dr. *Felix Zelder*. They supplement the research fields of the Institute with strong activities in timely areas of inorganic chemistry such as molecular light switches, homogeneous catalysis with transition metal complexes, light harvesting devices on the basis of mesoporous silica, the metal-induced chemistry of Z-DNA and organometallic photochemistry.

Today's Research at the Institute of Inorganic Chemistry – in memoriam Alfred Werner

The Institute of Inorganic Chemistry of the University of Zurich thus hosts momen-

tarily a current total of five research groups headed by professors and five young scientists' groups. All of them are working in some relationship to Alfred Werner's chemistry in the special fields of radiopharmaceutical, bioinorganic and organometallic chemistry to forge links to medicine, biology, biochemistry and organic chemistry. Concomitantly, the fields of solid-state chemistry and coordination chemistry are also included forming sub-disciplines at the center of the specialist area. What all these branches of study have in common is their focus on the chemistry of metals, thus reviving Alfred Werner's heritage.

At many points of its way through history a chemistry institute with such a long-standing tradition has to reflect on its role in society and science, in particular on the occasion of a university anniversary. On this occasion a few substantial questions may be raised.

Inorganic Chemistry – what does that mean nowadays? In the way chemistry presents itself today, the field of inorganic chemistry can now only be seen in historic terms. The use of this expression to designate a discipline is a matter of form. 'Inorganic' no longer means the 'chemistry of non-living matter' but expresses the general circumstance that inorganic chemistry deals with all chemical elements. Modern inorganic chemistry forges links to many disciplines such as biology, medicine, organic chemistry, biochemistry, physics, materials science and many other areas, with the core discipline 'still' existing as such and being investigated with many fundamental aspects in addition. However, basically it is much more than just the core discipline.

What role does inorganic chemistry play in our everyday life today? Most of the substances created by human hand and shaping everyday life such as silicon chips in computers, in particular materials from metals, magnetic and electrical substances or hard coatings on moving parts in motors, are purely inorganic in nature. Many other such materials are organometallic. They always offer special characteristics which are used by man, for example silicones as heat-resistant plastics or chromophoric materials, so-called pigments in car paintwork, and so on. The range of inorganic substances that transform everyday life for the better is too enormous to list in full. The fundamental question is to which fields of research and application inorganic substances will contribute substantially? The answer to this question will define the directions in which an Inorganic Chemistry Institute will go at present and in future. Contributions in the energy sector, e.g. hydrogen storage, fuel cells, large (lithium) batteries as well as catalysts for natural gas into petroleum conversion will certainly belong to these directions. Corresponding research is cur-



Current Faculty Members at the Institute of Inorganic Chemistry: Heinz Berke, Greta Patzke, Roger Alberto and Roland Sigel

rently being performed in two groups at the Institute in collaboration with industrial partners.

Further key issues of research at the institute revolve around the biological role of metals. The Faculty of Natural Sciences, MNF, at the University has decided recently to focus on life science-related research. The improvement of health care by understanding and controlling fundamental molecular processes leads, for example, to

studies on the interaction of metal ions with nucleotide based macromolecules – DNA or RNA as well as with proteins. The diagnosis and treatment of diseases such as cancer will remain a major concern. Only the understanding of life processes in combination with distinctly designed compounds will successfully tackle this challenge. Radioactive substances containing metal ions to specifically find and cure cancer are an instrument to that objective but not the only

one. Projects stemming from biologically motivated research are widespread at our institute, always with metal ion complexes as central tools. Well-structured materials such as polyoxometalates serve as building blocks for various purposes or are a tool for understanding and guiding the formation of new structures on the nanoscale, topics which are investigated in two groups at the institute. The indispensable demand for efficient metal-based catalysts further enhancing the conversion in particular of organic molecules to other refined products, whereby saving energy and avoiding waste, does not need to be emphasized. Returning to purely inorganic compounds, historical blue pigments that played an important role in ancient times, are being prepared and investigated. Due to the rarity of the blue color in nature, such pigments were manufactured artificially early on in the development of man, *i.e.* with the help of chemical processes that have since been lost, but are now being revived at the Institute of Inorganic Chemistry.

This quite concise description of research projects at the Institute is not comprehensive but it gives a taste of the fact that our research seizes the challenges of the future by focusing on topics highly relevant for the future. Being a University Institute, fundamental research is the base, but application is the objective. For a relatively small institute it stands to reason that international networking is the only way to be successful. Accordingly, manifold co-operations exist, and exclusively through these the objectives are sought to be reached. Indeed, that is how past and future go together at the Institute of Inorganic Chemistry.

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