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Scientific Biography Harald A Øye

Harald A Øye was born in Oslo, Norway in 1935 and lives with his wife in Trondheim, Norway. They have 3 children and 4 grandchildren.

Harald A Øye received his M.Sc. Eng in 1958 and Dr. Techn. in 1964 from the Norwegian Institute of Technology. He became Associate Professor 1965 – 1972 and Professor 1973 – 2005 at Norwegian Institute of Technology, later NTNU. He is now Emeritus Professor at the same university. He has had several prolonged research stays in scientific foreign institutions. He has supervised 38 doctor students and numerous M.Sc. students. He has published more than 400 international papers.

His Doctor Thesis topic was on solid and molten mixtures with Ag_2SO_4 . Some of the solid phases had unusual properties being quasi molten with very high disorder and electrical conductivity. He did not continue in this field and the research was continued by a group at Chalmers University.

At a 2 year post-doctoral stay at Argonne National Laboratory with Dr. Dieter Gruen, he started study of systems with AlCl_3 by Ligand Field Spectroscopy. These mixtures are ionic when AlCl_3 is a minority compound, but strong Lewis acids with excess AlCl_3 . They are useful for organic synthesis or stabilization of unusual oxidation states as for instance TiCl_2 . Later he also used Raman and Infrared Spectroscopy. New species as Al_2Cl_7^- and $\text{Al}_3\text{Cl}_{10}^-$ were characterized. The mixtures with AlCl_3 had high enough vapor pressures to determine their thermodynamic properties. Aluminium chloride has in addition an unusual strong ability to vaporize other chlorides. For instance it was possible to vaporize NdCl_3 already at 200°C even if the vapor pressure is only 3 Torr at 1000°C . Large gas complexes as $\text{NdAl}_3\text{Cl}_{12}$ and $\text{NdAl}_4\text{Cl}_{15}$ were found.

The driving force for Øye's study of the aluminium chloride systems was curiosity towards the complexity and the surprising behavior. But in 1973 the studies did suddenly become highly industrially relevant as ALCOA announced a new aluminium process with electrolysis of an $\text{AlCl}_3 - \text{LiCl} - \text{NaCl}$ molten mixture. He worked closely with ALCOA for nearly 10 years, obtaining a lot of useful results. ALCOA produced about 10000 tons of aluminium by the process, but in the end the process was unfortunately stopped due to environmental and technical reasons.

In 1965 Harald A Øye started cooperation with Professor Kai Grjotheim to obtain reliable physico-chemical properties of a molten electrolyte used for a new electrolysis process for magnesium. The studies included phase diagrams, electrical conductivity, surface tension, wetting, viscosity, back reactions and influence of impurities. A very special case was the development and construction of an absolute viscometer for low viscous liquids at elevated temperature. The principle was damping of an oscillating pendulum with a laser detection system. The viscometer was later also used for measurement of the viscosity of the aluminium electrolyte. At the request of IUPAC, standard values

for molten salts and hydrocarbons were determined. In order to prove the accuracy of the instrument, oscillating cylinders of different sizes as well as a sphere were used. They all should give the same viscosity value. A final campaign to prove the accuracy was determination of water at room temperature. The viscosity was determined with a standard deviation of 0,02% and a conservative estimated accuracy of 0,05%.

Norway is a large silicon producer. Half of the silicon is used in alloys with aluminium and the quality is not problematic if only the iron content is reasonable low. The rest is used to make silicones or electronic and solar silicon. These productions start with chemical reactions with CH_3Cl or HCl and the silicon must go through refining steps in order to have the right structure and amount of catalytic elements as well as minimum amounts of impurities. In 1979 Øye met accidentally two Elkem directors that just had sold silicon for chemical use to Dow Chemical. They had however, waited 3 months for acceptance from Dow. We agreed that the present sales procedure was not acceptable and Elkem should be able to characterize the refined silicon themselves. A research and development program with laboratory reactors was started with Øye and his doctor students. At the start of the program nearly all the scientific knowledge was by the customers and kept secret. In order to obtain sharing of knowledge the semi - annual conference "Silicon for the Chemical Industry", later "Silicon for the Chemical and Solar Industry" was started in 1992 with Harald A Øye as permanent chairman until he stepped down in 2015. This conference is arranged in different places in Norway and has been a big success. The 12 Proceedings till now are the most important source of information for this silicon with contributions from producers, customers and academia.

In 1981 Øye stepped up research connected to Hall-Heroult aluminium electrolysis which since then has been his main activity in addition to silicon research. He specially concentrated on material science in connection with the process. The most important material is carbon which is used as container, cathode and anode. His research is a combination of laboratory experiments, industrial cell behavior and cell autopsy. In addition to the Norwegian aluminium industry, important industrial cooperation partners have been ALUMAX, ALCOA, RUSAL, Middle East smelters and Chinese smelters. He did also work with Professor Vittorio de Nora to develop wettable TiB_2 based electrodes for aluminium electrolysis. He is a member since 1982 and chairman 2006 – 2013 of the ISO/TC 226 "Materials for the Production of Primary Aluminium". The goal was to develop new realistic test methods. Today the committee stands behind 114 methods. Much of his research work is summarized in the 3rd edition monograph "Cathodes in Aluminium Electrolysis" together with Morten Sørli; English edition 2010, 662 pp; Russian Edition 2013, 699 pp; Chinese Edition 2015, 428 pp.

Øye saw the need for a science based education for employees of the international aluminium industry and started 1982 a yearly one week course "The International Course on Process Metallurgy of Aluminium" in Trondheim. At the request from some smelters he also started in 1997 the course "Fundamentals and their Application in Aluminium Production" two weeks before the one week course for those who wanted a still more thorough education. The courses have had more than 3000 participants from 51 countries the last 32 years

Harald A Øye is member of 7 Scientific Academies and was President of Norwegian Academy of Technological Science 1985 – 1992. He has received several honors, the most important are:

Knight First Class of the Royal Norwegian Order of St. Olav for Technological Research conferred by King Harald V of Norway, 1999.

The Research Council of Norway 1997 Prize for Outstanding Research.

The Gunnerus Medal from the Royal Norwegian Society of Science and Letters, 2004.

The Guldberg – Waage Medal from the Norwegian Chemical Society, 1998.

Honorary Professor of North-East University, Shenyang, China, 1996