Symposium Applied Noble Gas Physics (SYNG)

jointly organized by
the Mass Spectrometry Division (MS),
the Molecular Physics Division (MO), and
the Environmental Physics Division (UP)

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Overview of Invited Talks and Sessions

(Lecture room: C/gHS)

Invited Talks

SYNG 1.1	Thu	11:00–11:30	C/gHS	**Development of a new facility for measuring 81Kr and 85Kr at ultra-trace level in environmental samples.** — •Bernard Lavielle, Eric Gilabert, Bertrand Thomas, Romain Rebeix, Grégory Canchel, Christophe Moulin, Sylvain Topin, Fabien Pointurier
SYNG 1.2	Thu	11:30–12:00	C/gHS	**Atom counting system to measure trace krypton contamination in ultra-pure xenon** — •Andre Loose, Tanya Zelevinsky, Elena Aprile
SYNG 1.3	Thu	12:00–12:30	C/gHS	**Krypton-85 and Radioxenon: Environmental Tracers and Indicators for Nuclear Activities** — •Clemens Schlosser, Verena Heidmann, Martina Konrad, Sabine Schmid
SYNG 2.1	Thu	14:30–15:00	C/gHS	**Using Noble Gases to Understand the History of Terrestrial Volatiles** — •Don Porcelli
SYNG 2.2	Thu	15:00–15:30	C/gHS	**Noble gas analysis in water: from temperature reconstruction over excess formation to oxygen turnover on environmentally relevant time scales** — •Rolf Kipfer, Matthias Brennwald
SYNG 2.3	Thu	15:30–16:00	C/gHS	**Applications of Noble Gases in Oceanography** — •Peter Schlosser, Robert Newton, Gisela Winckler, Angelica Pasqualini

Sessions

SYNG 1.1–1.5	Thu	11:00–13:00	C/gHS	**Applied Noble Gas Physics Part 1**
SYNG 2.1–2.5	Thu	14:30–16:30	C/gHS	**Applied Noble Gas Physics Part 2**

SYNG 1: Applied Noble Gas Physics Part 1

Time: Thursday 11:00–13:00 Location: C/gHS

Invited Talk SYNG 1.1 Thu 11:00 C/gHS
Development of a new facility for measuring 81Kr and 85Kr at ultratrace level in environmental samples. — •Bernard Lavielle[1], Eric Gilabert[1], Bertrand Thomas[1], Romain Rebeix[1], Grégory Canchel[1], Christophe Moulin[2], Sylvain Topin[2], and Fabien Pointurier[2] — [1]CENBG, University of Bordeaux, BP 120, F-33175 Gradignan Cedex, France — [2]CEA-DASE, F-91297 Arpajon, France

Mainly produced on Earth by nuclear reactions induced by cosmic rays in the atmosphere, the radionuclide 81Kr (t1/2=229,000yr) is considered as the best tracer for absolute dating of old groundwaters or ice cores in the range of 50,000 yr to 1,000,000 yr. Kryton-85 (t1/2=10.76yr) is mainly released into the atmosphere by the reprocessing facilities for nuclear fuel. This isotope is of great interest as a tracer for nuclear activities but also for dating young groundwater (<50 yr). Several instruments and lines are being developed at CENBG in order to measure both 81Kr and 85Kr in groundwater using small volume of water (20 l). It includes: 1) a line for gas extraction from water, Kr separation and purification; 2) A double-focusing mass spectrometer operating a 81Kr and 85Kr enrichment process based on implantation of separated Kr isotope in Al foils; 3) An instrument based on RIS-TOF technique capable to perform Kr isotopic abundance measurements from samples containing only a few thousands of atoms. The extremely high sensitivity of this instrument also allows measurements of cosmogenic Kr at very low concentration to determine cosmic ray exposure of small meteorite samples.

Invited Talk SYNG 1.2 Thu 11:30 C/gHS
Atom counting system to measure trace krypton contamination in ultra-pure xenon — •Andre Loose, Tanya Zelevinsky, and Elena Aprile — Columbia University, 550 W 120th Street, New York, NY 10027, USA

The Atom Trap Trace Analysis (ATTA) Project at Columbia University is an experiment designed to measure the abundance of Kr in a Xe sample to the parts per trillion (ppt) level. Setting an upper limit on the amount of Kr-85 present in natural Xe is critical for knowing the sensitivity of dark matter searches based on LXe as target and detector medium. In particular, the ATTA will be an essential assaying tool for the XENON program. We completed the full ATTA setup and it's characterization for metastable Ar-40* in Ar and Kr-84* in Xe. The abundance of Kr-85 will then be inferred using previously measured relative isotopic abundances. We designed and tested custom pipettes to avoid air contamination of samples during the transport from the XENON1T detector to our ATTA setup. We verified the system calibration by comparing ATTA and rare gas spectrometer measurements for the same sample, and conducted first ATTA measurements of ultrapure Xe.

Invited Talk SYNG 1.3 Thu 12:00 C/gHS
Krypton-85 and Radioxenon: Environmental Tracers and Indicators for Nuclear Activities — •Clemens Schlosser, Verena Heidmann, Martina Konrad, and Sabine Schmid — Bundesamt für Strahlenschutz, Rosastraße 9, 79098 Freiburg

Already in the 1940s scientists recognized the usefulness of radioactive noble gases as for monitoring nuclear activities. Krypton-85 is a very good indicator for the reprocessing of nuclear fuel and Xe-133 can be used for the detection of clandestine nuclear weapon tests and nuclear reactor operation. Additionally, Kr-85 can be used as tracer in environmental sciences. The German Federal Office for Radiation Protection (BfS) operates a noble gas laboratory and a global network which continuously monitors the Kr-85 and Xe-133 activity concentrations in ground level air since the 1970s. The laboratory of the BfS and the techniques used will be presented. Currently, the mean activity concentrations at German sampling sites are approx. 1.5 Bq/m3 for Kr-85 and in the order of 1 mBq/m3 for Xe-133. Based on the long time series of the BfS the global atmospheric distribution and the influence of different sources on the atmospheric activity concentrations over the last decades are discussed. Since 2004, radioactive Xenonisotopes are continuously measured at Schauinsland by an automated system *SPALAX* as part of the International Monitoring System of the Comprehensive Nuclear-Test-Ban Treaty (CTBT). The network capacity of this global monitoring network is demonstrated on the basis of particular events, like the Fukushima nuclear power plant accident and the Nuclear Weapon Tests in North Korea.

SYNG 1.4 Thu 12:30 C/gHS
Miniature High Sensitive Time-of-Flight Noble gas Mass spectrometer for very low gas measurements — •Ramakrishna Ramisetty and Ingo Leya — University of Bern, Space Research and Planetary Sciences,Bern, Switzerland

Noble gas analysis in early solar system materials, which can provide valuable information about early solar system processes and timescales, are very challenging because of extremely low noble gas concentrations (ppt). We therefore developed a new, high sensitive, compact sized (33 cm length, 7.2cm diameter, 1.3 L internal volume) Time-of-Flight (TOF) noble gas mass spectrometer. The instrument uses electron impact ionization coupled to an ion trap, which allows us to ionize and measure all noble gas isotopes with high efficiency. Using a reflectron set-up we reach a mass resolution of >1000amu. In addition, the reflectron set-up also enables some extra focusing. The detection is via MCPs and the signals are processed either via ADC or TDC systems. The instrument can be tuned automatically and under normal operational conditions the electronics and valves are fully computer controlled Noble gas calibrations showed a detection limit in the range 10-14 cm3STP and about 7 orders of dynamic range.

SYNG 1.5 Thu 12:45 C/gHS
Studying the constancy of galactic cosmic rays using cosmogenic noble gases and radionuclides in iron meteorites — •Thomas Smith[1], Ingo Leya[1], Silke Merchel[2], Georg Rugel[2], Stefan Pavetich[2], Anton Wallner[3], Keith Fifield[3], Stephen Tims[3], and Gunter Korschinek[4] — [1]University of Bern, Switzerland — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]The Australian National University, Canberra, Australia. — [4]TU Munich, Germany.

Cosmogenic noble gases and radionuclides in meteorites are the only tools that provide information about the cosmic ray exposure (CRE) history of meteorites. In space, meteoroids are irradiated by galactic cosmic ray (GCR), which produces, among others, stable and radioactive cosmogenic nuclides. It has been demonstrated that periodic variations in the GCR intensity induce periodic peaks in the CRE age histograms. Therefore, searching for periodic peaks in CRE histograms enables one to obtain information about GCR fluency variations. Since expected GCR fluency variations have periodicities of a few hundred million years, one needs meteorites irradiated for at least that long. Iron meteorites, which have CRE ages ranging from a few million to a few billion years, are the best candidates. So far we measured noble gases and radionuclides in 28 iron meteorites by noble gas mass spectrometry and accelerator mass spectrometry. First CRE age histograms have been established and will be presented. Further analyses are ongoing and will improve the statistical interpretation, providing new information on the temporal variability of the GCR fluency.

SYNG 2: Applied Noble Gas Physics Part 2

Time: Thursday 14:30–16:30 Location: C/gHS

Invited Talk SYNG 2.1 Thu 14:30 C/gHS
Using Noble Gases to Understand the History of Terrestrial Volatiles — •Don Porcelli — Oxford University, Dept Earth Sciences, Oxford, UK

Noble gas isotopes provide essential information on the origin and distribution of terrestrial volatiles. The 3He/4He ratios measured in mantle-derived volcanics indicate that the noble gases initially incorporated into the Earth remains heterogeneously distributed, although it is not yet clear how this relates to mantle structure. Xe isotopes indicate that separate noble gas reservoirs were established during Earth formation, with variations that must have been created before complete decay of short-lived 129I and 244Pu. Further, Ne isotopes suggest that there have been several different solar system sources of noble gases. Also, Xe isotopes indicate that substantial quantities of noble gases were incorporated into the Earth and lost soon after. A number of key questions remain, as data are limited due to the subtle variations and low concentrations involved, and the presence of atmospheric contamination. More precise measurements of all noble gases, and with greater sensitivity, are essential to better identify how many sources of noble gases there have been; the extent of isotope variability within the Earth and so the history of early losses and subsequent reservoir isolation; the role of the core in storing noble gases; and the relationship between variations of the different noble gases and so the history of each separate reservoir. With such data, the history of terrestrial volatiles can be understood within the context of evolving theories of planetary accretion.

Invited Talk SYNG 2.2 Thu 15:00 C/gHS

Noble gas analysis in water: from temperature reconstruction over excess formation to oxygen turnover on environmentally relevant time scales — •Rolf Kipfer and Matthias Brennwald — Eawag, Swiss Federal Institute of Aquatic Science and Technology, 8600 Dübendorf, Switzerland

Noble gases (and other quasi-conservative transient trace gases) in aquatic systems have commonly been used to determine water residence times and to reconstruct past environmental and climatic conditions.

However, these analyses were hampered by the occurrence of a surplus of atmospheric gases in natural ground water, e.g. the presence of excess air (EA) which in former days was only considered as contamination.

Recent developments in understanding the physics of air (gas) / water partitioning in porous media as well as revisiting noble gas diffusion in water now allows EA formation to be understood in mechanistic terms and facilitates the robust interpretation of EA as a proxy for the hydraulic conditions during groundwater recharge.

Furthermore, portable membrane-inlet mass spectrometers enable continuous and real-time analysis of dissolved (noble) gases directly in the field, allowing, for instance, quantification of O2 turnover rates on time scales as small as minutes.

This presentation will touch some of these recent achievements with the intention of stimulating a broader discussion on the future applications of gases in conventional and unconventional aquatic systems.

Invited Talk SYNG 2.3 Thu 15:30 C/gHS

Applications of Noble Gases in Oceanography — •Peter Schlosser[1,2,3], Robert Newton[3], Gisela Winckler[3], and Angelica Pasqualini[2,3] — [1]Dept of Earth and environmental Sciences, Columbia Universiy — [2]Dept of Earth and Environmental Engineering, Columbia University — [3]Lamont-Doherty Earth Observatory, Columbia University

Over the past decades, methods for detection and routine measurement of noble gases and their isotopes at ultra-low levels have been developed. They enabled application of these trace substances to many problems of ocean circulation, dynamics, and air/sea exchange. In principle, noble gases are used in studies such as (1) radioactive clocks (Tritium/He-3; Ar-39), (2) natural or anthropogenic injections into specific water masses (He isotopes), and (3) global dyes (Kr-85 or the quasi noble gas sulfurhexafluoride). To illustrate these applications three oceanographic noble gas studies are presented and discussed. Determination of the major circulation pathways and man residence times of the waters in the Arctic Ocean (tritium/He-3; Ar-39): knowledge of the Arctic Ocean circulation pattern is needed to understand the implications of rapid Arctic Environmental Change. Large-scale mixing at mid-depth in the Pacific Ocean: the turbulent mixing coefficients derived from these studies are used to quantify redistribution of water and dissolved substances (He-3). Air/sea exchange, especially in the high-wind regimes of the Southern Ocean: air/sea gas exchange rates, together with measurements of the partial pressure of carbon dioxide, are applied to calculate the uptake of carbon by the oceans.

SYNG 2.4 Thu 16:00 C/gHS

Basal ice-shelf melting in the Weddell Sea inferred from oceanic noble-gas observations — •Oliver Huhn[1], Monika Rhein[1], and Michael Schröder[2] — [1]Institute of Environmental Physics, University of Bremen, Germany — [2]Alfred-Wegener-Institute, Bremerhaven, Germany

We use oceanic noble-gas observations from the Weddell Sea from the period 1990 to 2013 to infer basal ice-shelf melting and the spatial distribution and temporal variability of the melt water input into the ocean. Helium and neon data were used to compute the glacial melt water contributing to the formation of Antarctic Bottom Water, a substantial water mass in the global ocean and important driver of the Meridional Overturning Circulation.

Oceanic measurement of low-solubility and stable noble-gases helium and neon provide a useful tool to quantify glacial melt water. Atmospheric air with a constant composition of these noble gases is trapped in the ice matrix during formation of the meteoric ice. Due to the enhanced hydrostatic pressure at the base of the floating ice, these gases are completely dissolved, when the ice is melting from below. This leads to an substantial excess of helium and neon in pure glacial melt water.

We find an increasing trend in helium, neon, and, hence, in the glacial melt water content in the deep Weddell Sea. Melt water fractions along a repeated section in the north-western Weddell Sea are almost doubling from 1990 to 2013, indicating increasing melting in the Weddell Sea.

SYNG 2.5 Thu 16:15 C/gHS

Environmental Tracer and helium measurements in the context of Coal Seam Gas exploration. — •Axel Suckow and Stanley D. Smith — CSIRO Land and Water Flagship, Gate 5, Waite Road, Urrbrae, SA 5064, Australia

The Surat Basin in Northeast Queensland, Australia is subject to massive exploration and development for coal-seam gas extraction. To extract the gases, reduction of hydrostatic pressure in the Walloon Coal Measures by up to 70bar is necessary. The impact of this groundwater de-pressurization on adjacent aquifers is unknown. Also the flow regime of the underlying Hutton Sandstone and Precipice Sandstone aquifers is not well understood. Environmental tracers (SF_6, CFCs, tritium, helium, $^{87}Sr/^{86}Sr$, ^{14}C, ^{36}Cl) were measured along two north-south transects in the Hutton Sandstone aquifer. Also helium pore water profiles were obtained in vertical profiles through two aquitards isolating the Walloon Coal measures from the underlying Hutton Sandstone and this from the underlying Precipice Sandstone. Results indicate that groundwater in the Hutton has very low flow velocities and ^{36}Cl decreases to background values along a flow distance of less than 150km. Vertical profiles of terrigenic helium through the aquitard formations indicate very low vertical flow in these formations and the aquifer system seems to be dominated by diffusion processes. However, it remains an open question to what extent the $^{36}Cl/Cl$ decrease can be attributed to aging or is dominated by diffusive inflow of dead Cl from adjacent aquitards. To further elucidate this flow system, samples for ^{81}Kr are planned along these transects.