# Summary of the research programme related to radionuclide metrology for the years 2002 and 2003 at the "Institut für Isotopenforschung und Kernphysik" (IIK) of the University of Vienna, Austria

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http://www.univie.ac.at/Kernphysik/irk_engl.htm

The activities at the IIK concentrate on the improvement and development of atomic and nuclear measuring techniques and data handling procedures for interdisciplinary applied physics work with special emphasis on the detection of long-lived radionuclides, particularly in the very-low-level range. Nuclear-decay-counting techniques have been widely replaced by mass-spectrometric techniques with high selectivity and high sensitivity. Updated and more detailed information about research at IIK during the last four years is also be provided via the institute's internet home page given above.

Names: R. Andrejic, M. Berger, R. Drosg, H. Friedmann, H. Figl, E. Friedl, R. Golser, P. Hille, J. Kühtreiber, W. Kutschera (director), J. Lukas, E. Pak, A. Pavlik, A. Priller, R. Schön, J. Schwarzenberg, P. Steier, B. Strohmaier, S. Tagesen, Ch. Vockenhuber, H. Vonach, E. Wild, G. Winkler, St. Winkler, P. Zimprich

## 1. The *tandem-accelerator mass-spectrometry facility VERA (Vienna Environmental Research Accelerator)* and its use

Accelerator mass spectrometry (AMS) is a major field of research at the IIK. With AMS the radionuclides are measured by direct atom counting; selectivity is achieved employing energy-, momentum- and velocity-selecting devices (electrostatic, magnetic and time-of-flight or Wien filters) and using ion detectors for counting and final energy measurement. The interesting nuclides (with extremely small radioisotope-to-stable-isotope ratios in the $10^{-10}$ to $10^{-15}$ range) cannot be measured at natural levels through radioactive-decay counting, particularly for small samples in the milligram range, typically containing only $10^5$ to $10^8$ radionuclide atoms. Predominantly isotope ratios are measured relative to appropriate standards. The VERA facility is based on a 3-MV Pelletron tandem accelerator (from National Electrostatics Corporation in Wisconsin, USA). For details on the experimental equipment see http://www.univie.ac.at/Kernphysik/VERA/welcome.htm . Recently, the rejection of interfering ions was improved by installing a large electrostatic analyser for precision energy measurements at the high-energy side of the tandem, after the analysing magnet. Further, interfering ions which pass all beam filters are discriminated by a high-resolution time-of-flight system, using a 0.5 $\mu g/cm^2$ diamond-like carbon foil in the start detector substantially reducing beam straggling.

Through the recent upgrades of VERA it has been possible to measure ions from very heavy long-lived radionuclides such as $^{129}I$ ($T_{1/2} \approx 1.6\times10^7$ a) [$^{129}I/^{127}I$ ratios], $^{210}Pb$ ($T_{1/2} \approx 22$ a), $^{236}U$ ($T_{1/2} \approx 23\times10^6$ a), $^{244}Pu$ ($T_{1/2} \approx 81\times10^6$ a), $^{242}Pu$ ($T_{1/2} \approx 3.8\times10^5$ a) and $^{182}Hf$ [$T_{1/2} \approx (9\pm2)\times10^6$ a] in natural samples.

In co-operation with GSI Darmstadt, University of Mainz, and Kurchatov Institute Moscow, ion detection with a *calorimetric cryodetector* (sapphire crystal whose temperature rise is measured at the superconducting transition edge of an aluminium strip at about 1.5 K) was studied at the flight path for discrimination and energy spectroscopy of heavy ions showing improvement of the energy resolution up to two orders of magnitude better than with a surface-barrier detector.

2. <u>AMS measurements combined with decay counting</u>

a) Study of the *stratosphere-troposphere exchange (STE) via* $^{10}Be/\,^{7}Be$ *isotope ratios:* Stratosphere-troposphere exchange is one of the key factors controlling the budgets of ozone, water vapour and other substances in the troposphere and lower stratosphere. The two cosmogenic isotopes of Be, $^{10}$Be (measured by AMS) and $^{7}$Be (measured by decay counting), have very different half-lives; the combination of production rates, half-lives, and different residence times in the troposphere and stratosphere, results in $^{10}$B/ $^{7}$Be isotope ratios that can be used as fingerprints leading to improved estimates of STE. Air-filter samples collected at high-alpine stations are employed.

b) *Be- and Al-isotope ratios* ($^{26}Al$) in sediments for dating in geology

c) Effort to *reduce the large uncertainty* of the knowledge of the *half-life* of the neutron-rich isotope $^{182}Hf$ [$T_{1/2} \approx (9\pm2)\times10^{6}$ a, measured 40 years ago].
The system $^{182}$Hf - $^{182}$W forms a geochronometer, which offers an excellent way to determine the time-scale for the early Solar System's accretion and the core formation of the planets. It can be used to study the early development of the Earth and the Moon through isotopic anomalies of its stable decay product $^{182}$W. $^{182}$Hf may also complement a few other radionuclides in the million-year half-life range to trace relatively recent stellar events with high neutron fluxes like nearby supernovas (inducing, e.g., $^{182}$Hf from the double neutron capture in $^{180}$Hf), e.g., by finding measurable traces of live $^{182}$Hf in suitable terrestrial archives.

3. <u>Conventional radionuclide instrumentation and evaluation</u>

*4π NaI(Tl) gamma well-type* detector (12.7 x 12.7 cm) with software to calculate total efficiencies and check the consistency of chosen decay schemes; shielded high-purity *Ge detector*; *3"x 3" NaI(Tl)* detectors; *Si(Li) x-ray* detector; sealed thin-window *Xe proportional* counter tube; *surface-barrier* detectors; *4π-beta-ray* counter; *2π-beta-ray* counter with anticoincidence shielding counter; two *methane proportional counters with screening counters* for dating using the *conventional* $^{14}C$ *method*; various types of *ionisation chambers* operated in current mode and a solid state detection system for measurements of *radon and thoron and their daughters*, an *electrete* measuring device for the same purpose; the universal *spectra-analysis program* "IRUK" [developed by H. Friedmann] for use on PCs (including peak search and macro programming).

4. Other projects

a) *Program to evaluate and check the reliability of the half-life values of some long-lived radionuclides("How well do we know our clocks")*
relevant to archaeochronology, geochronology and cosmochronology
[compare, e.g., F. Begemann et al., Call for an improved set of decay constants for geochronological use, Geochim. Cosmochim. Acta 65 (2001) 111-121].
In addition, the basic question of the change of half-lives due to stellar environments or other extreme environmental conditions will also be discussed.

b) *Re-evaluation* of experimental data for the *half-lives of the uranium isotopes* $^{235}U$ *and* $^{238}U$ [R. Schön, G. Winkler, W. Kutschera]

c) *Austrian National Radon Project (ÖNRAP)* [H. Friedmann]:
The Austrian Radon Project (ARP) started in 1992 and ended in 2002. The aim of the project was to determine the radon exposure of the population in Austria and to classify areas according to their potential radon risk from the ground. The observed radon concentration does not always reflect the radon risk from the ground because of different dwelling situations, house types, maintenance, and living conditions. Therefore, the ARP had two goals: firstly finding areas with houses of enhanced indoor radon concentrations for future radon mitigations and secondly defining areas with elevated radon risk where radon-safe construction is necessary for new houses. The project was carried out by systematic indoor measurements in randomly selected houses using different types of detectors. A radon potential was derived from the results of these measurements and the information received from additional questionnaires. This radon potential was defined as an expected radon concentration in a standard situation and shall characterise the radon risk from the ground without the influence of different living situations. Expected lung-cancer mortalities were computed on basis of ICRP 65 estimates from mean radon exposure on county level and the results compared with actual lung-cancer mortality. [Final results to be published in 2003].
See also http://www.univie.ac.at/Kernphysik/oenrap/welcome.htm ;
english version: http://www.univie.ac.at/Kernphysik/oenrap/oenrap_e.htm
and list of publication given there, and
H. Friedmann: Radon in Austria, Proc. 5th Conf. on High Levels of Natural Radiation and Radon Areas, Munich, 4-7 Sep. 2000, Vol. II, BfS- Schriften 24/2002, ISSN-0937-4469, ISBN 3-89701-808-X, Salzgitter 2002.];
also available: "Radon information CD" (H. Friedmann).

d) *Conventional radiocarbon dating* (up to about 40000 years B.P.):
Interdisciplinary co-operation is continued.

5. Work and co-operation on special reports and standard concepts, training tasks

Co-operation with the *Austrian Standards Institute* (OENORM) to achieve a uniform interpretation of low-level measurements and to harmonise measurement-uncertainty statements in radiation protection is continued:

a) ÖNORM S 5250-2: *"Counting statistics in radioactivity measurements - Spectroscopic measurements"* defines the requirements for the treatment of uncertainties in spectroscopic measurements, especially for low-level high-resolution spectroscopy. The decision limit and the lower limit of detection is introduced, procedures for single-peak evaluation and for the evaluation of several peaks produced by a specific radioisotope are treated. Criteria for deciding whether a measured quantity is below or above a (e.g. legally) set value are given. The practical handling of the given rules is demonstrated by examples. The program is to be extended to the certification of drinking water.

b) OENORM S5280-1 and OENORM S5280-2: *"Radon-measurement methods and their range of applications"* and *"Civil engineering precautionary measures in the case of buildings"* (Austrian Standard for indoor radon measurements and for a certification of dwellings).

Students' training in the field of general experimental physics, quantum physics, atomic physics, nuclear physics, ion physics and radioactivity measurements is taken care of by the staff of the IIK.

6. Participation in international organisations

- International Committee for Radionuclide Metrology (ICRM) [G. Winkler];
- Consultative Committee for Ionising Radiation (CCRI), Section II (Measurement of Radionuclides) at the BIPM, Sèvres, France [member: G. Winkler];
- Science and Technology Committee, EURATOM [delegate P. Hille]

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