# Summary of the research programme related to radionuclide metrology for the years 2000 and 2001 at the "Institut für Isotopenforschung und Kernphysik" (IIK) of the University of Vienna, Austria

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The historical name of the institute was changed from *Institut für Radiumforschung und Kernphysik* (IRK) to *Institut für Isotopenforschung und Kernphysik* (IIK*).*
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.

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## 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/Wien filters) and using common ion detectors for counting and final energy measurement. The VERA facility is based on a 3-million-volt Pelletron tandem accelerator from National Electrostatics Corporation in Wisconsin, USA. Details on the experimental equipment can be found at http://www.univie.ac.at/Kernphysik/VERA/vera2.htm .
The bending power of the magnetic elements of VERA were chosen such as to transport even the heaviest long-lived radionuclide of interest ($^{244}Pu^{5+}$ ions). Presently the AMS technique is applied to measurements of $^{14}C$, $^{10}Be$ ($T_{1/2}$=1.6×10$^{6}$ a), $^{26}Al$ ($T_{1/2}$=7.2×10$^{5}$ a), $^{129}I$ ($T_{1/2}$= 1.6×10$^{7}$ a) with extremely small radioisotope-to-stable-isotope ratios in the $10^{-10}$ to $10^{-15}$ range. The interesting nuclides 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). A large electrostatic analyser was recently installed for precision energy measurements at the high-energy side of the tandem, after the analysing magnetic, to extend the system's capabilities. For $^{10}Be$, which is accompanied by a strong isobaric background of stable $^{10}B$, the different range of the two isobars in matter can be utilised for their separation: $^{10}B$ is completely stopped in a gas absorber (homogeneous!) in front of a Si detector, while the longer range of $^{10}Be$ allows its detection. The measurement of $^{129}I/^{127}I$ ratios required an additional time-of-flight discrimination when a Wien filter was used.

New efforts concentrate on developing techniques for determining the concentration of actinides, such as uranium (e.g., $^{236}U$) and plutonium isotopes.

The Proceedings of the *8$^{th}$ International Conference on Accelerator Mass Spectrometry AMS-8*,which was organised by the IIK in Palais Auersperg, Vienna, Austria, 6-10 September 1999, have been published as a special issue of Nuclear Instruments and Methods B 172 (2000). It contains several contributions from the IIK.

2. Conventional radionuclide instrumentation and evaluation:

*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; the universal *spectra-analysis program* "IRUK" [developed by H. Friedmann] for use on PCs (including peak search and macro programming); *PC-based multiscaler* (to study decay curves, frequency-of-events distributions, pulse correlations); *programmable precision counter modules.*

3. Other projects:

*Atom Trap Trace Analysis (ATTA):*

For environmental research it would be profitable to introduce as a second leg a technique to measure long-lived radioisotopes of the rare gases, which are inaccessible by tandem-accelerator AMS because they do not form negative ions. *ATTA*, a new method of ultrasensitive trace-isotope analysis, has recently been demonstrated by a group at the Physics Division of Argonne National Laboratory to work for this purpose [C. Y. Chen et al., Science **286**, 1139-1141 (1999)]. This method is based on the techniques of laser cooling of neutral atoms with a Zeeman slower, following trapping in a magneto-optical trap (MOT), and counting individual trapped atoms by laser-spectroscopy techniques. The technique has been used to count individual $^{81}$Kr and $^{85}$Kr atoms present in an atmospheric krypton sample with isotopic abundance at the parts-per-trillion level. Counting $^{81}$Kr (half-life $2.3 \times 10^5$ years) will, e.g., help determine the ages of ancient ice and groundwater samples. Counting $^{85}$Kr (half-life 10.8 years), a fission-produced isotope, can serve as a means to verify compliance with nuclear non-proliferation treaties. On the occasion of a research stay for several months, a member of IIK [G. Winkler] could explore the new technique, which looks very promising.

*Austrian National Radon Project* (ÖNRAP) [H. Friedmann]:

The project aiming at a country-wide survey on radon concentrations in buildings and the radon-dose distribution in Austria is completed. Predominantly three measurement methods were used: charcoal sampling with LSC measurements (Picorad) for short-term exposures (3 days), track-etch (system Karlsruhe) and electrete detectors (E-Perm) for long-term (3 months) exposures.

Measurement of $^{226}$*Ra and* $^{222}$*Rn* concentrations in *spring waters* in Austria (by means of ionisation chambers) is continued routinely.

Interdisciplinary co-operation based on *conventional radiocarbon dating* up to about 40000 years B.P. is continued.

4. Work 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 radio-isotope are treated. Criteria for deciding whether a measured quantity is below or above a (e.g. legally) set value are given. Part 3 of the above standard, i.e. ÖNORM S 5250-3, will demonstrate the practical handling of the given rules by examples.

b) OENORM S5280-1: *Radon-measurement methods and their range of applications*: first part of an Austrian Standard for indoor radon measurements (for a certification of dwellings) has been prepared.

c) ÖNORM S 5255: *Uncertainties* of measurements and given *limits in radiation protection, principles and examples*: deals with input and influence quantities, the evaluation of standard uncertainties and the combination of the various uncertainties including correction factors to obtain a combined uncertainty in the case of calibrated and verified instruments. Finally problems are addressed, which arise when measured values with their uncertainties are compared with (e.g. legally) set limiting values.

A review article on "High-efficiency NaI(Tl) detection systems for accurate activity measurements" (suggested by CCRI, Section II) is to be finalised [G. Winkler].

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.

5. Participation in international organisations:

- International Committee for Radionuclide Metrology (ICRM) [G. Winkler, past president];
- Consultative Committee for Ionising Radiation (CCRI), Section II (Measurement of Radionuclides) at the BIPM, Sèvres [member G. Winkler];
- Science and Technology Committee, EURATOM [delegate P. Hille];
- Various scientific advisory boards (e.g., the Advisory Board of Radiochimica Acta and the Advisory Committee for Education in Science of the Internat. Research School on Fundamental and Applied Nuclear and Atomic Physics (FANTOM) [W. Kutschera].

March 2001 Gerhard Winkler