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CINCH-II

(Project Number: 605173)




DELIVERABLE D3.4

**Six nuclear chemistry remote controlled experiments ready
for use**

Lead Beneficiary: **IRS**

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For the Lead Beneficiary	Reviewed by Workpackage Leader	Approved by Coordinator	
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Jan John

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Dissemination Level		
PU	Public	

Version control table

Version number	Date of issue	Author(s)	Brief description of changes made
1.0	07/12/2015	Claudia Fournier	First version
1.1	13/01/2016	Jon Petter Omtvedt	Added Oslo RoboLab parts
1.2	14/01/2016	Jon Petter Omtvedt	All track changes removed and some more text for the UiO RoboLabs added
1.3	15/01/2016	Jon Petter Omtvedt	Added description of ^{234m}Pa system
1.4	15/01/2016	M. Stilijanova	MST check

Relevance

This deliverable contributes to the following Work-Packages and Tasks:

<input type="checkbox"/> ALL
WP 1
<input type="checkbox"/> Task 1.1 <input type="checkbox"/> Task 1.2 <input type="checkbox"/> Task 1.3 <input type="checkbox"/> Task 1.4
WP 2
<input type="checkbox"/> Task 2.1 <input type="checkbox"/> Task 2.2 <input type="checkbox"/> Task 2.3 <input type="checkbox"/> Task 2.4
WP 3
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WP 4
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WP 5
<input type="checkbox"/> Task 5.1 <input type="checkbox"/> Task 5.2 <input type="checkbox"/> Task 5.3 <input type="checkbox"/> Task 5.4

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EXECUTIVE SUMMARY

Using modern computer controlled hardware, remote operation of an experiment in a real radiochemical laboratory was demonstrated in a pilot project "RoboLab" ran at the University of Oslo in 2006-2009. Even though such remote operated exercises will never substitute real hands on training, it is a nice addition to traditional training with a particular value to institutions without laboratories classified for radioactive work, or laboratories with very limited equipment and radioactive sources.

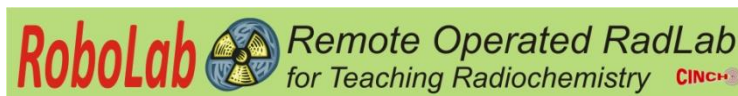
Two sites were established, at IRS and UiO, where five RoboLab remote controlled exercises were developed and are now (December 2015) in operation. A sixth exercise, at UiO, is under development and expected to be operational in April 2016.

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1 THE ROBOLAB CONCEPT

Using modern computer controlled hardware, remote operation of an experiment in a real radiochemical



laboratory is possible, even on a limited budget. This was demonstrated in a pilot project ran at the University of Oslo, where two such "RoboLab" remote controlled exercises were implemented and used in their basic nuclear chemistry course in 2006-2009.

Such remote operated exercises can be used as preparation training before entering a real lab, or as a stand-alone exercise. Such exercises will never be a substitute for real hands-on training, but it is a useful addition to traditional training. It will be of particular value to institutions without laboratories classified for radioactive work, or just laboratories with very limited equipment and radioactive sources, as the learners can nevertheless do some practical work.

Two sites have been established (at IRS and UiO), which provide remote access to a total of six remote controlled exercises, based on the UiO RoboLab concept.

At the IRS site three experiments have been built:

- HPGe gamma-spectrometry
- Autodeposition on different metals
- An Ion exchange column with "on-line" detection

At the UiO site, in Norway, the two original experiments have been totally rewritten and expanded to take advantage of today's more advanced software and hardware. The physical location was also moved to a new location with more space, enabling the exercises to operate independently of each other (previously they shared hardware and could thus only be operated one at a time). The two exercises are:

- Absorption of radiation in matter
- Neutron-activation of silver

Furthermore, a new and much more sophisticated experiment has been developed in Oslo. This experiment will use a cation exchanger to separate ^{234}Th from uranium, retaining the thorium. Protactinium can then be eluted from the column, providing a 1.2 minute radionuclide. This experiment will both illustrate the concept of a radionuclide generator and provide the opportunity to measure a decay curve for a short-lived radionuclide. The experimental conditions and necessary parameters for construction of the system have been determined and the necessary equipment purchased, but the complete system has yet to be constructed. It is expected to be available for use in April 2016.

In chapter 2 & 3 the respective exercises from IRS and UiO are described in detail.

1.1 RoboLab and NucWik

NucWik is a wiki developed as part of the CINCH project to share and distribute material for Nuclear and Radiochemistry teaching (see Deliverable 3.1 of the CINCH-II project). This wiki is also used for distributing the RoboLab exercises described in this Deliverable. The NucWik RoboLab introduction page is copied on the next page.

NucWik Nuclear and Radiochemistry Teaching Material Wiki CINCH

Wiki Home Projects Recent Changes Pages and Files Members Search

NucWik Main Pages:

- Laboratory Exercises
- Calculation Exercises
- RoboLab Exercises
- CSE Exercises
- Simulations
- NRC EuroMaster

Find Topics:

- NucWik Tag list
- NucWik NRC Textbook

Useful External Links:

- Nuclear Chart (IAEA)
- Links to external tools
- NRC Courses
- The CINCH Project
- The Living NRC Textbook

RoboLab Exercises

What is RoboLab?

RoboLab is remote-controlled exercises in a real radiochemistry laboratory. It allows you to perform radiochemistry experiments with real equipment in an actual laboratory without all the hassle of being trained, authorized and suited up. It's main purpose is to be used as a complementary teaching tool when teaching radiochemistry to undergraduate and graduate students at university level. This NucWik page explains teachers how to use it.

Available Exercises (per December 2015)

- RL1: [Absorption of radiation in matter](#) (UiO, online)
- RL2: [RoboLab Exercise: n-activation of Ag](#) (UiO, online)
- RL3: [HPGe \$\gamma\$ -spectroscopy of environmental samples](#) (IRS, online)
- RL4: [Autodeposition on different metals](#) (IRS, online)
- RL5: [Ion exchange column with "on-line" detection](#) (IRS, online)
- RL6: Milking 234mPa from 234Th adsorbed on DOWEX column (UiO, under development)

About the RoboLab Project

RoboLab exercises is currently being developed in a joint EU-project (CINCH-II) at Institute for Radiation Protection and Radioecology (IRS) at the Leibniz University of Hanover and at the Nuclear Chemistry Section at Department of Chemistry, University of Oslo (UiO). The original concept was developed at UiO in 2004-2007.

How do I run RoboLab?

RoboLab runs in your normal web-browser, but you need to install a plug-in from National Instrument:

- <http://www.ni.com/download/labview-run-time-engine-2014-sp1/5199/en/> (LabView version 2014 SP1)

When the right plug-in is installed you can access RoboLab exercises from the links above (under the Available Exercises heading). You should immediately see the message and after a short download the virtual application should load and execute. You then need to grab control (right click on the instrument panel) and click on the "Request Control of the VI" menu item. Once in control you can start the application (click the white arrow) and log in (see section about Scheduling and Access Control below). Remember to stop the application when you are finished.

A rough video explaining the basics was quickly put together, [download it here](#) (old and slightly outdated, but it shows you the basics).

Scheduling and Access Control

As RoboLab runs on a physical system in a real lab, only one student/person can use it at any one time. Thus, it will be "war" if several persons tries to use it simultaneously. For this reason you should not run any RoboLab exercise without having been appointed a "time slot". You will then also get a username and password for login on to the system. Without the username you will not be able to start the system.

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TES: The largest network of teachers in the world

Screenshot of the RoboLab welcome page at found at the NucWik site:

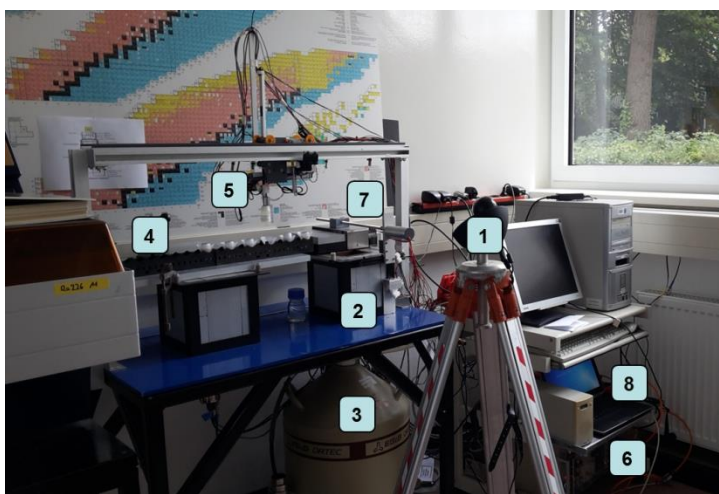
<http://nucwik.wikispaces.com/>

2 ROBOLAB EXERCISES DEVELOPED AT IRS

2.1 GammaLab

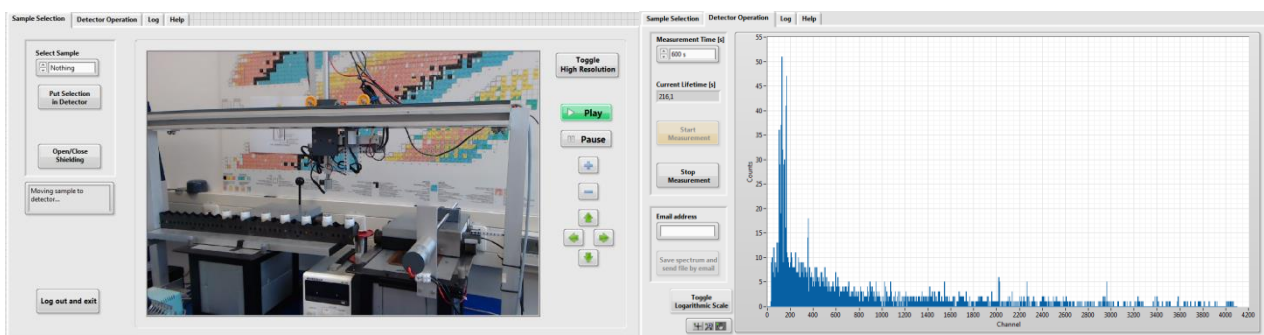
The GammaLab remote controlled experiment is focused on teaching gamma spectrometry with focus on environmental samples, and on showing the importance of characteristic limits in the evaluation of a gamma spectrum.

The experimental setup is developed using Lego Mindstorm NXT motors, which makes it possible to position by remote control different samples in a freely selectable sequence on a germanium detector. The user also has the possibility close a shielding which is located over the germanium detector, in order to decrease the background (this is very useful when measuring samples with low radioactivity).



1. webcam for video-feed
2. germanium detector
3. liquid nitrogen coolant
4. rack with radioactive samples containing different activities
5. remote controlled sample changer
6. data acquisition system
7. lead shielding of the detector
8. computer for data transfer

The user controls the setup through an interface that allows him to move the samples, to start the measurements and to retrieve the measurement results (by sending a mail).



Front panel of the remote controlled gammaspectrometry experiment

This RoboLab experiment can be used for several teaching goals:

- Demonstration on gamma spectroscopy.
- A list of unattributed samples is given, and the task would be to find out which samples is which.

- Understanding when and why the knowledge of the characteristic limits is important and how it determines.

Depending on the teaching goal of the experiment, a more or less detailed explanation of the physical process behind gamma spectrometry is provided.

There are several available samples, which can be measured:

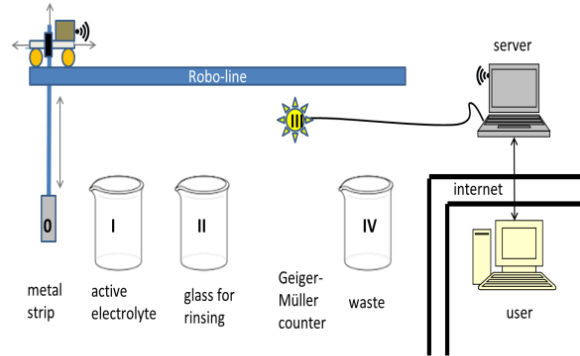
- a depleted U-fuel pellet which contains nuclides of the U-238 and U-235 decay chains
- uranium glass beads
- monazite sand, which contains mostly the radionuclides of the Th-232 decay chain
- contaminated soil from an IAEA collaborative study (Ra-226 contamination)
- phosphogypsum from an IAEA collaborative study, which has an increased content of natural radionuclides
- two U-232 solutions of different filling height
- two pitchblende solutions of different filling heights, with radionuclides of the U-238 and U-235 decay series
- a sample taken from the gate of the Fukushima Daiichi nuclear reactor after the accident
- an environmental water sample

This experiment can be accessed under

<http://cinch.irs.uni-hannover.de/gammalab.html>

2.2 AutodepositionLab

With this experiment the user is able to control over the internet an autodeposition experiment as if he would be in the laboratory. Autodeposition means the deposition of an electrolyte on a metal surface alone because of its electromotive force. In the figure the real experiment is presented, side by side with a diagram.

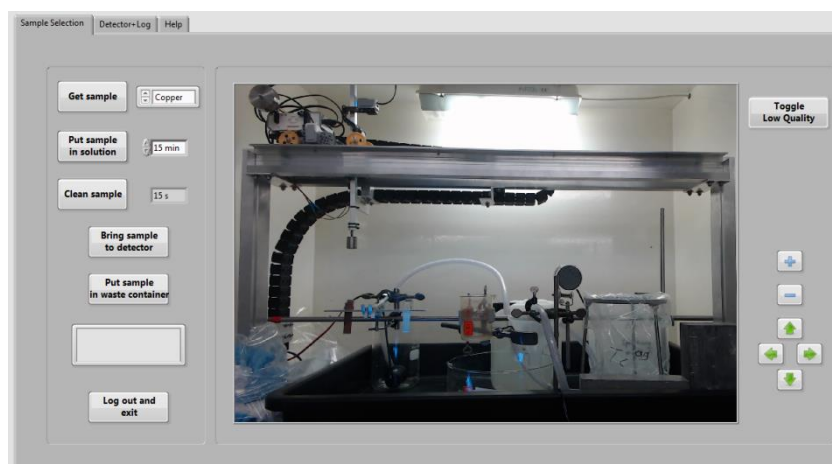


The setup is similar to the one of GammaLab, the robotic arm being also built with Lego Mindstorm NXT. The remote controlled arm makes it possible to move a metallic strip to different stations:

- a sample selection station, where the user can select the desired metallic strip
- a glass which contains an active electrolyte
- a pump, to rinse the metallic strip
- a Geiger-Müller counter
- a waste bag

The teaching goal of the experiment is the demonstration of the potential of electrochemical deposition techniques for the measurement of radionuclides.

After doing a blank measurement with a Geiger-Müller counter of a steel strip, the user has to immerse the strip in an ammonium-pertechnetate solution in water $\text{NH}_4^{99}\text{TcO}_4$. After the process of autodeposition takes place, the strip has to be cleaned by rinsing it with water (to ensure that the solution is not sticking to it anymore). A new measurement of the strip will show that some radioactivity has deposited on it. After finishing the experiment, the strip can be disposed of in the waste container. The previous steps can be repeated using a more noble metal (for example copper); on this strip no radioactivity will be deposited.



Front panel of the remote controlled autodeposition experiment

This experiment can be accessed under

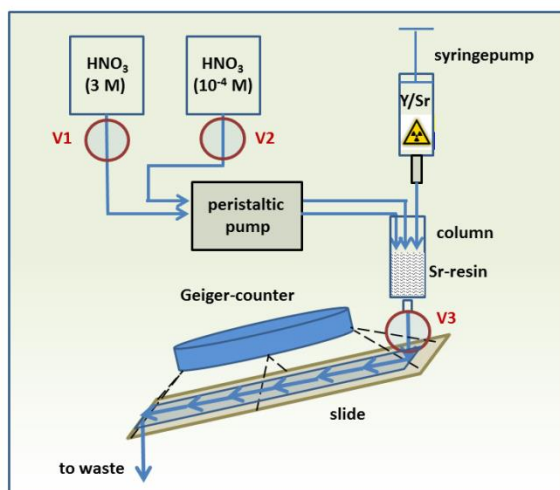
<http://paula.zsr.uni-hannover.de/AutodepositionLab.html>

2.3 Ionlab

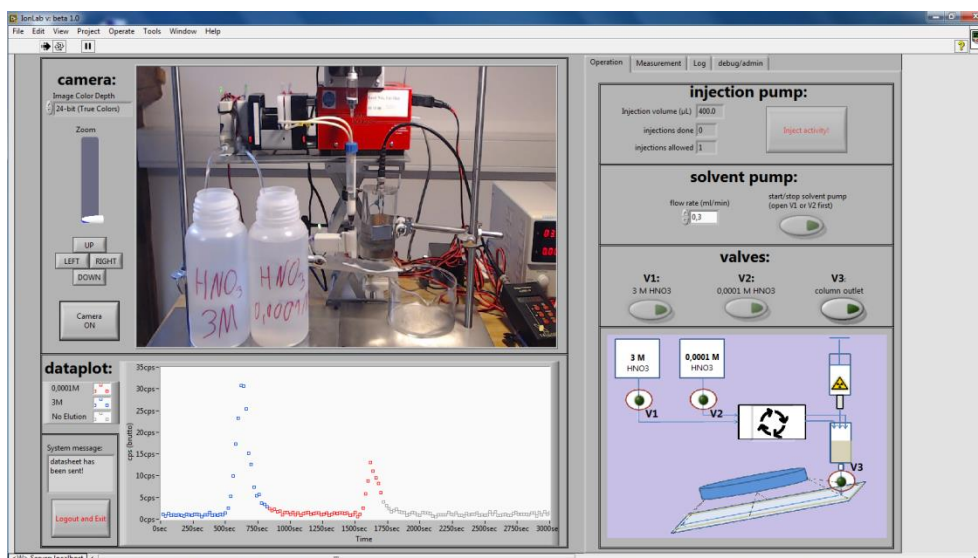
This remote controlled experiment shows the chemical separation of radionuclides. The goal of this experiment is to give students the possibility to conduct from their computer an ion-exchanger experiment (which is located at the IRS) in real time by controlling the equipment. A video camera gives the student the possibility to observe the experiment in real time, and through a front panel he also has control of the equipment through the internet. The equipment is already set up, but students are responsible for operating the equipment, retrieving data, and interpreting the results. IonLab gives the possibility to perform a nuclide separation, and to record a column chromatography, with the help of a Geiger-Müller-counter.

The setup consists out of

- a syringe pump, which injects activity onto a column
- a peristaltic pump, which helps to bring two different eluents to the column
- two containers, one with 3M HNO_3 and one with 0.0001M HNO_3
- a Geiger-Müller counter
- a slide, which slows down the liquid drop, so it stays longer under the detector and the measurement lasts longer
- a waste container



The interface is divided in three parts: a camera feed (the student sees in real time what is happening), a chromatogram and an area through which the user can interact with the experiment.



Front panel of the remote controlled ion exchanger experiment

The first action that the student has to undertake is to condition the column for approximately five minutes. The counting rate can be set in the tab 'measurement', by introducing the desired time interval in the field 'measurement time' (the optimal choice for the measurement interval is 20s). By default is the measurement time 30 minutes; this value can be modified by the user (for example for background assessment). After the column is sufficiently conditioned, the actual separation experiment can begin: the radioactive solution can be injected using the peristaltic pump by pressing 'Inject activity' in the field 'Injection'. The animated experimental scheme in the lower right corner, as well as the camera window of the injection process, can be used to follow the status of the experiment. After completion of the injection the student has to wait a few seconds, for the applied volume to distribute uniformly at the upper end of the separation column. In the field 'solvent pump' the desired elution rate for the experiment can be chosen and the elution can start. At this moment also the Geiger-Muller-counter measurement should start. After several minutes, a clear signal will be drawn in the chromatogram. After this signal drops significantly, the user should change the eluent. After a while a second peak will start to form in the chromatogram. When also this second peak fades, the experiment is finished.

This experiment can be accessed under

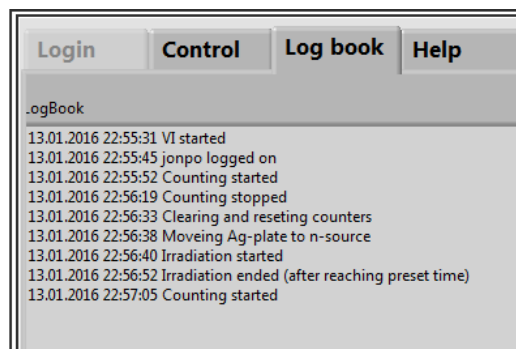
<http://ionlab.zsr.uni-hannover.de/ionlab.html>

3 ROBOLAB EXERCISES DEVELOPED AT UIO

The RoboLab concept for making remote controlled exercises in a physical laboratory was originally developed in 2006-2009¹ by Jon Petter Omtvedt (UiO). As part of the FP7 CINCH-II project this concept was developed further and expanded as a collaboration between IRS and UiO. The RoboLab group in Oslo consisted of: Jon Petter Omtvedt (group leader and also WP3 leader), Hans V. Lerum (responsible for NucWik and RoboLab testing), Terje Grønås (electronic engineer and LabView programmer), Johannes Ø. Matsdal (development of the radionuclide generator exercise).

Before work on the individual exercises was started, a RoboLab "template" program was developed to avoid duplicate software development and to provide the exercises with a uniform look and operational concept. The template use the LabView "Message Handler" main structure that provides a robust software environment where multiple sections of code can run in parallel and interchange data in a secure way. In this way watchdog loops taking care of e.g. safety, counting tasks or supervision of hardware in operation will safely execute in parallel with user initiated tasks. The reader is kindly referred to the LabView manuals and examples provided on the National Instruments (<http://ni.com>) web pages for further information about the Message Handler structure.

The template includes complete video handling functionality, as this is common for all exercises regardless of topic. The Graphical User Interface (GUI) presenting the LabView Virtual Instrument (VI) to the user can be seen in the screenshots from the software developed for the various exercises in the following sub-chapters. In addition to the video handling all programs have a logbook, accessible from the "Log" tab. Here the program will automatically log all commands the user has issued to the system and results from the system itself (e.g. number of counts measured when a preset time is reached). This provides the user with an accurate and useful record of the experiment.



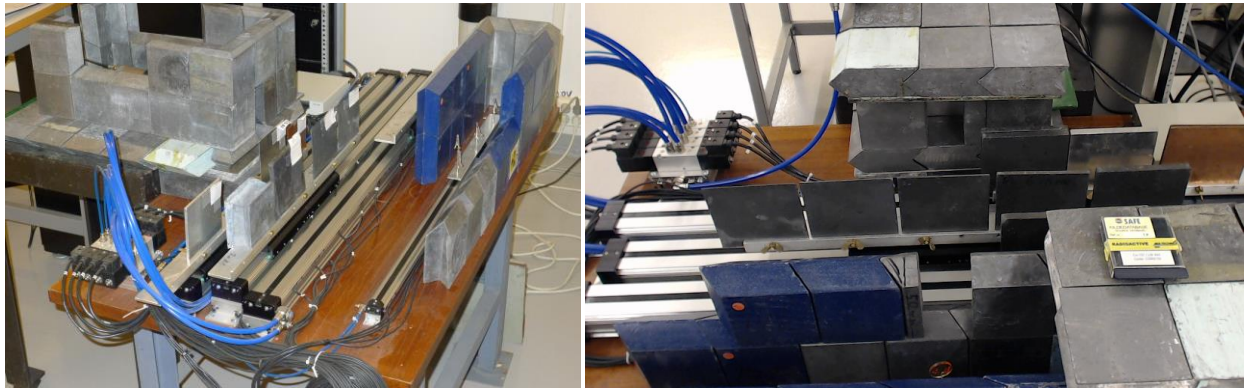
Example of logbook automatically maintained by the RoboLab software.

3.1 Absorption of γ Radiation in Matter Exercise

This exercise allows the student to measure the attenuation of gamma radiation by lead, copper and aluminum absorbers of various thicknesses. The intended learning outcome of this exercise are to learn about absorption of gamma radiation in matter and how to calculate the corresponding absorption coefficient.

The absorbers, which are made of blocks/sheets that measure 10 cm by 10 cm, are mounted on pneumatically operated tracks that each has 7 predefined positions. The user select one of the predefined positions and ask the system (by clicking the corresponding "move me" button) to move the associated absorber into position between the source and the detector. There are three parallel tracks with absorber blocks, thus allowing the student to select any combination of up to three absorbers. See pictures and the schematic diagram below for details about the physical setup.

¹ Omtvedt, Jon Petter (2009): "Laboratorieøvelser som fjernundervisning - Erfaringer fra utvikling av det fjernstyrte laboratoriumet RoboLab" in "Ringer i vann. Lenge leve fleksibel læring ved Universitetet i Oslo" editor Susanne Anette Kjekshus Koch. UiO ISBN 978-82-997407-3-9. page 49 – 58.



Pictures showing the pneumatically operated tracks to shift absorbers in and out of the path between the γ source and the detector. The picture to the left was taken during construction and only part of the lead shielding for the detector and source are in place. The holders for the source(s) can be seen inside the lead "garage". The picture to the right is from the current and operational system (taken by the web camera actually used by the online system). Here it is possible to see the γ source in the middle, lower part. When not in use the source is "stored" by pushing the source wagon to the far right, inside the lead "garage" to the right in the picture, which now has a lead roof.

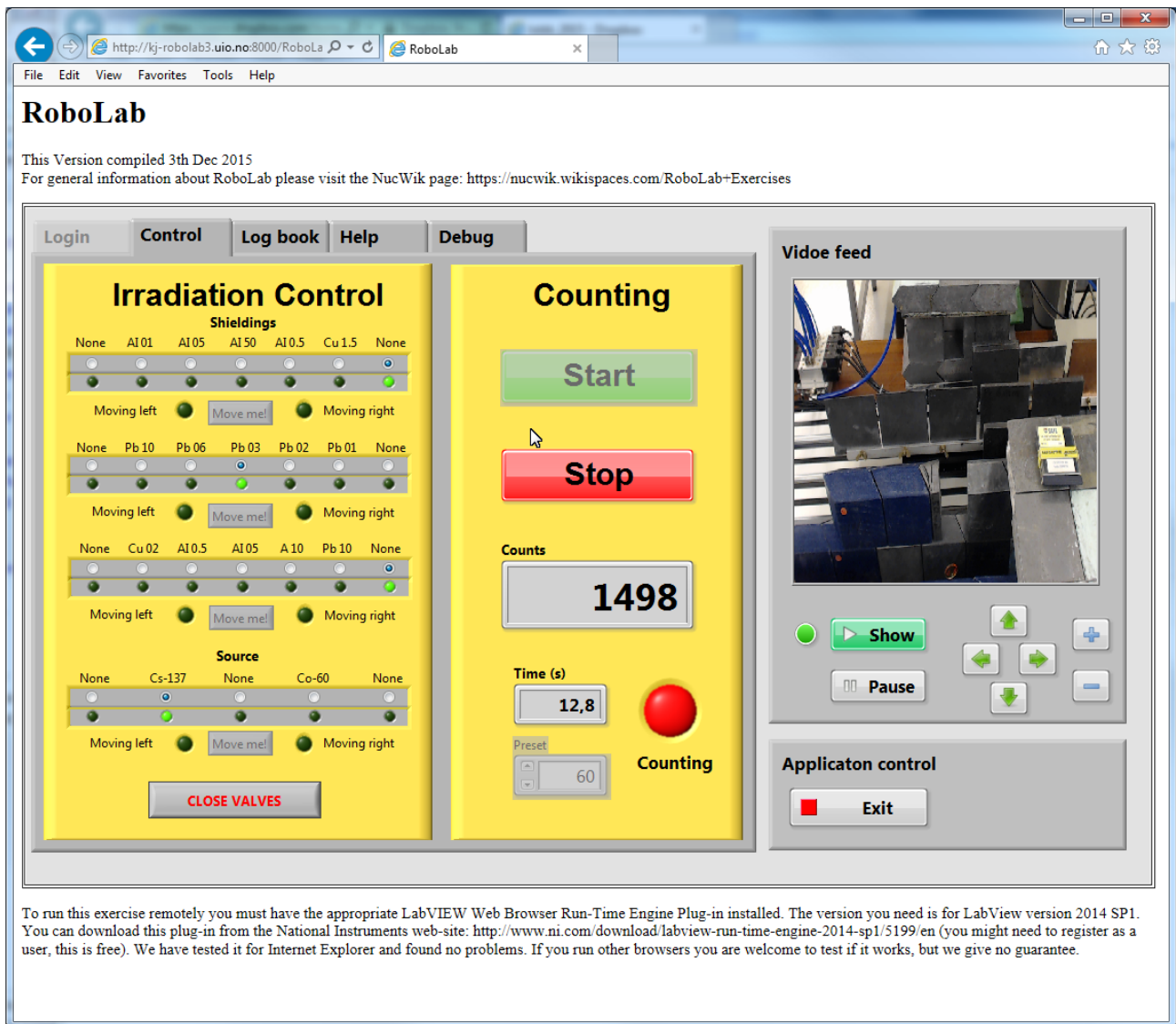
The gamma measurement is performed by a 2" NaI detector set up with a Single Channel Analyzer (SCA). The SCA has a fixed energy window set for the ^{137}Cs gamma source that the system currently uses. The gamma source is mounted on a fourth track which in principle can allow the user to select different gamma sources (preparation is done for 3 sources). However, this would either demand that the SCA is replaced with a Multi Channel Analyzer (MCA) to measure the complete spectrum or alternatively have one SCA for each source/gamma energy to be used. This can easily be added to the system as it is currently built, but will demand further investment in counting electronics.

As for the other RoboLab exercises, the complete system is controlled by LabView. This system is based on one of the first RoboLab systems and still uses the original PXI chassis with PXI-type IO-modules from National Instruments. Today there are cheaper and more easy to use USB-based modules available, but there was no point in replacing the working PXI-system.

The LabView user interface, made available to the student/user through a web-based virtual instruments that is supplied with LabView, provide a simple overview of the position of the tracks carrying the absorber blocks. It provided the user with feedback from magnetic sensors mounted along the tracks, shown as "led" indicators along the track. The tracks are diagrammatically presented to the user in the left part of the web-interface (see screenshot on the next page), together with buttons to control it.

In the middle of the user interface the SCA counter is controlled and read out. The user can set here a preset time for the wanted counting period. The counting is started by clicking the start button (which also will reset the counter). The user then either waits for the preset time to be reached or can manually stop the counting. The number of counts should then be written down by the user.

To the left on the user interface is a video feed providing a visual feedback of the position of the absorbers. The video can be panned and zoomed digitally, allowing the user to inspect details of the physical system in the laboratory.



A NucWik RoboLab page has been set up for this gamma-absorption exercise. The page contains the correct network address for accessing the RoboLab exercise. In addition, the page provides general instructions for using the RoboLab exercises, information on how to "book" timeslots for this exercise, and teaching material to accompany the exercise (some of the teaching material is still under development). It is intended that teachers using the exercise will share their experience through the NucWik site and contribute to develop more and better teaching material. Currently (January 2016) the NucWik address is:

<https://nucwik.wikispaces.com/RoboLab+Exercise+-+Absorption+and+Detection+of+gamma-radiation>

A screenshot of the page has been included on the next page. Since the NucWik pages are frequently updated, we advise potential users to access the exercises from the NucWik main menu, which has a direct link to the RoboLab exercises.

The screenshot shows a web browser displaying the NucWik website. The page title is "RoboLab Exercise - Absorption and Detection of gamma-radiation". The left sidebar contains navigation links such as "Wiki Home", "Projects", "Recent Changes", "Pages and Files", "Members", "Settings", and "Search". The main content area includes sections for "Run the Exercise", "Booking", "Learning Goals", "Introduction", "Student Guides", "Teacher Guides", "Alternative uses", "Developed By", and "Feedback from Users and Supervisors". A "CINCH APPROVED" logo is visible on the right side of the page.

NucWik Nuclear and Radiochemistry Teaching Material Wiki CINCH

Wiki Home Projects Recent Changes Pages and Files Members Settings Search

RoboLab Exercise - Absorption and Detection of gamma-radiation

Edit 0 13 ...

Run the Exercise

To run this exercise click here: <http://kj-robolab3.uio.no:8000/RoboLab.html>. Before you can run the exercise you need to have booked a time slot (see below) and have installed the appropriate LabView plug-in (as explained on the [main RoboLab](#) page).

Booking

To book a time slot for using this remote controlled laboratory you must contact [Jon Petter Omtvedt \(UiO\)](#). Please provide full name, affiliation and when you would like to run the exercise. You will not be able to use the system before you have received a username and password.

Learning Goals

- To understand how gamma radiation is absorbed and attenuated by matter

Introduction

In this exercise, you use RoboLab to measure the radiation of a γ source with a NaI detector. Absorbers of different materials and varying thickness are placed between the source and the detector to demonstrate how the gamma ray intensity is attenuated by the shielding.

Student Guides

- Absorption of Gamma Radiation (to be written)
- [Robolab procedure for absorption of \$\gamma\$ -radiation](#)
- Analysing the Data (to be written)
- [General theory on absorption of radiation](#) (from NucWik NRC textbook)

Teacher Guides

- About learning benefits from this exercise (to be written)
- How to prepare for using this exercise (to be written)
- Notes on methods for analysing the data (to be written)

Alternative uses

- This RoboLab setup can be used to investigate counting statistics and standard deviation related to measurement of radiation. Attenuate the count rate by selecting a suitable lead absorber thickness and have the students perform measurement series under identical conditions to observe the deviation in the number of counts.

Developed By

Jon Petter Omtvedt, Nuclear Chemistry Group
Department of Chemistry, University of Oslo, Norway

Feedback from Users and Supervisors

Here there should be a link to a open page where people who have used the exercise can leave feedback. How the exercises worked and troubles in performing it.

CINCH APPROVED

3.2 Neutron activation of Silver exercise

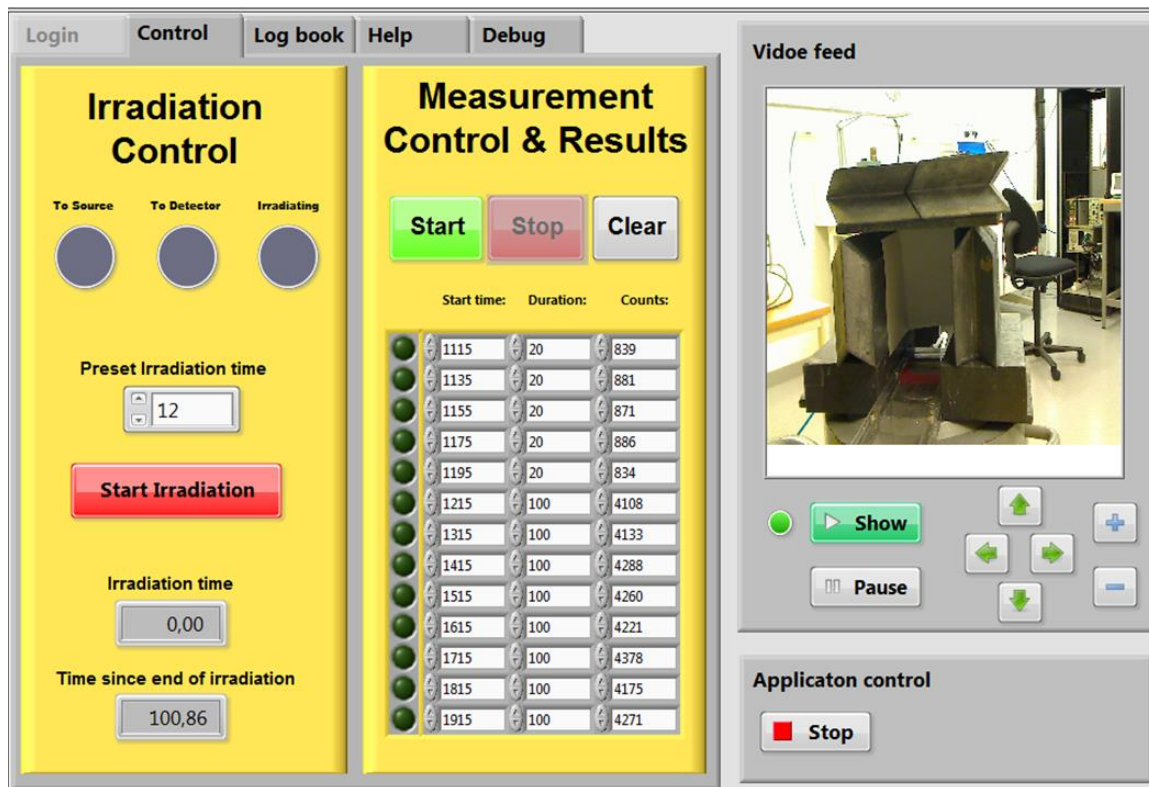
This exercise provides access to a rather strong neutron source ($370 \text{ GBq } ^{238}\text{Pu/Be}$) which is used to activate silver. The nature of the RoboLab exercises provides a completely safe environment for working with such a source and enables students to perform activation experiments without the need for supervisors to be present. The source is placed behind a 1 m thick wall of concrete and accessed using a 2 m long slide system. Pressurised air will move the silver disk, weighing about 11 g, back and forth between the activation position and a detector position. The relevant activation reactions and products, together with cross section (for thermal neutrons) and half-life are shown in the table to the right. Obviously, only the ground state for ^{108}Ag and ^{110}Ag will be countable for short activation times. This provides a mixture of two relatively short-lived nuclides that is ideal for teaching the students how to deconvolute a two-component decay curve. The system allows the student to select different irradiation times by setting a preset time. The silver disk will automatically be returned to the detector position at the end of irradiation. A general principle used for the development of the RoboLab exercises is not to provide too much automation, as this will undermine the feeling of actually performing a physical experiment for the student. In this case the need for accurate control of the irradiation time overrides this principle, since lag in communication through the web in some cases can be significant. Pictures showing the physical layout are provided below.

$^{107}\text{Ag}(n,\gamma)^{108m}\text{Ag}$	$\sigma = 1,0\text{b}$	$t_{1/2} = 418\text{years}$
$^{107}\text{Ag}(n,\gamma)^{108}\text{Ag}$	$\sigma = 36,0\text{b}$	$t_{1/2} = 2,41\text{min}$
$^{109}\text{Ag}(n,\gamma)^{110m}\text{Ag}$	$\sigma = 4,4\text{b}$	$t_{1/2} = 249,9\text{day}$
$^{109}\text{Ag}(n,\gamma)^{110}\text{Ag}$	$\sigma = 87\text{b}$	$t_{1/2} = 24,6\text{s}$



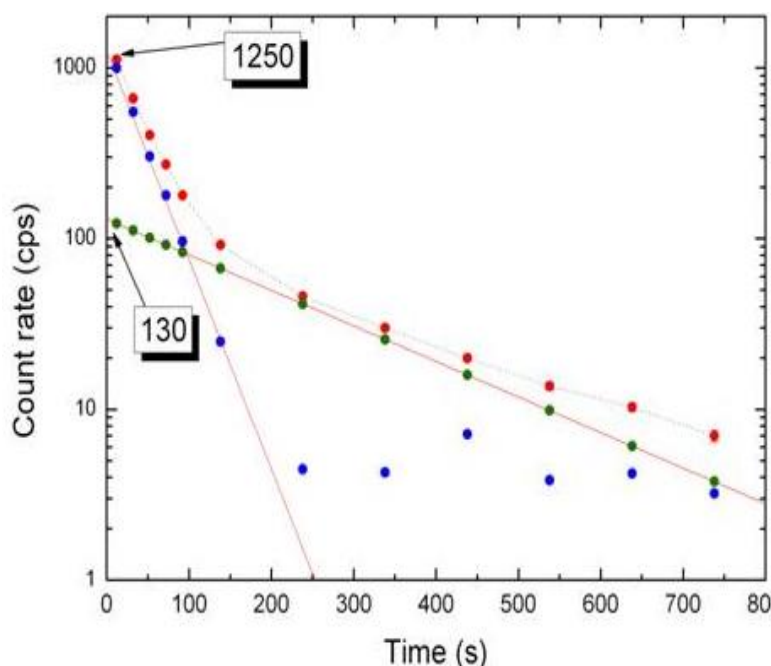
Picture in upper left corner shows the shielding for the $^{238}\text{Pu/Be}$ n-source. The transport slide comes through the 1 m thick concrete wall and ends inside the pile with boron paraffin. The n-source is placed under the slide and surrounded by about 20 cm of pure paraffin in all directions. On the other side of the concrete wall is the detector inside its lead shielding, as can be seen in the two other pictures.

For detection of the induced activity a 2" NaI detector connected to a SCA is used. The γ rays within the selected energy interval are counted by the SCA at preset intervals and tabulated in the GUI, as can be seen from the screenshot below. The presets can be changed by the user at will (or as instructed by the teacher...).



The SCA energy interval covers both the 633 keV for ^{208}Ag and 658 keV for ^{210}Ag . The two γ lines are considered close enough in energy to have approximately the same detector efficiency. The student must measure the background count-rate and subtract this from all measurements.

All data plotting and analysis must be performed by the student using whatever software is available. At UiO the recommended software is Origin from OriginLabs, which provide good fitting tools that easily take into account the uncertainty of each measured data point. An example of plotted and fitted data is provided below for a 12 s irradiation. Analysis can also be done manually the "old-fashioned way" by subtracting the background, then plotting on semi-logarithmic paper and fitting the long-lived component. Then the determined amount of the long-lived component is subtracted from the data and the remaining short-lived data is plotted and fitted. Regardless of method or software the aim is to determine the count rate at end of irradiation. In the fits (manual or by software) the known half-lives should be used for best possible accuracy. The analysis of the obtained data is quite suitable for training students in handling and understanding uncertainty. E.g. the fitted curves will be totally wrong if the fitting is not weighted according to uncertainty. Another important detail is to plot each datapoint after 1/3 of the time interval (where the weighted "middle" point is located). Failure



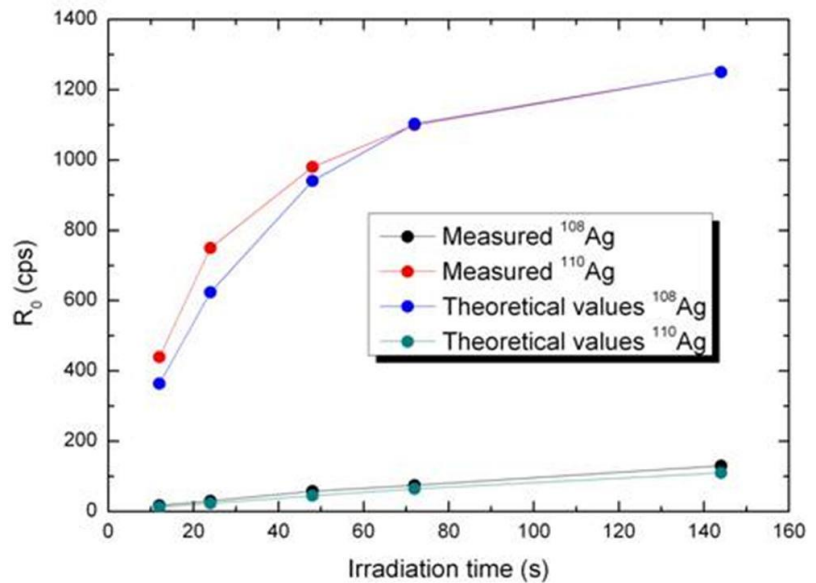
Actual data from a 12 s irradiation. The red points are measured data, the green points are due to the long-lived silver and the blue due to the short-lived isotope, clearly showing the residual counts due to background.

to do so will produce strange looking graphs. Depending on student/teacher ambitions the count rate at end of irradiation can be plotted as function of irradiation time (e.g. 12, 24, 48, 72, and 144 s). This will produce a growing-in curve as shown on the graph below.

The data from the growing-in curve can be fitted theoretically if one assumes that e.g. the data point for 144 s irradiation for ^{110}Ag is "true". Based on this value all other data points can be calculated. The calculated data will only fit the measured curve if the intensities for the two γ lines are included correctly in the calculation.

At NucWik there is also simulation software that will enable the students to simulate measured decay data. This might be useful as preparation for performing the exercise.

For this exercise there already is quite a lot of support material added on NucWik to help teachers use the exercise in their teaching. A screenshot of the NucWik page for this exercise is shown on the next page. This page provides links to the relevant material. It can also be seen that the teacher's still need to be written. The idea is that this should be done together with teachers actually using the exercise.



In-growth curve from measured and calculated data.

File Edit View Favorites Tools Help

http://nucwik.wikispaces.com/RoboLab+Exercise+... Jon Petter Omtvedt - Outlook ... Weblogin Forsiden - Aftenposten NucWik - RoboLab Exercise ...

NucWik

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NucWik Main Pages:

- Laboratory Exercises
- Calculation Exercises
- RoboLab Exercises
- CSE Exercises
- Simulations
- NRC EuroMaster

Find Topics:

- NucWik Tag list
- NucWik NRC Textbook

Useful External Links:

- Nuclear Chart (IAEA)
- Links to external tools
- NRC Courses
- The CINCH Project
- The Living NRC Textbook

edit navigation

☆ RoboLab Exercise - n-activation of Ag Edit 0 22 ...

Run the Exercise

To run this exercise click here: <http://ki-robolab2.uio.no:8000/RoboLab.html>. Before you can run the exercise you need to have booked a time slot (see below) and have installed the appropriate LabView plug-in (as explained on the [main RoboLab page](#)).

Booking

To book a time slot for using this remote controlled laboratory you must contact [Jon Petter Omtvedt \(UiO\)](#). Please provide full name, affiliation and when you would like to run the exercise. You will not be able to use the system before you have received a username and password.

Student Guides

- [Neutron activation of Ag with a Pu/Be source](#)
- [How to calculate end-of-irradiation yields](#)
- [General theory on n-activation analysis](#) (from NucWik NRC textbook)
- [General theory on desintegration](#) (from NucWik NRC textbook)

Suggested Preparation before RoboLab Exercise



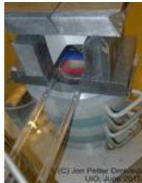



- [Preparations before you perform the RoboLab exercise](#). Find relevant data and information.
- [Simulation of Two-component Decay](#). Simulate the count rate resulting from desintegration of two nuclei with different half-lives and a constant background.

Teacher Guides

- To be written..

Pictures and Videos

Pictures and videos from the physical laboratory (click on the picture/video for full-size image):

 <p>Overview picture: The 2 m long transport rail exits the hole in the 1m thick concrete wall where the Pu/Be source is located and enters the detector tower. To the right is the rack with counting electronics and pneumatic control electronics.</p>	 <p>Picture of the counting tower also showing position of the webcam.</p>	 <p>View inside lead tower, the silver disk is placed inside the red holder. The detector (2" NaI) can be seen under the red holder.</p>
 <p>The counting electronics (left and middle) and the pneumatic control (right)</p>	 <p>View from behind the 1 m thick concrete shielding wall, showing the boron paraffine used to absorb the neutrons (which are slowed down to thermal energies by 20 cm of paraffine inside the boron paraffine). The transport rail for the silver disk enters the paraffine shielding from a whole in the concrete brick wall (not visible in the picture).</p>	 <p>The RoboLab2 control computer, which is the server you connect to when running this exercise.</p>

3.3 Separation and detection of ^{234m}Pa

This experiment will use a cation exchanger to separate ^{234}Th from uranium, retaining the thorium when a solution containing uranyl (dissolved in hydrochloric acid) is run through the column. When ^{234}Th decays it will create ^{234m}Pa ($T_{1/2} = 1.2$ min). Thus, saturation is reached within 12 minutes and the protactinium can be "milked" from the column by using a citric acid solution. The protactinium is easy to detect by a beta-detector and enables the students to accurately determine the half-life of this nucleus. Thus, the learning outcome is knowledge about radionuclide generators, radioactive equilibria, beta detection and measurement and analysis of decay curves. The original plan was to set up a column preloaded with ^{234}Th . Thus the students would only "milk" the column but not actually do the chemical steps to separate thorium from uranium, change solvent and then extract the protactinium. This would however remove an important part of the learning outcome of this exercise, as most of the chemistry steps would have been vacant. Therefore, a method to retain the chemical procedure to set up the column, starting with a uranyl solution, was sought after. However, it was soon realised that for this to be meaningful the uranium must be removed from the column after the experiment, otherwise the separation column would have to be replaced between each experiment. This would have been either time consuming (if done manually) or complicated (if done by mechanical system). In conclusion, the experiment as originally planned become significantly more complex but the learning outcome for training radiochemists increased proportionally. It was decided to build the more sophisticated system, even if the December 2015 deadline would most likely be surpassed.

As predicted the exercise was not finished by the end of 2015, but is about 4 months delayed. The main reason for this is the construction and prototyping of the more elaborate setup that was selected to enhance the learning outcome. In addition to having more stock solutions to handle as also the uranyl solution for loading the column must be controlled by the student, the enhancement also included the ability to perform actual checks on the solvent exiting the column (i.e. to check for presence of uranyl after flushing out remains of the uranyl solution with HCl, then followed by checks for chloride ions when the later solution need to be replaced by citric acid solution. These checks should be performed by the student to provide the right "feel" – i.e. that she/he actually are performing a chemical procedure, albeit through a remote controlled system. The verification steps adds two more liquid feeds and an extra mixing chamber which can be inspected with the video camera. To handle the extra feeds and mixing chamber a number of extra valves needs to be incorporated in the setup. This again made it necessary to expand the control electronics for the relays driving the valves. Building the extra electronics also contributed to the delay. It is our belief that the delay are well worth the extra functionality. We expect the exercise to be finished around April 2016.

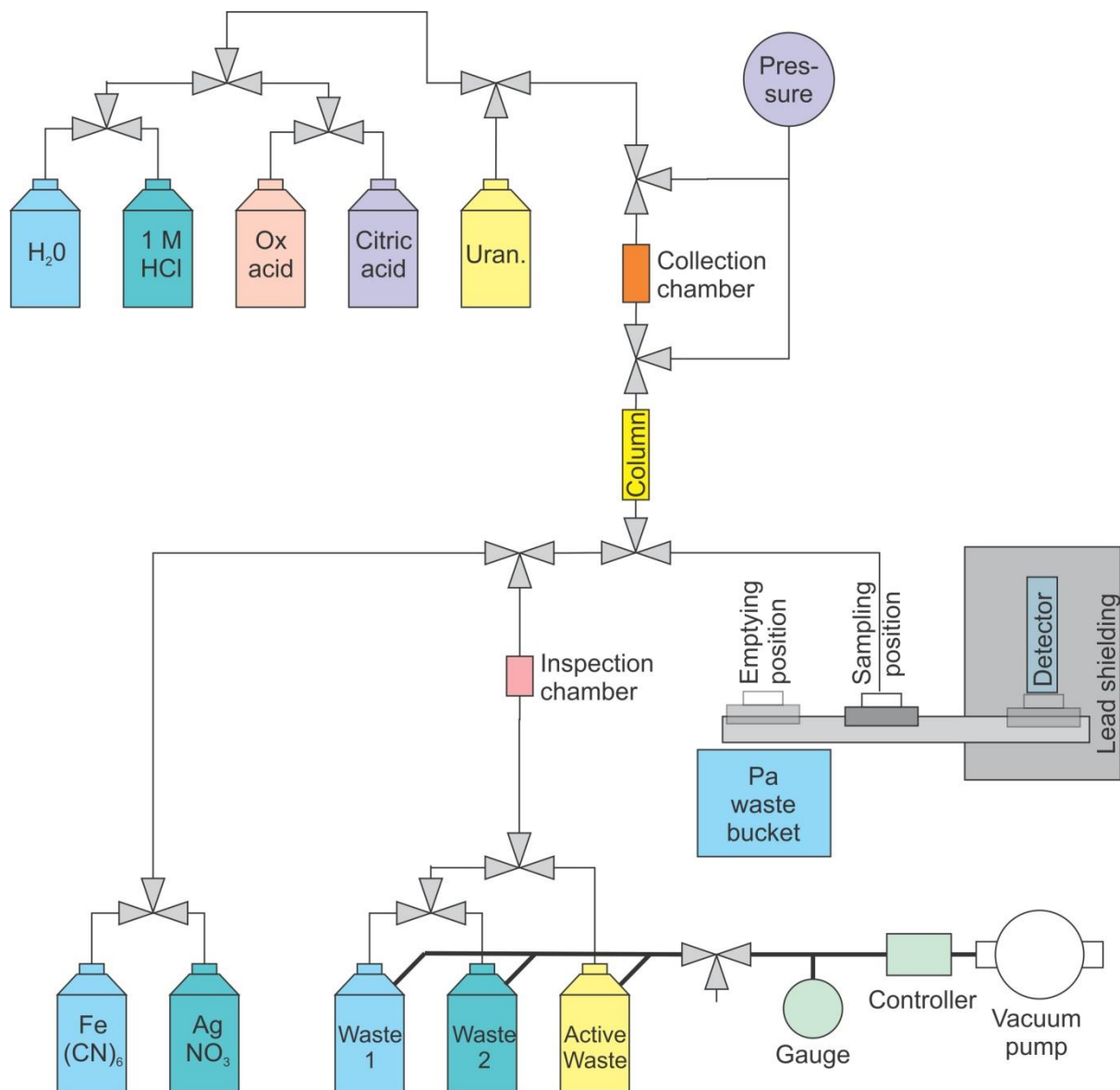
All parts necessary to build the final system have been purchased and fabricated, but not mounted. The extra control electronics will be finished during January 2016. A pilot setup of the system has been operational during the autumn of 2015 and used to determine operational parameters. As cation exchange column we have selected the Bond Elut Plexa PCX column from Agilent Technologies. It uses a polymeric cation exchange resin that combines their Bond Elut Plexa support matrix with strong cation exchange functionalities.

The chemical procedure (to be performed remotely) will be as follows:

1. Precondition the column with 1 M HCl solution.
2. Load thorium on the column by pumping uranyl solution (prepared from dissolving $\text{UO}_2(\text{NO}_3)_2$ in 1 M HCl) through the column.
3. Flush out all remains of uranyl using 1 M HCl solution. Check for remains of uranyl by adding small amounts of $\text{Fe}(\text{CN})_6^{4-}$ solution to a mixing chamber mounted under the column. (The $\text{Fe}(\text{CN})_6^{4-}$ solution is prepared by mixing 8 g $\text{Na}(\text{CH}_3\text{COO})$ with 40 g $\text{K}_4[\text{Fe}(\text{CN})_6]$ in 1 L water). Presence of uranyl will give a brown color.

4. Flush out the 1 M HCl solution using 10% citric acid. Check for chloride ions with small amounts of 0.1 M AgNO₃ solution (again using the mixing chamber under the column).
5. ^{234m}Pa can now be milked from the column as many times as needed (12 minutes is needed to reach saturation after each elution).
6. To remove thorium from the column flush thoroughly with 0.5 M oxalic acid.
7. Fill the column with 1 M HCl solution for storage.

Pumping of liquids through the system will be done by applying "vacuum" (between 100-300 mBar seems to be suitable for the initial testing) to "pull" liquids from the stock solution bottles. Using vacuum instead of pressure makes leaks and other breakdowns less likely. For "milking" protactinium from the column we will use a weak pressure (1-2 Bar), since this need to be done quickly due to the short half-life. All connections will be by 1/16" inner diameter tubing, which provides practical flow rates when the mentioned under pressure is applied. Below is the schematic diagram of the system:



Practical details about the system, once it is operational, will be published on NucWik in a similar fashion to the other RoboLab exercises.

4 CONCLUSIONS

The five remote operated exercises described in the previous chapters have been developed and are ready to use. They are stand-alone exercises, which can be remote controlled. These exercises can be used by any institution which is offering courses in radiochemistry, but that do not have the possibility to work with radioactive substances. This way the students can perform some practical work.

The subjects taught in the experiments are covering a variety of areas, being fundamental to the understanding of basic radiochemistry.