NEUTRON ACTIVATION ANALYSIS FOR LIFE SCIENCES

INTERNATIONAL STUDENT PRACTICE 2018, JINR, DUBNA

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Introduction

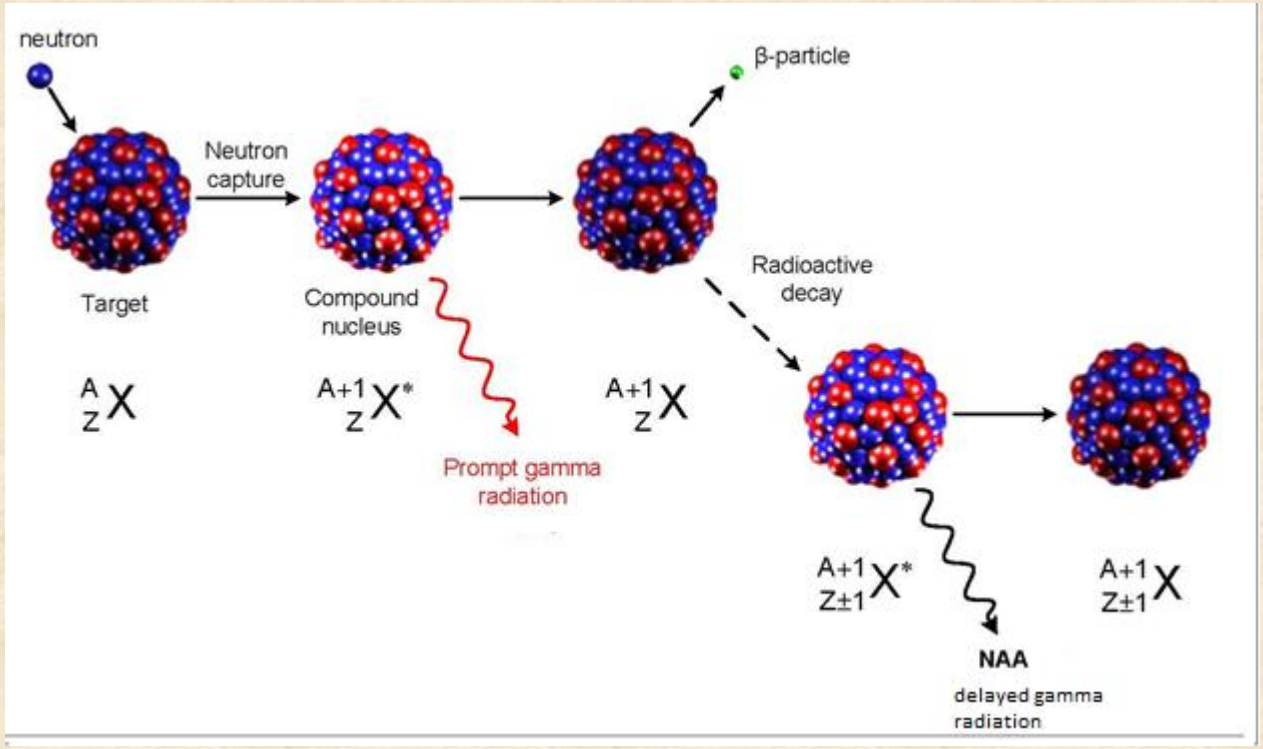
Neutron activation analysis (NAA) is an isotope specific analytical technique for the qualitative and quantitative determination of elemental content.

P. Bode, J. J. M. de Goeij, '***Activation Analysis***', Encyclopedia of Environmental Analysis and Remediation, J. Wiley & Sons, New York, **1998**, ISBN 0-471-11708-0, pp 68–84

- 1936: G. Hevesy and H. Levi discovered that rare earth elements became radioactive after being activated by neutrons.
- Element identification = qualitative

  Element concentration = quantitative
- NAA is a primary analytical technique.

Principle of NAA



https://nmi3.eu/neutron-research/techniques-for-/chemical-analysis.html

NAA is based on Fundamental facts:

- High penetrability of matter by neutrons
- The probability of (n,γ) reactions on a wide variety of isotopes.
- The characteristic radiation emitted in the specific decay of the unstable nuclei which are formed

Types of NAA

- If the resulting radioactive sample is chemically decomposed, and by chemical reparation the total number of radioanuclides is split-up into many fractions with few radionuclides each: it is refered to as **Radiochemical Neutron Activation Analysis** (destructive).

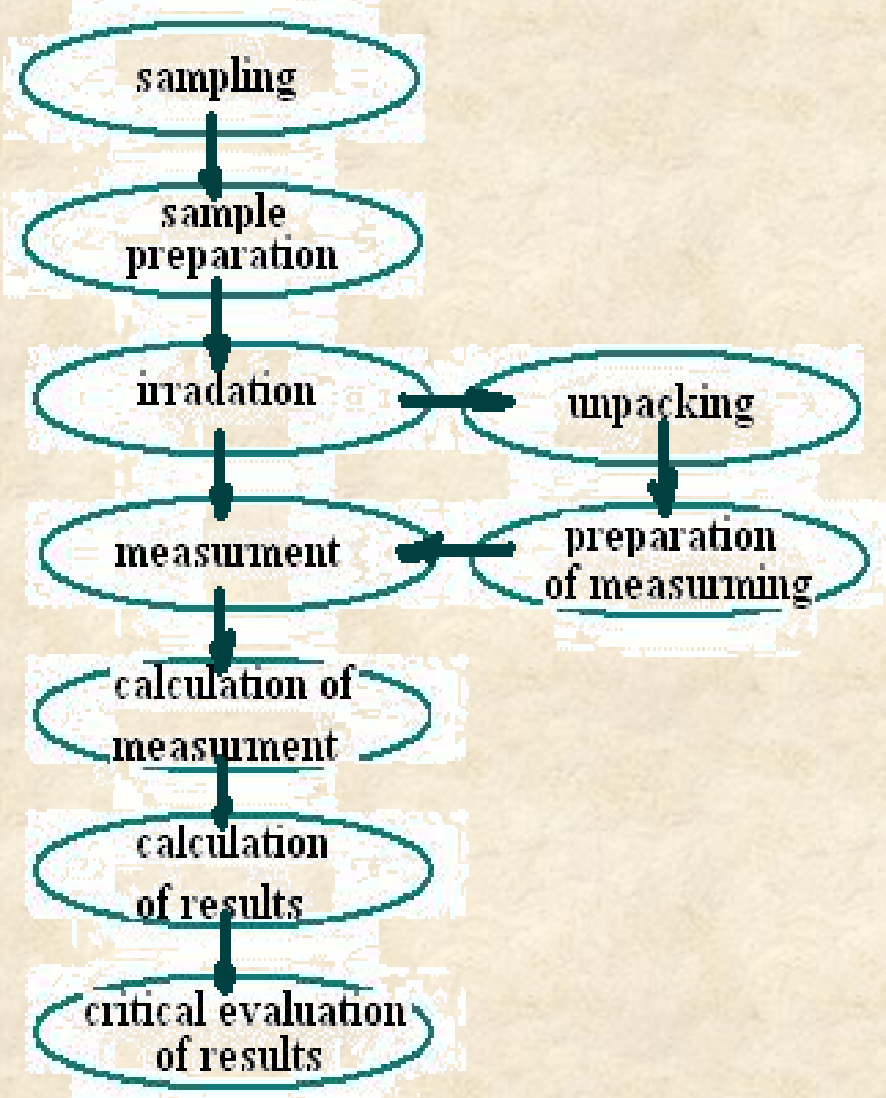
- If the resulting radiochemical sample is kept intact, and radionuclides are determined by taking advantage of the differences in decay rates via measurements at different decay intervals utilizing equipment with high energy resolution for gamma-radiation: it is refered to as **Instrumental Neutron Activation Analysis** (non-destructive)**.**

Sample preparation

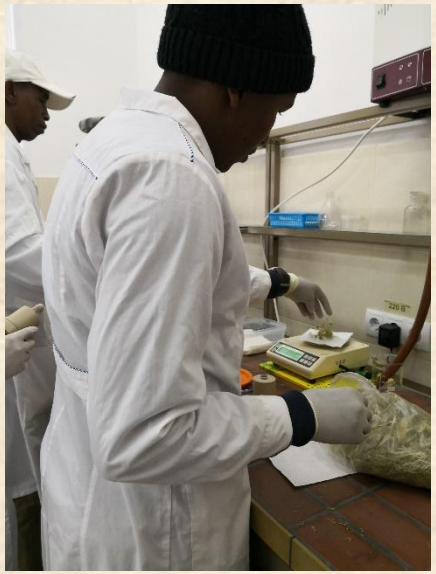
Types of sample

- Geological samples
- Biological samples
- Foodstuffs
- Environmental samples

Experimental Procedure

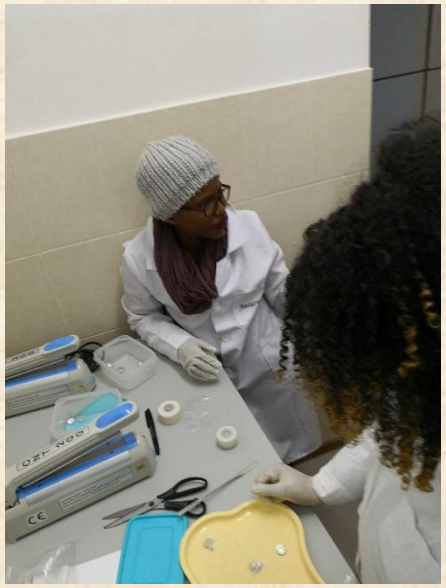


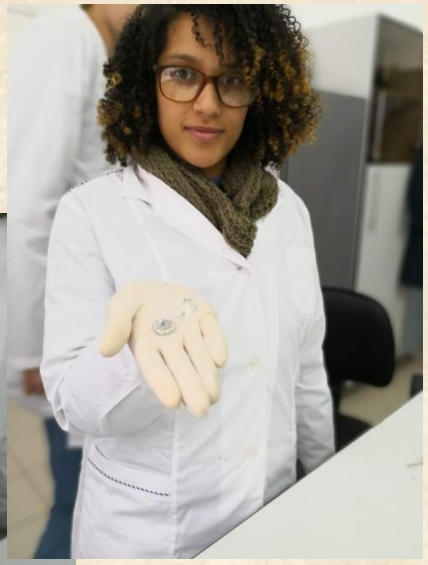
Environmental sampling and preparation



Sample Packing

- Moss samples wrapped in polyethylene bag and aluminium pan for short and long-lived irradiations respectively.
- Samples placed in transport capsules
- Short-lived isotopes - samples irradiated for 60 seconds
- Long-lived isotopes – samples irradiated for 4 days

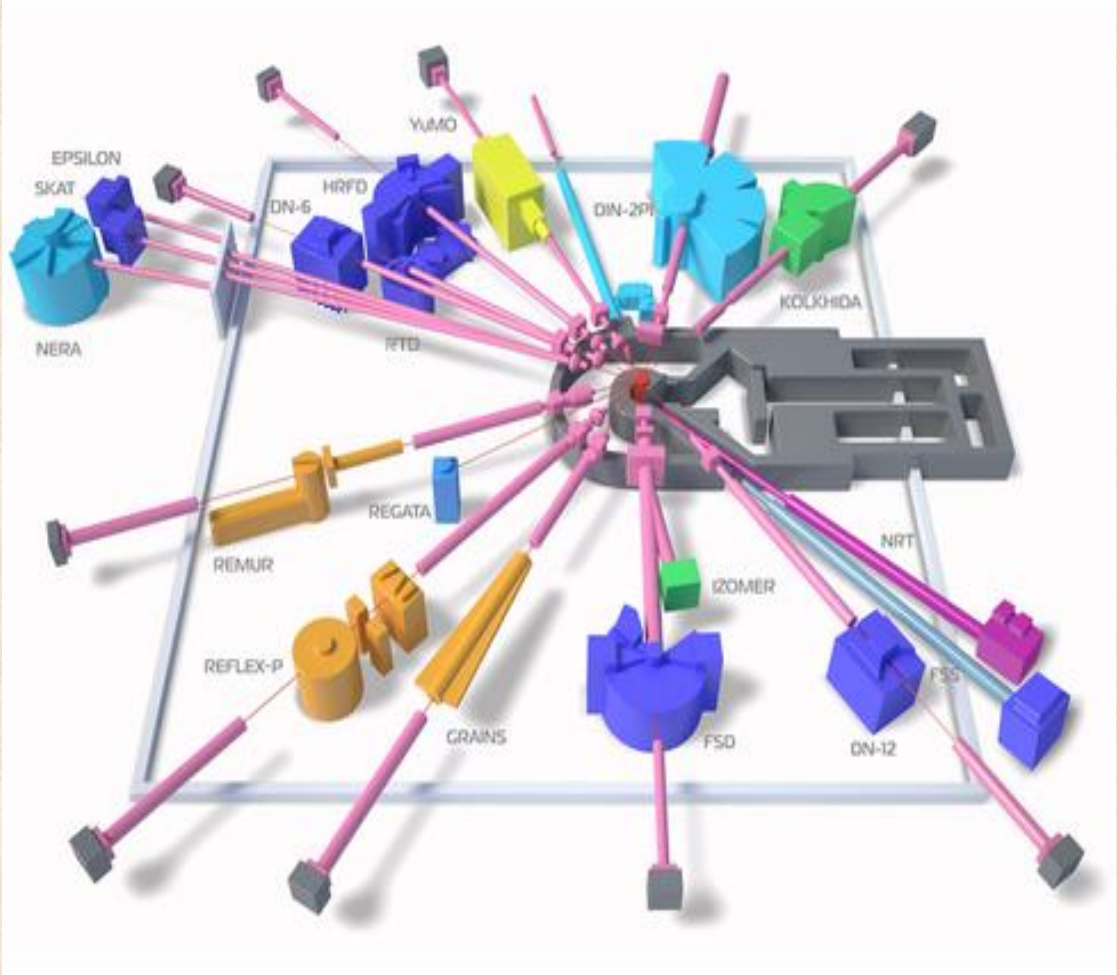




Irradiation at IBR-2

The principal characteristics of spectrometers and spectra analysis

- Four HPGe detectors with efficiency 40-55% and resolution 1.8-1.9 keV (Canberra)
- Spectrometric electronics - analog type and digital processors (Canberra)
- Automated system for spectra measurement for three detectors
- Software for spectra analysis - Genie-2000 (Canberra)
- Software package for storage of information and automation of all stages of NAA (FLNP JINR)
- Low background detector with low background shield (Canberra) for measurement of environmental samples

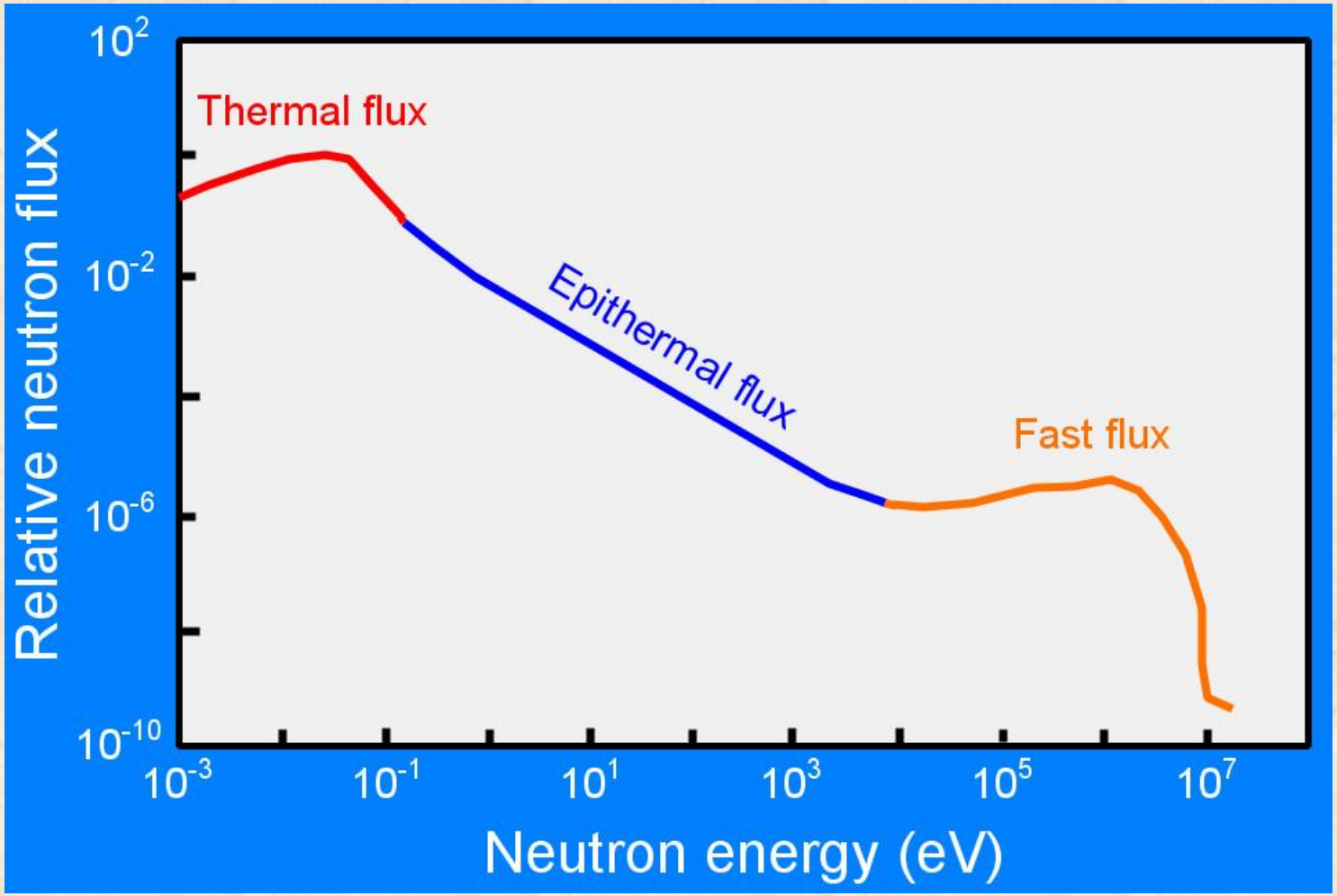


REGATA

Russian European GAte To Africa

REGATA

- Every atom has a unique excitation energy
- Depending on the sample different neutron flux is required
- Thermal 0.025 eV-0.5 eV
- Epithermal 0.5 eV-100 keV
- Fast 100 keV-25 MeV
- Cd screen is used to suppress thermal neutrons



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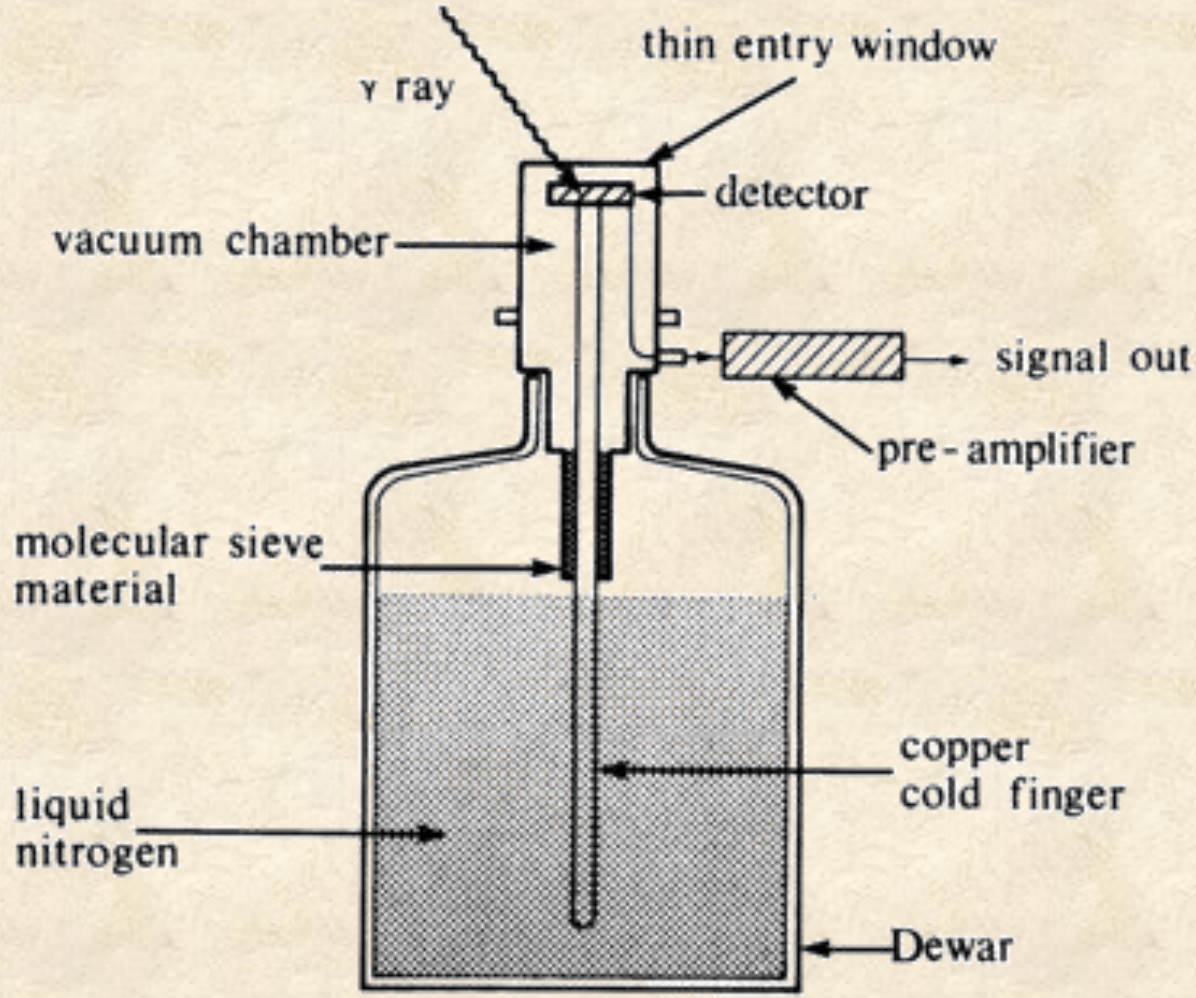
HPGe Detector

- 4 Hyper-Pure Germanium detectors
- Detector crystal cooled by liquid Nitrogen

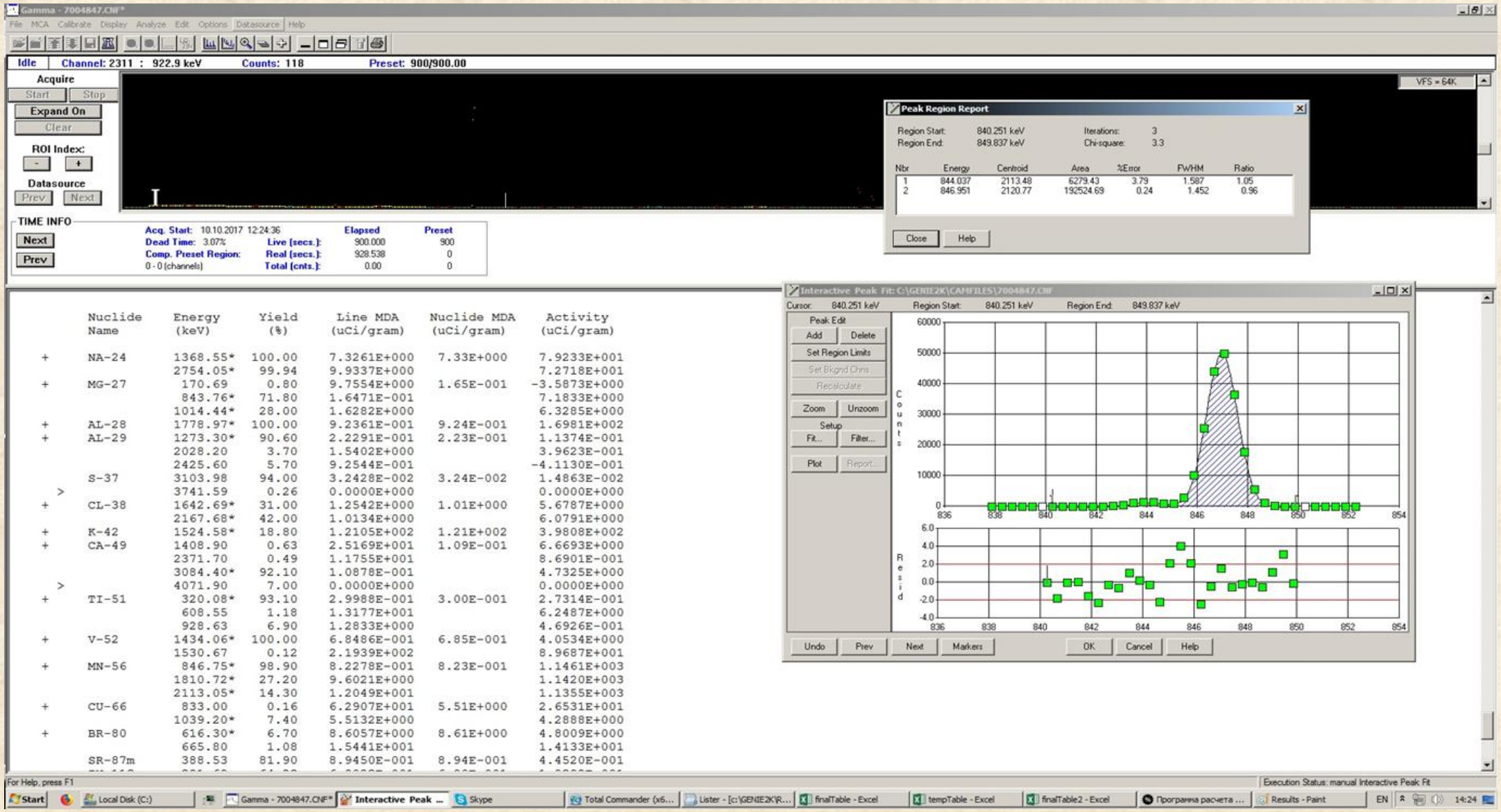


Analysis of results (spectrum)

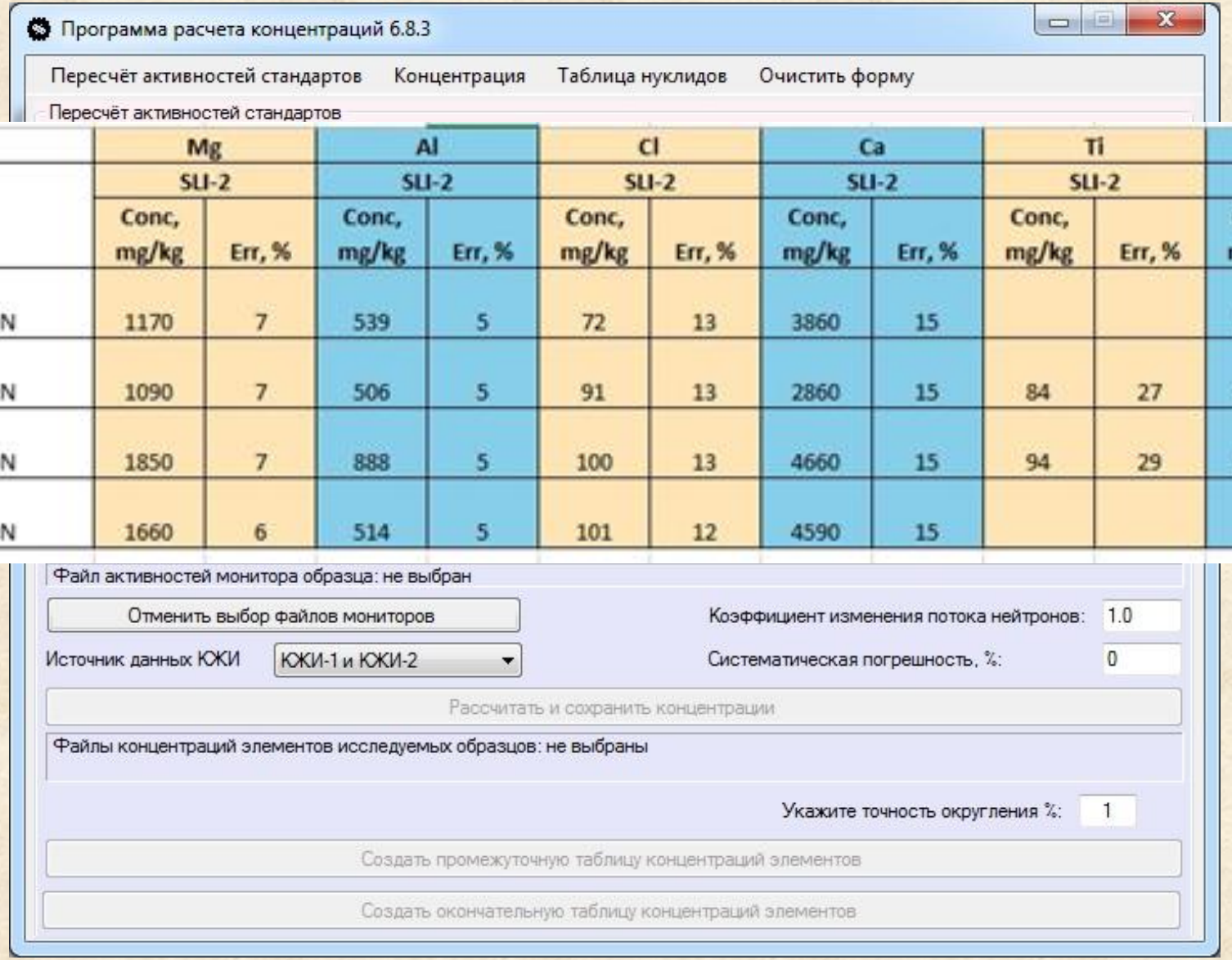
Peak Processing:

- Determine the position of peaks in the spectrum
- Obtain peak areas and activities (together with uncertainties)
- Calculate the elemental concentration

GENIE 2000

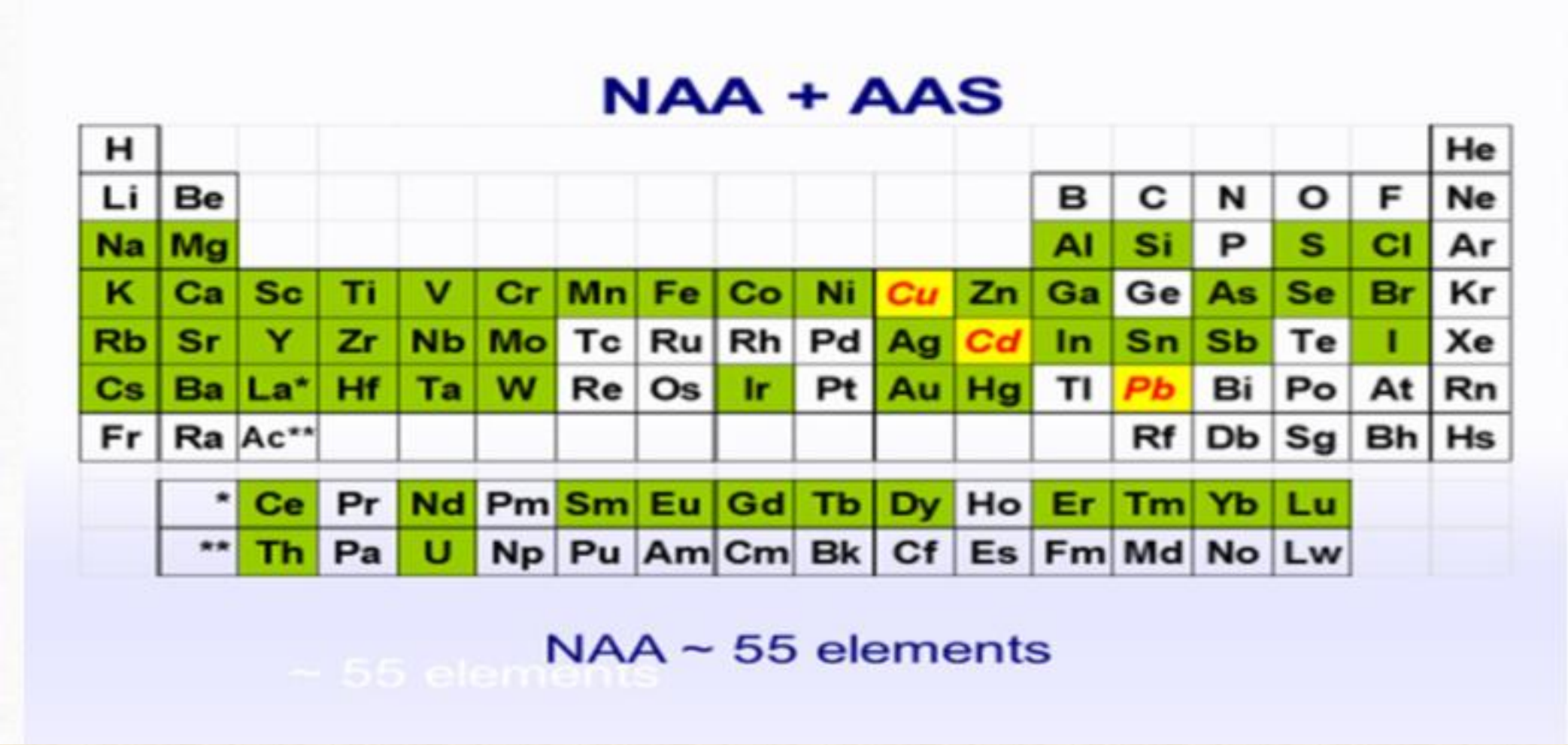

Gamma - 7004847.CNF*
File MCA Calibrate Display Analyze Edit Options Datasource Help
Idle Channel: 2311 : 922.9 keV Counts: 118 Preset: 900/900.00
Acquire
Start Stop
Expand On
Clear
ROI Index:
Datasource
Prev Next
VFS = 64K
TIME INFO
Next
Prev
Acq. Start: 10.10.2017 12:24:36
Dead Time: 3.07%
Comp. Preset Region:
0 - 0 (channels)
Live (secs.):
Real (secs.):
Total (cnts.):
Elapsed
900.000
928.538
0.00
Preset
900
0
0
Peak Region Report
Region Start: 840.251 keV
Region End: 849.837 keV
Iterations: 3
Chi-square: 3.3
Nbr Energy Centroid Area %Error FWHM Ratio
1 844.037 2113.48 6279.43 3.79 1.587 1.05
2 846.951 2120.77 192524.69 0.24 1.452 0.96
Close Help
Interactive Peak Fit: C:\GENIE2K\CAMFILES\7004847.CNF
Cursor: 840.251 keV Region Start: 840.251 keV Region End: 849.837 keV
Peak Edit
Add Delete
Set Region Limits
Set Bkgnd Chns
Recalculate
Zoom Unzoom
Setup
Fit... Filter...
Plot Report...
Counts
Resid
Undo Prev Next Markers OK Cancel Help
Nuclide Name Energy (keV) Yield (%) Line MDA (uCi/gram) Nuclide MDA (uCi/gram) Activity (uCi/gram)
+ NA-24 1368.55* 100.00 7.3261E+000 7.33E+000 7.9233E+001
2754.05* 99.94 9.9337E+000 7.2718E+001
+ MG-27 170.69 0.80 9.7554E+000 1.65E-001 -3.5873E+000
843.76* 71.80 1.6471E-001 7.1833E+000
1014.44* 28.00 1.6282E+000 6.3285E+000
+ AL-28 1778.97* 100.00 9.2361E-001 9.24E-001 1.6981E+002
+ AL-29 1273.30* 90.60 2.2291E-001 2.23E-001 1.1374E-001
2028.20 3.70 1.5402E+000 3.9623E-001
2425.60 5.70 9.2544E-001 -4.1130E-001
S-37 3103.98 94.00 3.2428E-002 3.24E-002 1.4863E-002
> 3741.59 0.26 0.0000E+000 0.0000E+000
+ CL-38 1642.69* 31.00 1.2542E+000 1.01E+000 5.6787E+000
2167.68* 42.00 1.0134E+000 6.0791E+000
+ K-42 1524.58* 18.80 1.2105E+002 1.21E+002 3.9808E+002
+ CA-49 1408.90 0.63 2.5169E+001 1.09E-001 6.6693E+000
2371.70 0.49 1.1755E+001 8.6901E-001
3084.40* 92.10 1.0878E-001 4.7325E+000
> 4071.90 7.00 0.0000E+000 0.0000E+000
+ TI-51 320.08* 93.10 2.9988E-001 3.00E-001 2.7314E-001
608.55 1.18 1.3177E+001 6.2487E+000
928.63 6.90 1.2833E+000 4.6926E-001
+ V-52 1434.06* 100.00 6.8486E-001 6.85E-001 4.0534E+000
1530.67 0.12 2.1939E+002 8.9687E+001
+ MN-56 846.75* 98.90 8.2278E-001 8.23E-001 1.1461E+003
1810.72* 27.20 9.6021E+000 1.1420E+003
2113.05* 14.30 1.2049E+001 1.1355E+003
+ CU-66 833.00 0.16 6.2907E+001 5.51E+000 2.6531E+001
1039.20* 7.40 5.5132E+000 4.2888E+000
+ BR-80 616.30* 6.70 8.6057E+000 8.61E+000 4.8009E+000
665.80 1.08 1.5441E+001 1.4133E+001
SR-87m 388.53 81.90 8.9450E-001 4.4520E-001
For Help, press F1
Execution Status: manual Interactive Peak Fit
Start Local Disk (C:) Gamma - 7004847.CNF* Interactive Peak ... Skype Total Commander (x6... Lister - [c:\GENIE2K\R... finalTable - Excel tempTable - Excel finalTable2 - Excel Программа расчета ... Results - Paint EN 14:24

Concentration Program



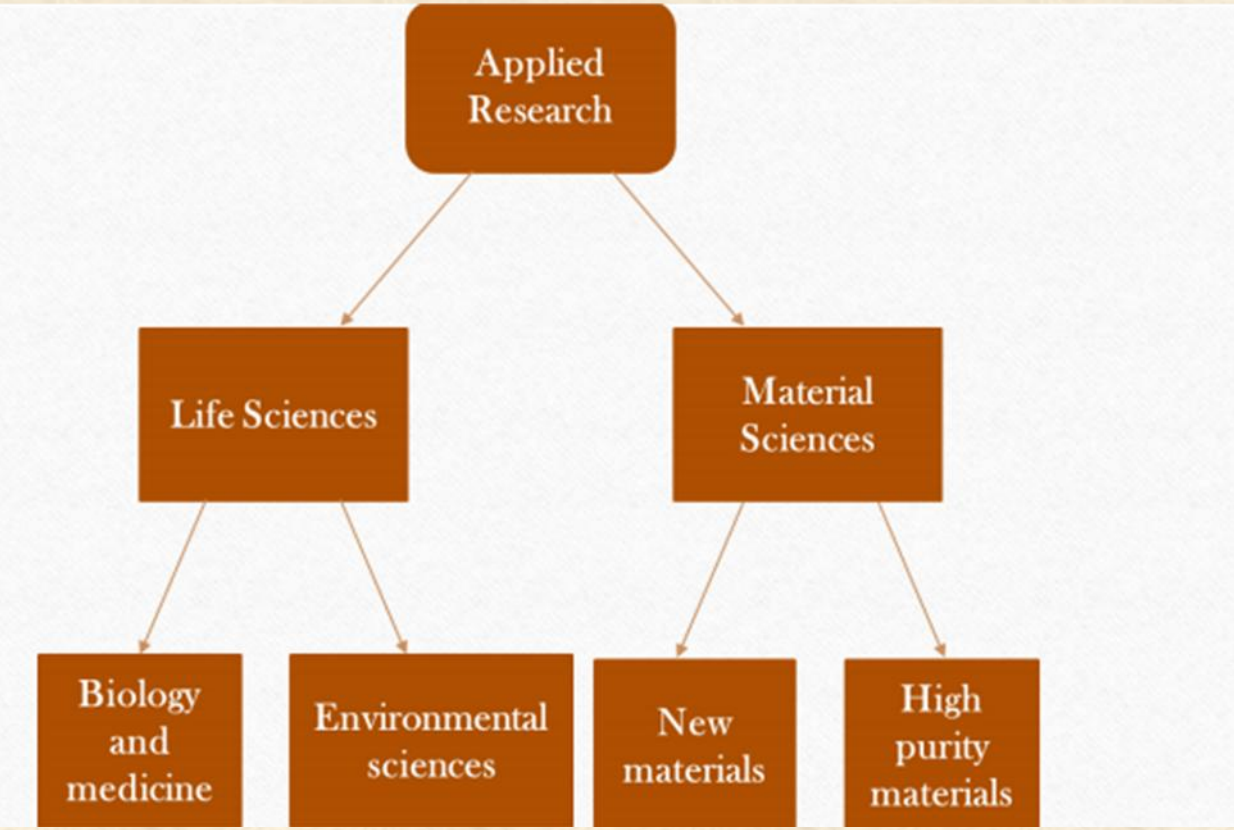
		Mg		Al		Cl		Ca		Ti		V		Mn	
		SLI-2		SLI-2		SLI-2		SLI-2		SLI-2		SLI-2		SLI-2	
Имя образца	SLI-2	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %	Conc, mg/kg	Err, %
i-01	7004845.CON	1170	7	539	5	72	13	3860	15			1,08	8	551	7
i-02	7004846.CON	1090	7	506	5	91	13	2860	15	84	27	0,94	8	680	7
i-03	7004847.CON	1850	7	888	5	100	13	4660	15	94	29	1,92	6	206	7
i-04	7004848.CON	1660	6	514	5	101	12	4590	15			1,4	7	315	7

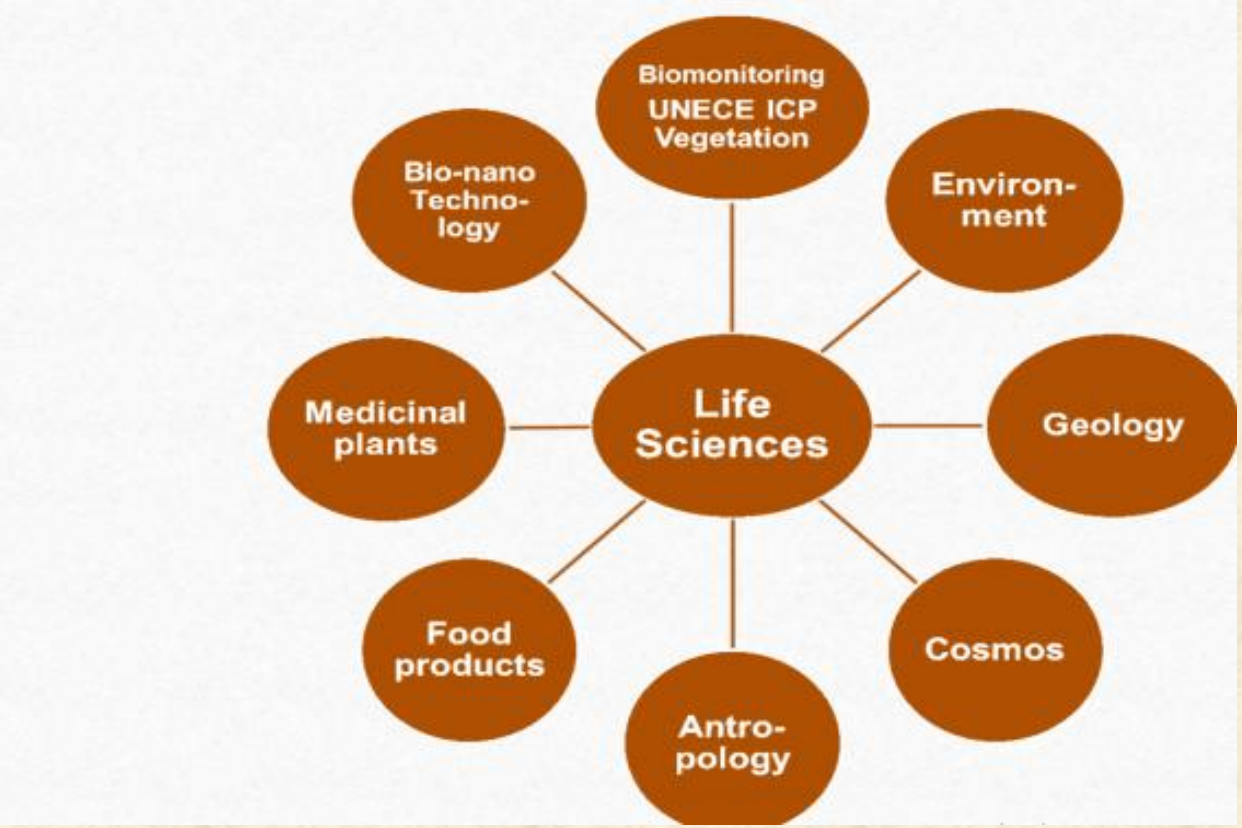
Elements measured using NAA



Applications of NAA

Applications of NAA





Application of INAA in Life Sciences

- Biomonitoring: use of living organisms to determine changes in the environment: Passive and active approach.
  - Biomonitoring of atmospheric deposition of heavy metals and other elements.
  - Active biomonitoring of air pollution in Baku, the capital of Azerbaijan (FLNP)
- Control of quality and safety of the foodstuff, grown in industrially contaminated areas.
- Assessment of different ecosystems and their impact on human health.
- Analysis of cosmic dust

Advantages and Disadvantages of NAA

Advantages

- High accuracy
- High sensitivity
- High precision
- Low detection limits
- Non-destructive analysis (INAA)
- The chemical form and physical state doesn't influence the results
- Limited sample handling.
- Multi-element analysis
- Simultaneous identification of elements

Limitations

- A reactor is required for high energy neutrons
- Samples remain radioactive for some time after activation
- This requires special training and handling for radioactive materials

Competing technique

ICP-MS: Inductively coupled plasma mass spectrometry

- ICP-MS is used to detect metals and certain non-metals.
- The sample must be dissolved before it is introduced into the ICP plasma. Here it is converted into a gaseous form and ionized.
- A mass spectrometer is used to separate the ions based on their mass-to-charge ratio. This allows ICP-MS to supply isotopic information.

Continued….

- Can’t easily determine elements that form negative ions like Cl, I, F…
- ICP-MS is a destructive method that requires dissolved samples. Therefore it has a lower throughput than INAA because samples may not be thoroughly dissolved.
- Used in the medical and forensic field for toxicology. It is also used for detection of inorganic impurities in pharmaceuticals.

Conti…

Criteria	ICP-MS	NAA
Price	5x	x
Multi-elemental	+	+
Non-destructive	-	+

What we learnt

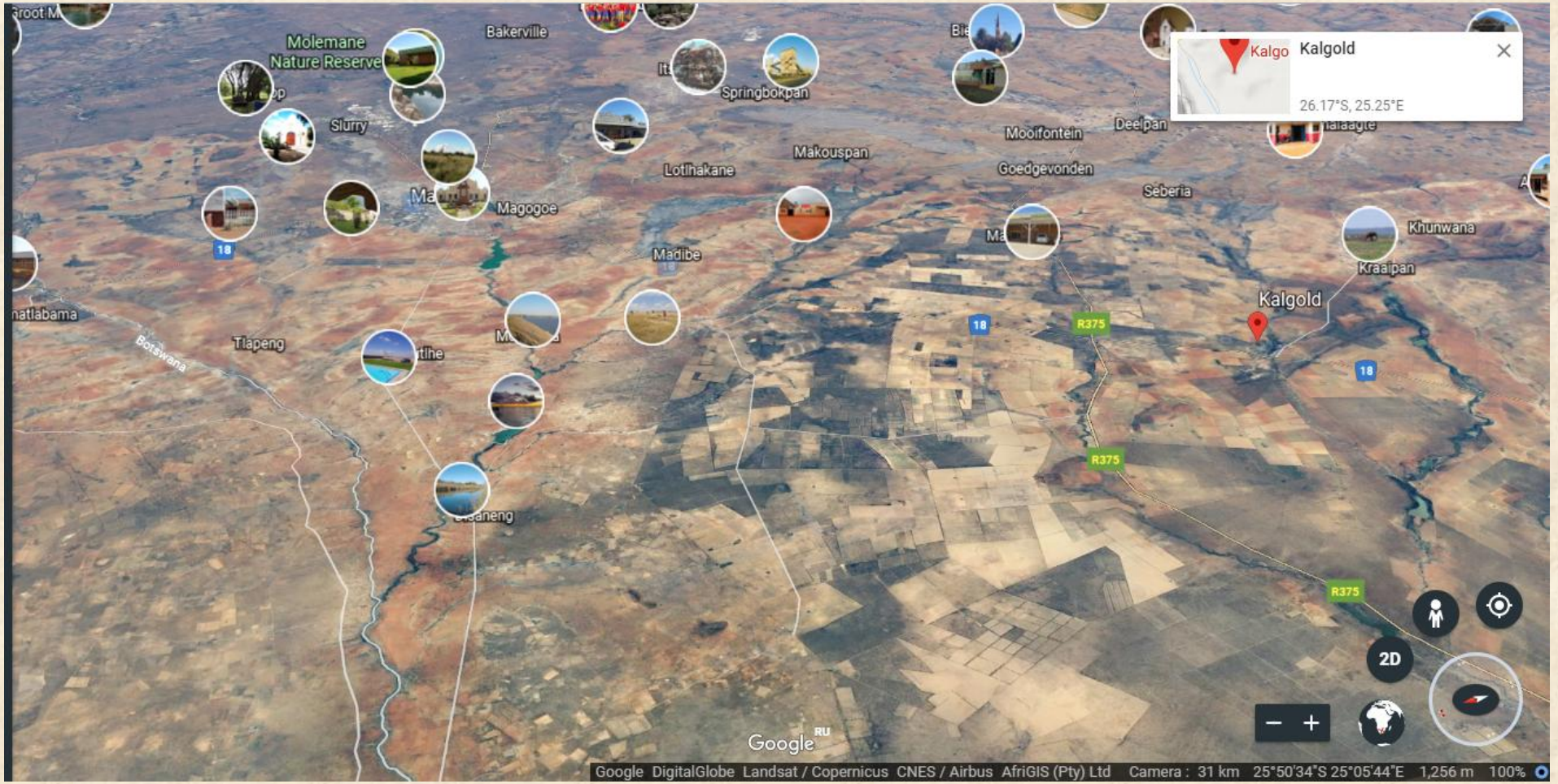
- We learned about NAA and its applications in biology, medicine and environmental studies.
- NRF and JINR exposed students from South Africa, Zimbabwe and Botswana to advanced research and facilities.
- This student practice supports the development of students at a world class standard.

Proposed Projects

Proposed Project

Our acquaintance with Neutron Activation Analysis and the projects which are carried out here for air pollution inspired me to carry out similar research in North-West.

NORTH WEST , SOUTH AFRICA




Kalgo
Kalgold
26.17°S, 25.25°E
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2D
Google RU
Google DigitalGlobe CNES / Airbus AfriGIS (Pty) Ltd Camera : 5,649 m 26°10'17"S 25°15'49"E 1,252 m 100%

Acknowledgements

We would like to acknowledge and thank the following:

- NRF
- iThemba LABS
- JINR
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