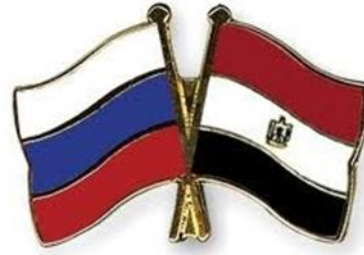




أكاديمية البحث العلمي والتكنولوجيا
Academy of Scientific Research
and Technology



Neutron activation analysis in life science

By

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&

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The Sector of Neutron Activation Analysis and Applied Research

Outlines:

- **introduction**
 - **Neutron Activation Analysis (NAA)**
 - **Fundamentals of NAA**
 - **Types of NAA**
 - **Applications**
 - **Advantages and limitations**
 - **REGATA**
- **Experimental work**
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 - **Irradiation of samples**
 - **Measurements of samples**
 - **Spectra processing**
 - **Calculation of concentration**
 - **Joint projects with Egypt**
 - **Gained experience**
 - **Social program**

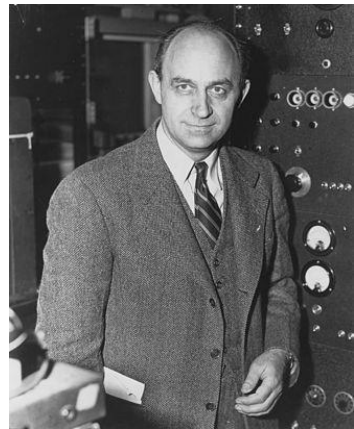
History and discovery of NAA

➤ The discovery of artificial radioactivity was forecast by **Herbert George Wells** (1914) to take place in 1933. **Frederic and Irene Joliot- Curie** almost obliged Wells: two weeks into 1934 they produced radioactive ^{30}P by bombarding aluminum with alpha particles.

➤ In Rome, the theoretician **Enrico Fermi** recognized that artificial radionuclides could be produced more efficiently with neutrons than alphas since neutrons striking a nucleus have no coulombic barrier to overcome. He was awarded Nobel Prize.



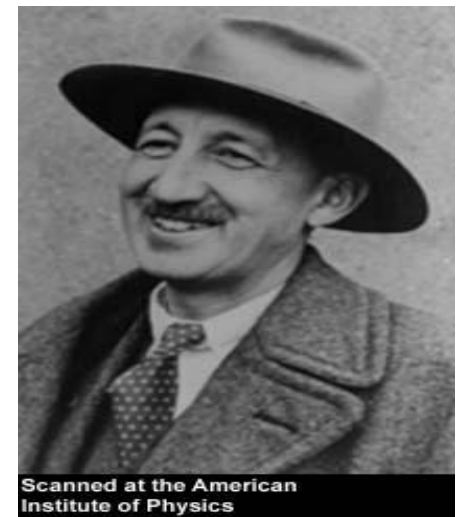
H. G. Wells
(1866-1946)



Enrico Fermi
(1901-1954)

Neutron Activation Analysis (NAA)

- NAA is a method for determination of elements based on conversion stable nuclei to other, mostly radioactive nuclei via nuclear reactions and measurements of reaction products [Bode, 1996]
- NAA was discovered in 1936 by G. Hevesy (Hungary) and H. Levi (Denmark)



Types of NAA

- Destructive:

(radiochemical) – the resulting radioactive sample is chemically decomposed, and the elements are chemically separated.



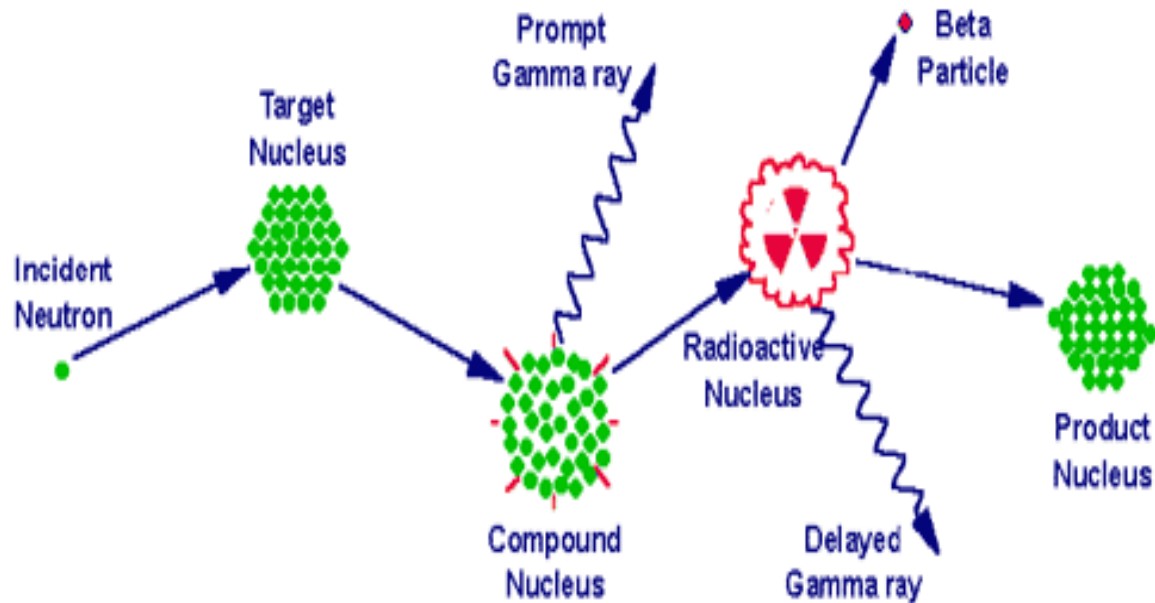
- Non-destructive:

(instrumental) – sample is kept intact and the radionuclides are determined, taking advantage of the differences in decay rates via measurements at different decay intervals.

INAA procedure is characterized by :

- **Activation via irradiation with neutron source (in our case, it is the reactor IBR-2)**
- **Measurement of gamma radiation after one or more decay times**
- **Interpretation of the resulting gamma ray spectra in terms of radionuclides, associated elements and their concentration**
- **Multi-element analytical technique**
- **The chemical form and physical state of the elements are not influenced by the activation and decay process**

Fundamentals of NAA



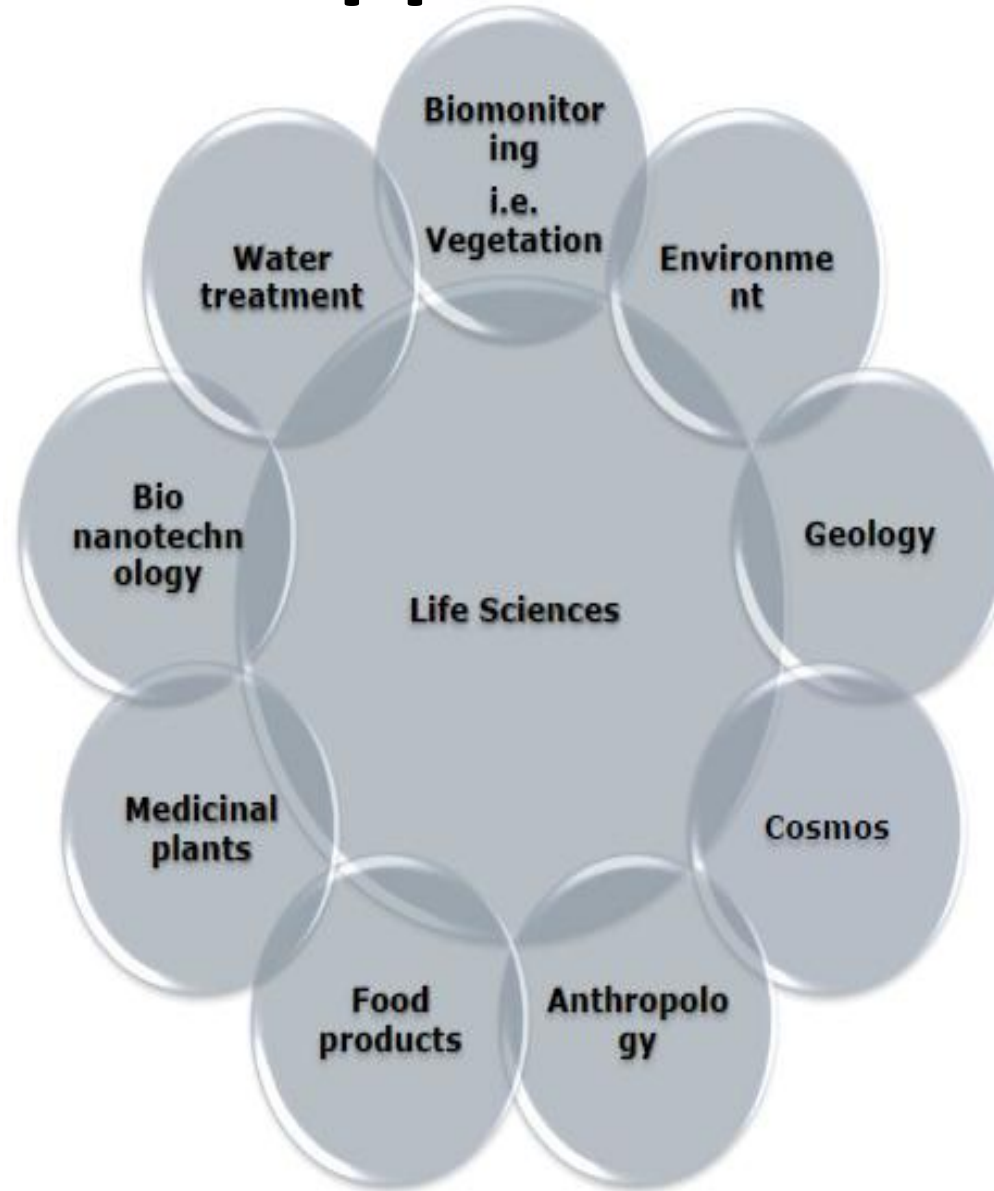
When a neutron interacts with the target nucleus via a non-elastic collision, a compound nucleus forms in an excited state. The excitation energy of the compound nucleus is due to the binding energy of the neutron with the nucleus.

The compound nucleus will almost instantaneously de-excite into a more stable configuration through emission of one or more characteristic prompt gamma rays.

In many cases, this new configuration yields a radioactive nucleus which also de-excites (or decays) by emission of one or more characteristic delayed gamma rays, but at a much slower rate according to the unique half-life of the radioactive nucleus. Depending upon the particular radioactive species, half-lives can range from fractions of a second to several years.

The radioactive emission and radioactive decay paths for each element are well known and using this information, it is possible to study spectra of emissions of the radioactive sample, and determine the concentrations of the elements within it.

Applications



Advantages

- Wide possibilities of applications
- Non destructive analysis
- Multi-element analysis
- Sensitivity to parts-per-billion for specific elements
- Customizable analysis

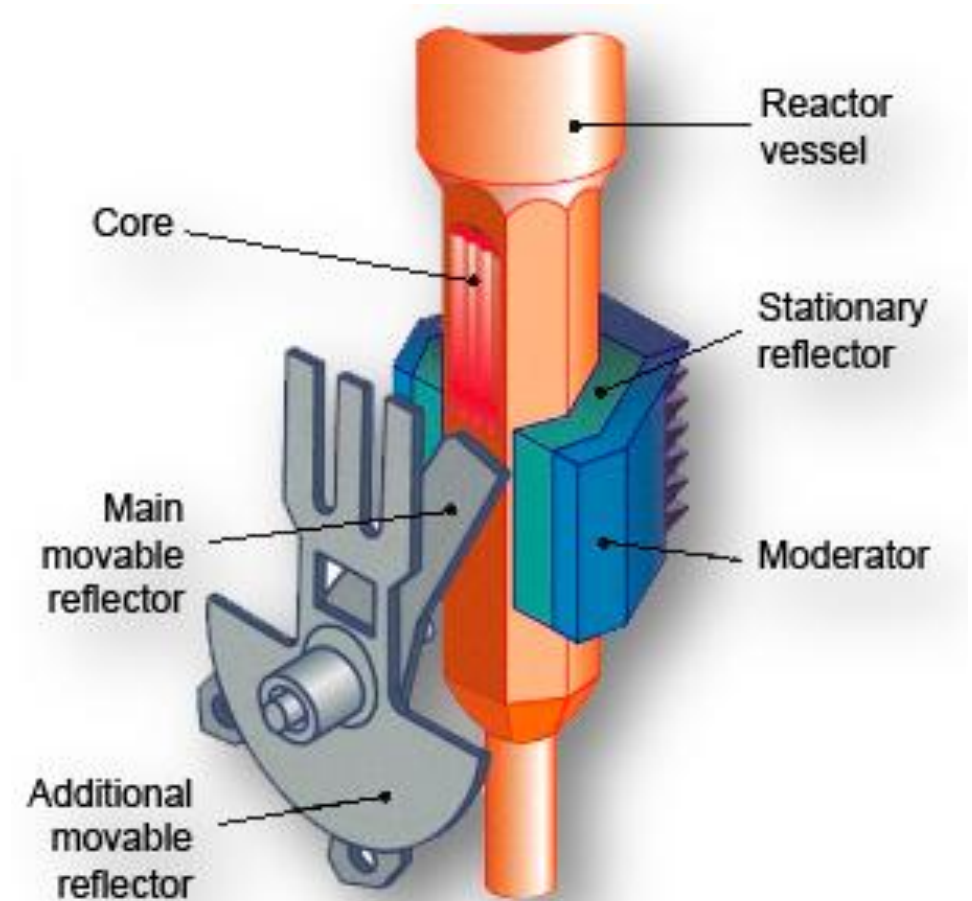
Limitations

- Need for nuclear reactor
- Work with radioactive materials
- Time of analysis
- Sample preference

IBR – 2 Reactor in JINR

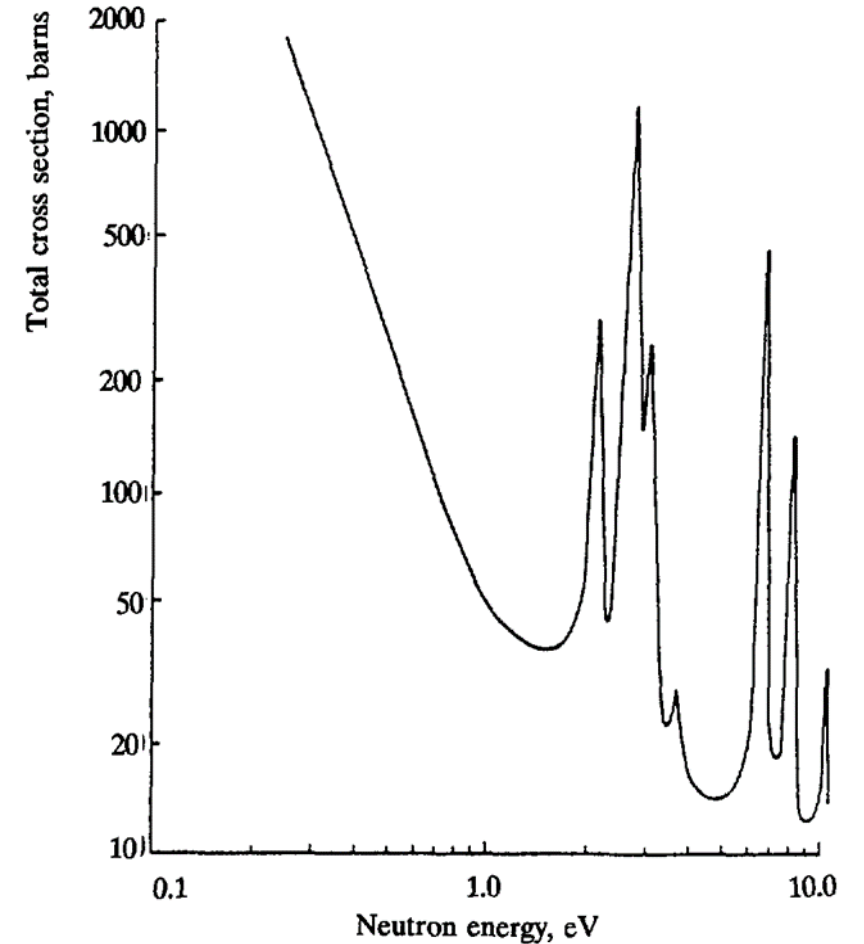
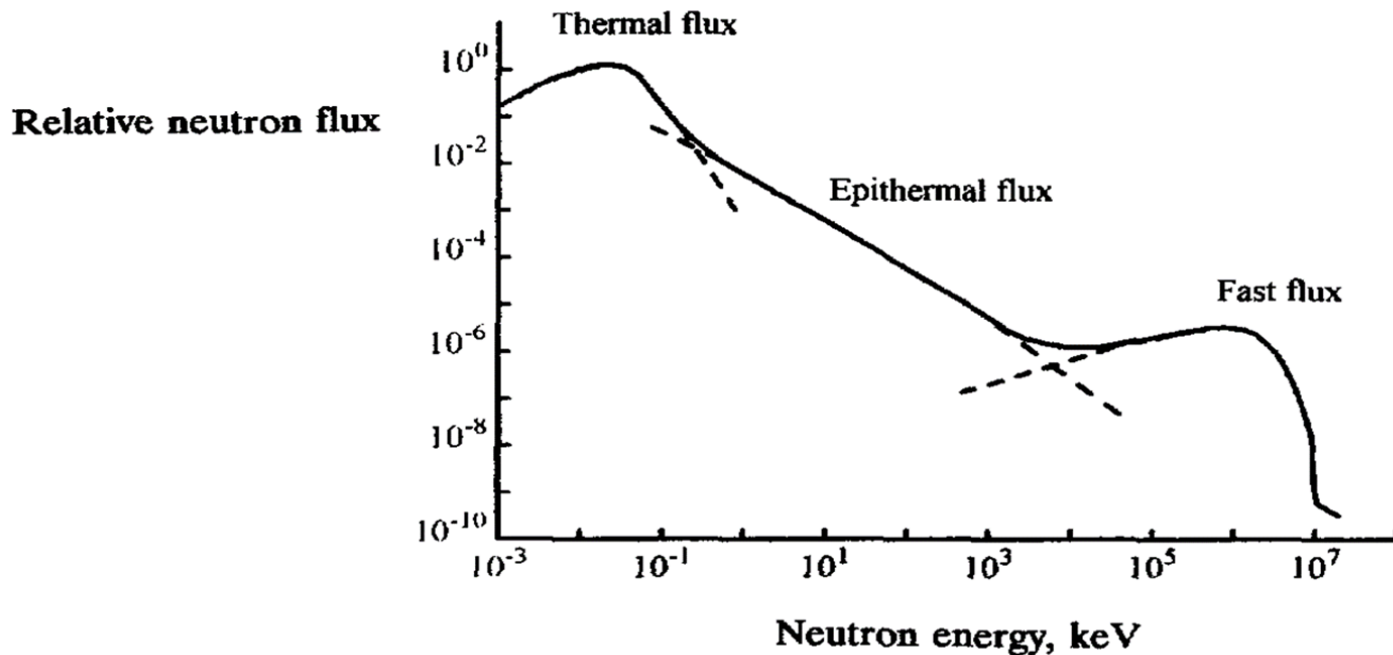
Parameters of IBR – 2:

- Average power 2 MW
- PuO₂ fuel
- Rotation rate, rev/min:
 - main reflector 600
 - auxiliary reflector 300
- Neutron density flux $10^{16} \text{ n} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$

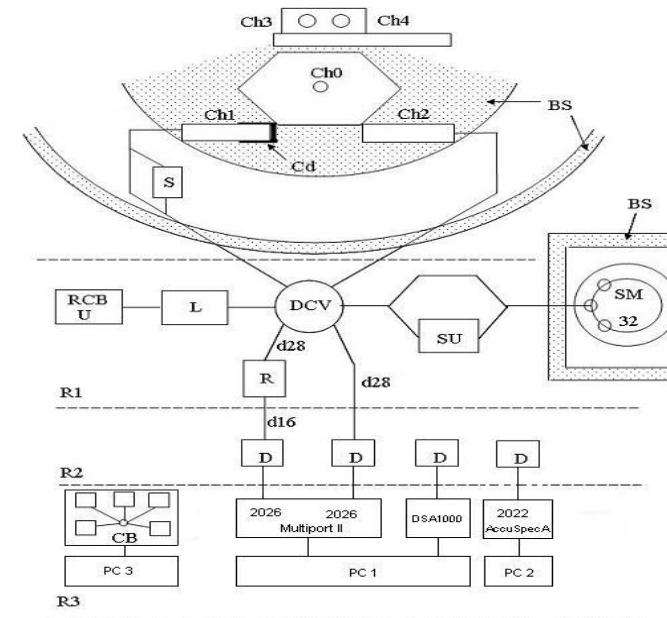
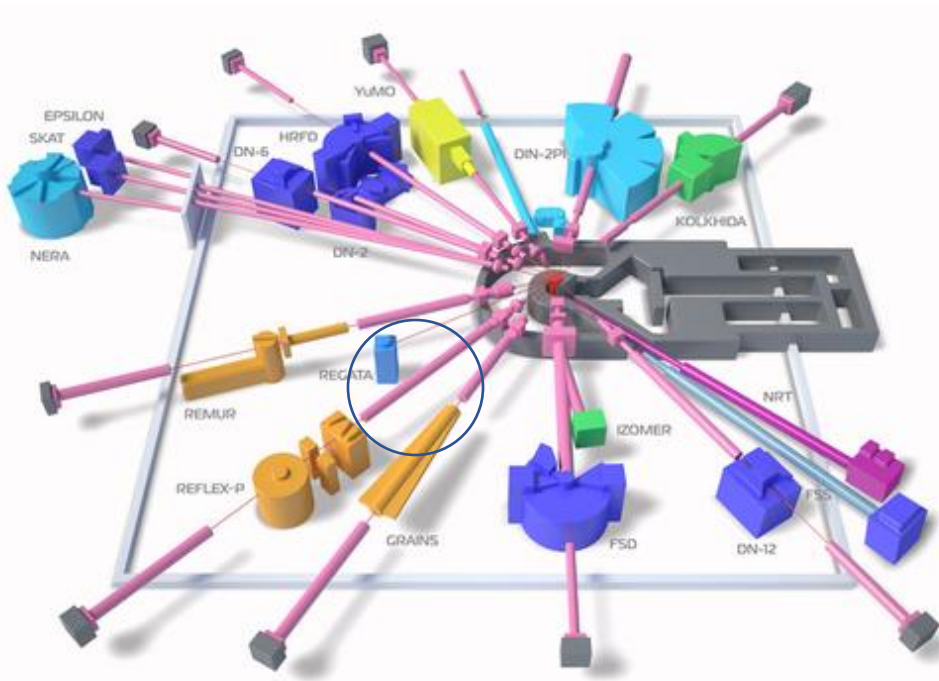


Neutron energy distribution

- Thermal 0.025 eV – 0.5 eV
- Epithermal 0.5 eV – 100 keV
- Fast 0.1 MeV – 25 MeV



Radioanalytical complex REGATA



Ch1-Ch4 –irradiation channels, S- intermediate storage, DCV- directional control valves, L- loading unit, RCB- radiochemical glove-cell, U- unloading unit, SU- separate unit, SM- storage magazine, R- repacking unit, D- detector, CB- control board, R1-R3- the rooms where the system is located.

Instrumental neutron activation analysis

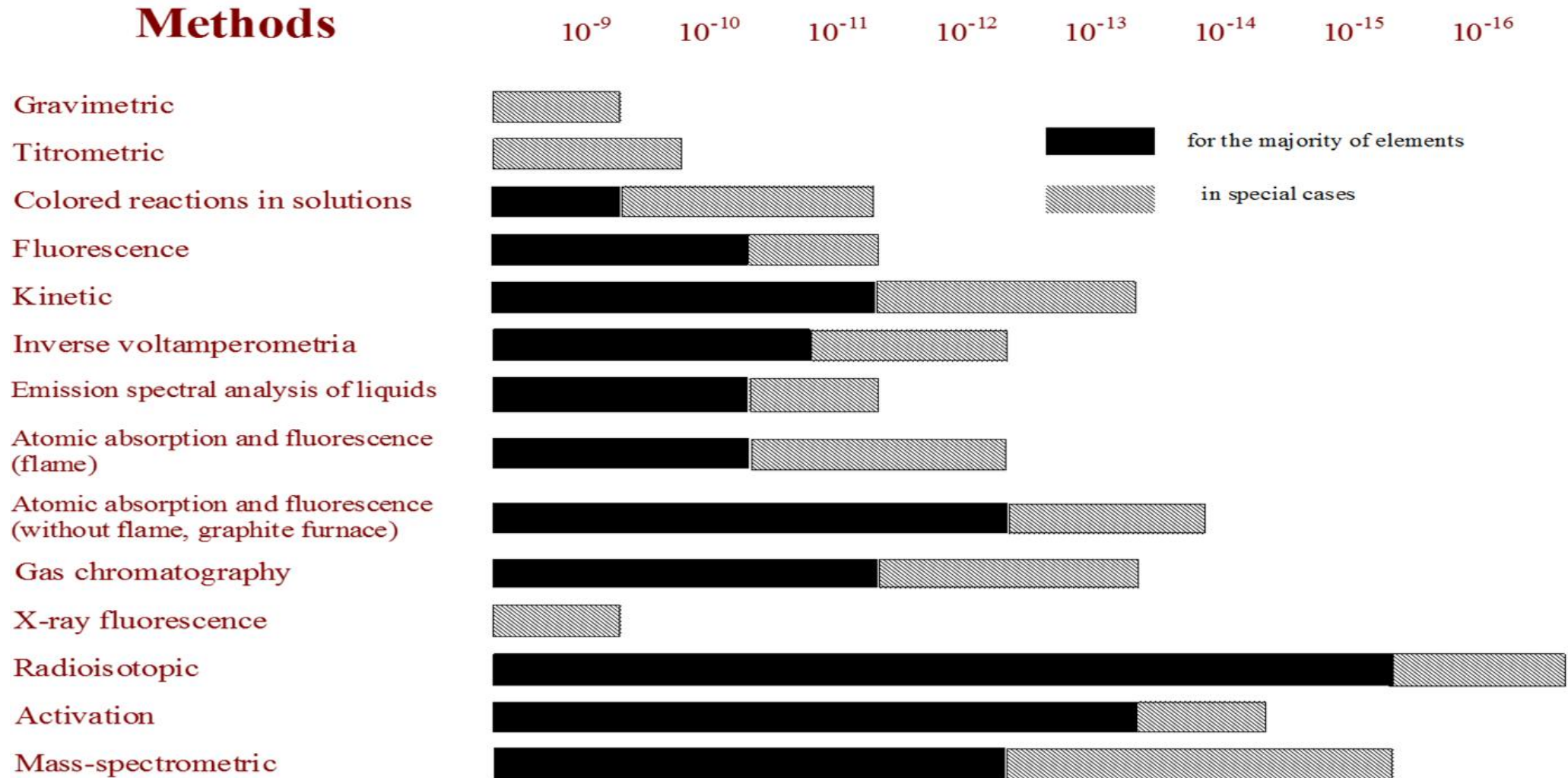
Instrumental neutron activation analysis (INAA) is used to determine the concentration of trace and major elements in a variety of matrices. A sample is subjected to a neutron flux and radioactive nuclides are produced. As these radioactive nuclides decay, they emit gamma rays whose energies are characteristic for each nuclide.

Elements Obtained By NAA

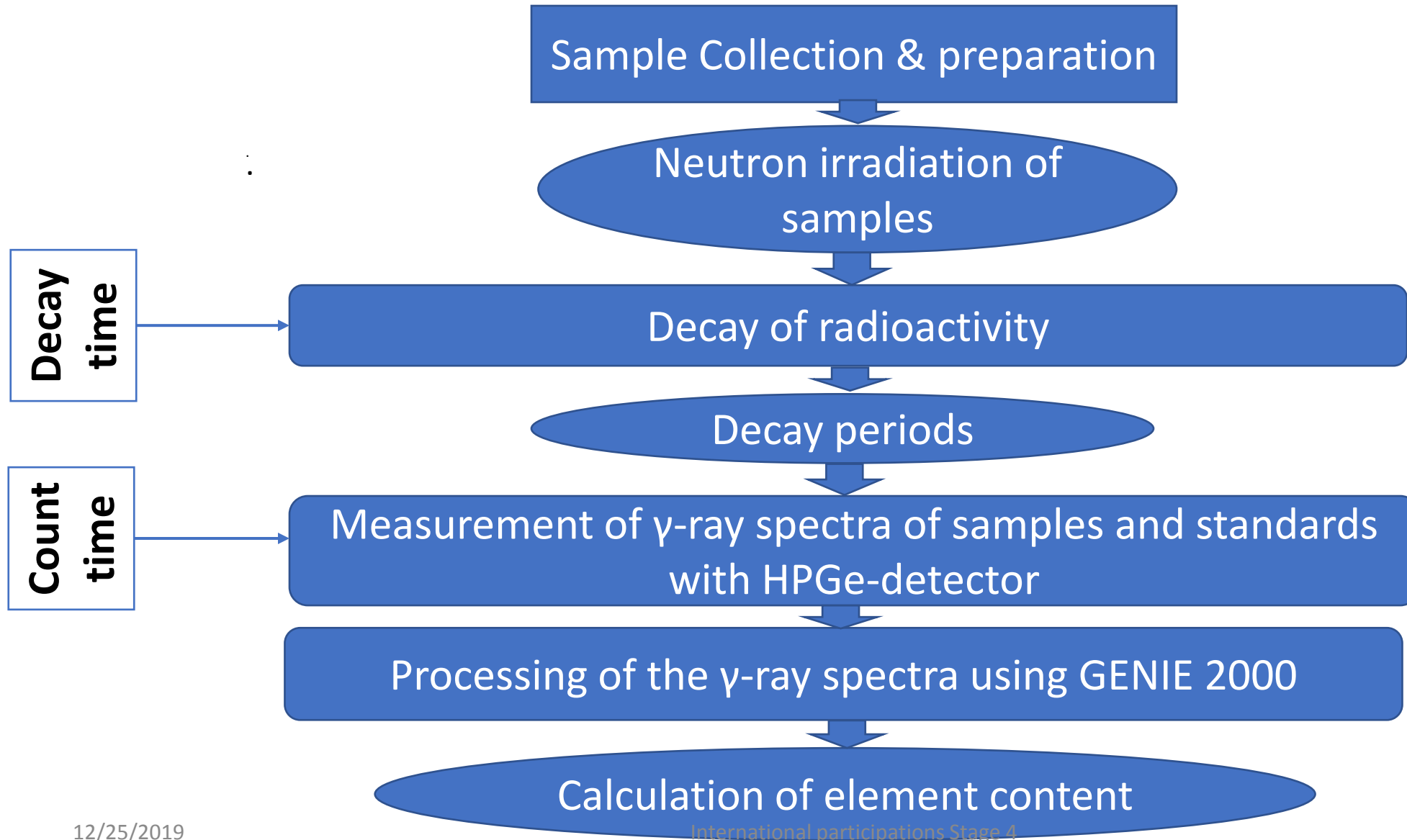
H																He	
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**											Rf	Db	Sg	Bh	Hs
		* Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
		** Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw		

How Powerful is this Analytical Technique?

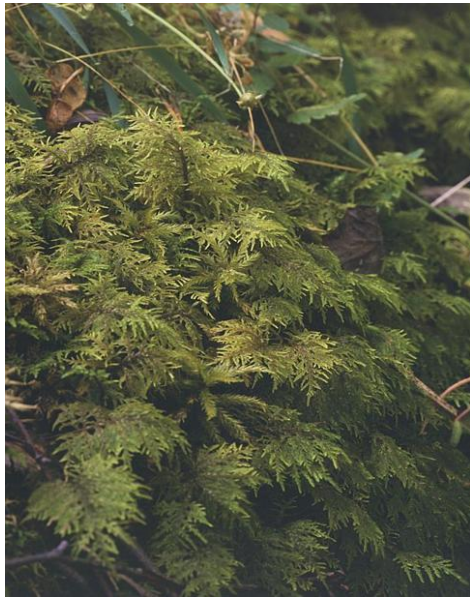
Absolute detection limit, g



Measurement of content of samples



Sample Collection



Moss



Annual Segments



Moss collection



Sediments

Soil



Sample Information programs

New sample acceptance

Country-Client-Year-Set ID-Set index Sample ID
ZA | 09 | 17 | 13 | m | 31

Client sample ID: 30
Sample type: soils

Latitude: _____ Longitude: _____

Collection place: Nigeria

Cupboard: _____ Box: _____ Received by: _____

Notes: SOS 41T

Sample preparation:
 cleaning
 drying
 evaporation
 freeze(drying)
 homogenizing
 pelletization
 fragmentation

Determined elements: all elements
 halogens
 heavy metals
 short-lived
 long-lived

Separate elements:
 F Cu In Tm
 Na Zn Sn Yb
 Mg Ga Sb Lu
 Al Ge I Hf
 Si As Cs Ta
 S Se Ba W
 Cl Br La Re
 K Rb Ce Os
 Ca Sr Pr Ir
 Sc Y Nd Pt
 Ti Zr Sm Au
 V Nb Eu Hg
 Cr Mo Gd Th
 Mn Ru Tl U
 Fe Pd Dy
 Co Ag Ho
 Ni Cd Er

Buttons: Save sample, Close, Fill in from file

Sample preparation

Country-Client-Year-Set ID-Set index
ZA | 09 | 17 | 13 | m

Sample ID	Client sample ID	Cleaning	Drying	Evaporation	Freeze drying	Homogenizing	Pelletization	Fragmentation	Weight SLI, g	Weight LLI, g	Sample preparation date	Maked
01	1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.1039	0.1083	13.02.2017	Yushin N.S
02	2	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0956	0.1082	13.02.2017	Yushin N.S
03	3	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0967	0.0961	13.02.2017	Yushin N.S
04	4	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.1043	0.1162	13.02.2017	Yushin N.S
05	5	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.1042	0.1033	13.02.2017	Yushin N.S
06	6	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.1045	0.0993	13.02.2017	Yushin N.S
07	7	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.1011	0.1046	13.02.2017	Yushin N.S
08	8	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	0.0916	0.0964	13.02.2017	Yushin N.S

Buttons: Check selected 'Cleaning', Check selected 'Drying', Check selected 'Evaporation', Check selected 'Freeze Drying', Check selected 'Homogenizing', Check selected 'Pelletization', Check selected 'Fragmentation', Fill in weights from file, Check selected 'Maked by', Select all rows, Save, Close

NAA DataBase - 5.8.9.0 iiz

Samples in NAA DB: 11539 tple sets

Country code	Client ID	Year	Sample set ID	Sample set index
RS	05	17	26	z
RU	33	17	27	a
GR	01	17	28	b
FR	01	17	29	c
PL	08	17	30	d
MD	01	17	31	e

Buttons: New sample set, Viewing set, Select sample set

Color	Description
pink	sample set accepted
light blue	sample preparation carried out
yellow	irradiation SLI
orange	irradiation LLI
green	SLI or LLI plus results
light green	SLI and LLI plus results
white	Show all

SRM sets:

Name	Number	Type	Weight, g	Purchasing date
Si	01	metal	0.02	01.11.2016
SI1	01	soil	10	21.12.2012
Tc	01	metal	1	23.03.2015
W	01	metal	5	23.03.2015

Monitor sets:

Name	Number	Type	Weight, g	Purchasing date
Zr	05	foil	15.89	19.01.2010
Zr	06	foil	15.89	19.01.2010
Zr	07	foil	14.76	19.01.2010
Zr	08	foil	14.76	19.01.2010

Buttons: Refresh, Physical environment, Search, Close

Фильтрация списка партий: Выберите поле для фильтра, Выберите тип фильтра

Информация о выбранной партии: Страна: Moldova, Организация: Institute of Microbiology and Biotechnology, Фамилия: Zinivovscaia, Кол-во образцов: 18, Тип образцов: vegetation

Дата КЖИ: 17.05.2017, Дата ДЖИ: 19.05.2017, Обработчик:

Results: SLI log: 18.05.2015, 09.12.2015; LLI log: 04.04.2017, 07.04.2017, 10.04.2017

Buttons: Select SLI irradiation log, Select LLI irradiation log, New SLI irradiation log, New LLI irradiation log

Buttons: New SRM set acceptance, Select SRM set, New monitor set acceptance, Select monitor set

Sample preparation:

- Samples air-dried and cleaned from roots of plants and wastes
- 3 g of the sample were weight and homogenized by an agate ball mill in pellets



12/25/2019



International participations Stage 4



19

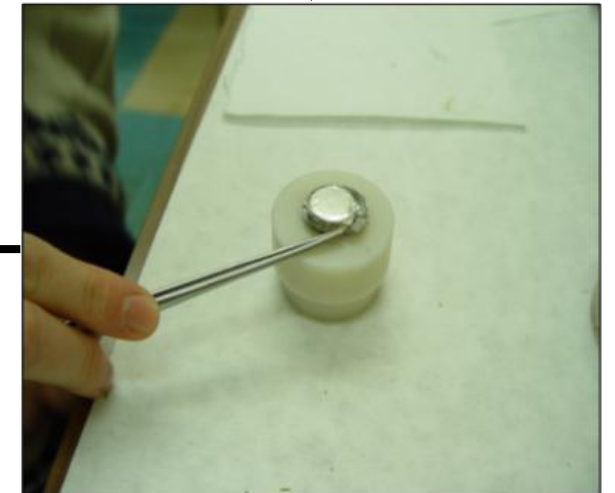
Sample Packing:

- The weight of the sample was then calculated and recorded by a weight software tool.
- Moss samples wrapped in polyethylene bag and aluminum pan for short- and long-lived irradiations respectively.

- Samples placed in transport capsules

- Short-lived isotopes - samples irradiated for 60

- Long-lived isotopes – samples irradiated for 3



Irradiation of Samples

- By using the pneumatic system the sample is sent to the reactor to be irradiated
- The short lived sample is irradiated for 60 s for soil and sediments. Whereas, moss for 180 s. the measurement is nearly 15 mins.
- The long-lived irradiation is 3 days and 3-4 days for decay and measured for 90 mins.



The practical stages of Irradiation in REGATA



Control panel

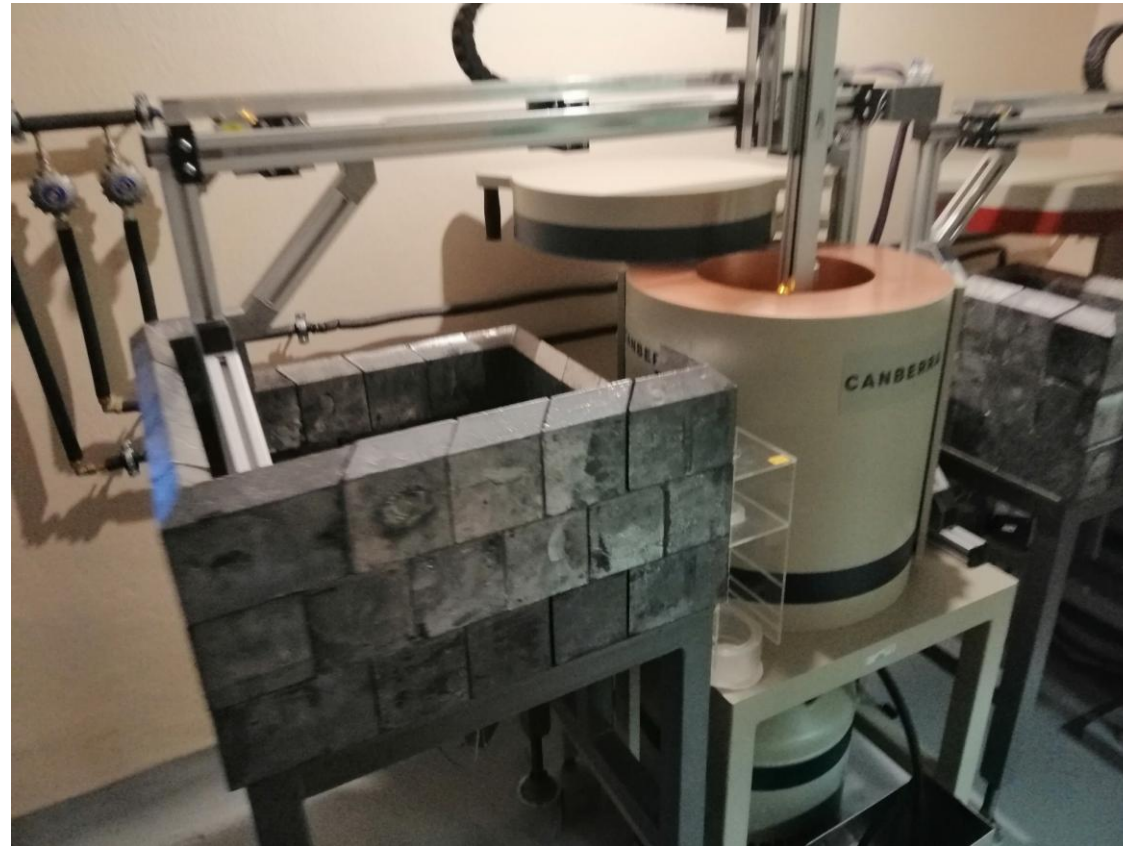


“Hot” cell



Detection of gamma ray

- By using the HPGe detector we can get the gamma spectrum of the sample

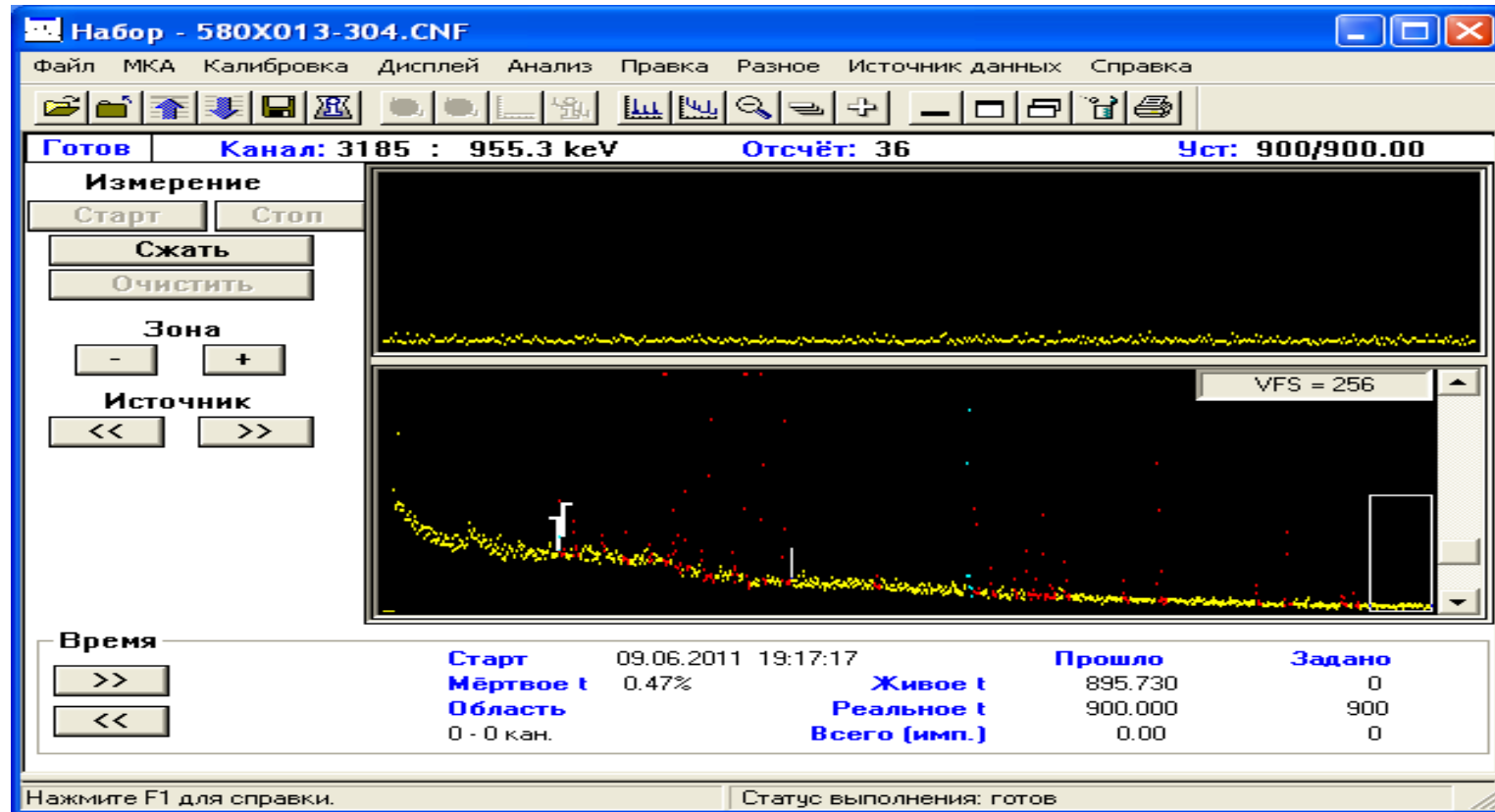


Analysis of gamma spectrum

➤ GENIE 2000

- the program allows minimizing human involvement in routine long-term measurements of the spectra of the induced activity
- simultaneous measurements are conducted

By using this program we can evaluate the activity of each element in the sample



Then we can determine the concentration of each element by using the con. Calculation program

Standart name	Nuclide name	Nuclide ID confidence	Wt mean activity, uCi/gram	Uncertainty, %	Passport concentration, mg/kg	Passport uncertainty, %	Mean-square error, %
2710	NA-24	0.995	5.31E+03	4.94	1.14E+04	5.30	7.24
1633e	NA-24	0.976	6.37E+02	6.94	1.71E+03	3.60	6.87
1547	NA-24	0.994	1.44E+01	14.10	2.40E+01	8.30	16.36
1547	MG-27	0.995	1.36E+01	2.92	4.32E+03	1.90	3.48
1633e	MG-27	0.976	1.16E+02	3.36	4.98E+03	10.40	10.93
2740	MG-27	0.993	9.00E+01	6.75	8.53E+03	4.90	7.55
2710	AL-28	0.876	1.20E+04	2.43	6.44E+04	1.20	2.71
1633e	AL-28	0.945	1.95E+04	2.44	1.33E+05	4.60	5.19
1547	AL-28	0.946	4.22E+01	2.58	2.40E+02	3.20	4.14
1547	CL-38	0.941	1.92E+01	5.04	3.60E+02	5.30	7.31
1547	K-42	0.991	1.11E+03	5.61	2.43E+04	1.20	5.74
1633e	K-42	0.974	7.22E+02	17.54	1.77E+04	3.70	17.90
1547	CA-49	0.992	1.34E+01	7.46	1.56E+04	1.30	7.57
1633e	CA-49	0.992	1.10E+01	9.37	1.37E+04	2.90	9.84
2740	CA-49	0.974	1.30E+01	10.04	1.26E+04	2.40	10.29
1633c	TI-51	0.982	2.30E+01	3.53	7.24E+03	4.10	5.41
2740	TI-51	0.984	1.03E+01	14.36	2.93E+03	3.60	14.78
1633c	V-52	0.92	4.81E+02	2.80	2.86E+02	2.80	3.96
2740	V-52	0.952	1.52E+02	4.25	7.66E+01	3.00	5.20
1547	V-52	0.988	5.00E+01	12.20	3.70E+01	8.10	14.64
2710	MN-56	0.989	5.69E+04	3.81	1.01E+04	4.00	5.52
1633e	MN-56	0.967	1.05E+03	4.27	2.40E+02	1.40	4.60

Joint projects with Egypt

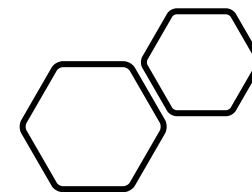
Projects:

- 1st Phase**
 - **Assessment of the environmental situation in the basin of the River Nile using nuclear and related analytical techniques (2011-2014).**
- 2nd Phase**
 - **Environmental studies in Egypt using neutron activation analysis and other analytical techniques (2015-2018).**
- 3rd Phase**
 - **Assessment of the environmental situation in the marine ecosystems in Egypt using neutron activation analysis and other analytical techniques (2018-2020).**
- 4th Phase**
 - **An announcement of new proposals are ready posted on the site of ASRT- Egypt**

Social program



International participations Stage 4



**Thank
you for
your
attention**

