

Neutron activation analysis in mid-21st century at DNS-IV of FLNP JINR

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Workshop: Advanced ideas and experiments for the new Dubna Neutron Source (DNS-IV). Related moderators and infrastructure (December 6-8, 2018, Dubna, RF)

Prof. **Amares CHATT** (Canada) – President of International Committee of Activation Analysis (ICAA); former Director of SLOWPOKE reactor in Dalhousie University in Canada (1976-2011)

Prof. **Eiliv STEINNES** (Norway) – founder of epithermal neutron activation analysis (JEEP II reactor at Kjeller near Oslo)
Honorable Doctor of Sciences at JINR since 2004

Prof. **Peter BODE** (The Netherlands) – Reactor Institute Delft (RID) at Delft University of Technology, Netherlands

“...Best regards and congratulations to your bright colleagues that did the pre-design of this fascinating neutron source concept”

Neutron Activation Analysis: A Primary (Ratio) Method to Determine SI-Traceable Values of Element Content in Complex Samples



Peter BODE
Delft University
of Technology
The Netherlands



Robert GREENBERG
National Institute of Standards
and Technology, NIST
USA



Elisabete FERNANDES
Univer. de Sao Paulo Centro de
Energia Nuclear na Agricultura
Brazil



Marina Frontasyeva

40.53 · Associate Professor · [Edit](#)

Projects (18)

Research items

All (426)

Article (287)

Book (25)

Chapter (13)

Conference Paper (72)

Patent (2)

Data (21)

Technical Report (3)

by December 2019

RG Score ⓘ
40.53

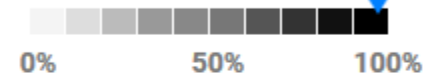


Breakdown:

- 99.83% Publications
- 0.00% Questions
- 0.00% Answers
- 0.17% Followers

Percentile:

Your score is higher than 97.5% of ResearchGate members'.



h-index ⓘ
32

h-index
26

excluding self-citations

Top *h* cited research:

Mosses as biomonitors of atmospheric heavy metal deposition: Spatial patterns and temporal trends in Europe ...

Article · Oct 2010 · Environmental Pollution

Our experience: pneumatic system; automated data management system (DATABASE)

Sector NAA & AR: ~ 35 persons

Male : Female ~ 50% : 50%

Mature age at 2035

PhD Dmitriy **Grozdov** (RF) (33)

PhD Inga **Zinikovskaya** (Romania, RF) (32)

Konstantin **Vergel** (RF) (36)

Boris **Rumyantsev** (RF) (27)

Pavel **Nekhoroshkov** (RF) (30)

Alexandra **Kravtsova** RF (30)

Margarita **Shvetsova** (RF) (26)

Yulia **Alexeenok** (Belarus) (34)

Omari **Chaligava** (Georgia) (24)

Daler **Abdusamadzoda** (Tajikistan) (27)

NAA at DNS-4

CENTRE OF COLLECTIVE USAGE

GEOCHI, GIN RAS, MSU...

GEOLOGY

EXTRATERRESTRIAL MATERIALS

NEW MATERIALS

MEDICINE and BIOLOGY

Nuclear Research Facilities

Neutron source: for what?

- **Neutron capture:**
 - Radioisotope production
 - Neutron activation analysis**
 - Neutron depth profiling
 - Geochronology
 - Boron neutron capture therapy
 - Prompt gamma analysis
 - Transmutation doping
 - Realization of positron beams
 - Cross section measurements
- **Neutron transmission:**
 - Radiography and tomography
- **Neutron scattering:**
 - Small Angle Neutron Scattering
 - Neutron diffraction, (de)polarization
 - Neutron reflectometry
- **Others:**
 - Material testing

Nuclear Research Facilities

How to make use of neutrons:

Bringing the target to the neutrons: irradiation facilities

Radioisotope/tracer production

Neutron activation analysis

Geochronology

Material testing

Transmutation doping

Bringing the neutrons to the targets; neutron beams

Neutron transmission imaging

Neutron diffraction

Neutron reflectometry

Neutron scattering

Neutron depolarization

BNCT

Neutron depth profiling

Prompt gamma analysis



Nuclear analysis at NBS and NIST

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Abstract

For more than 50 years, nuclear methods have been applied to chemical analysis at the National Institute of Standards and Technology. Radiochemical, instrumental, and prompt-gamma activation analysis are used, as well as neutron depth profiling and other techniques. The history of this group in methods development and the certification of Standard Reference Materials, among other applications, is reviewed.

Keywords Neutron activation analysis · Neutron depth profiling · Prompt-gamma activation analysis · Radiochemistry · Reference materials · Method development

NIST, USA (2018)

Future directions

...The development of **versatile time-stamped digital data acquisition** is making multi-detector gamma–gamma coincidence counting more generally applicable to elemental analysis [117–119]. Extensions to the **PGAA system** include a beam chopper to separate prompt from delayed signals [120, 121], **gamma–gamma coincidence counting** [120], and a relocated beam stop and other improvements for **improved background** and more **versatile sample positioning** [122, 123]...

The main advantage of NAA at DNS-4

mono-energetic or within a sufficiently narrow "energy window"

for determination of elements which can't be determined with the whole neutron spectrum

(для определения ряда элементов, которые с полным спектром нейтронов не определить)

$10^{14} \text{ n}/(\text{cm}^2 \cdot \text{s})$

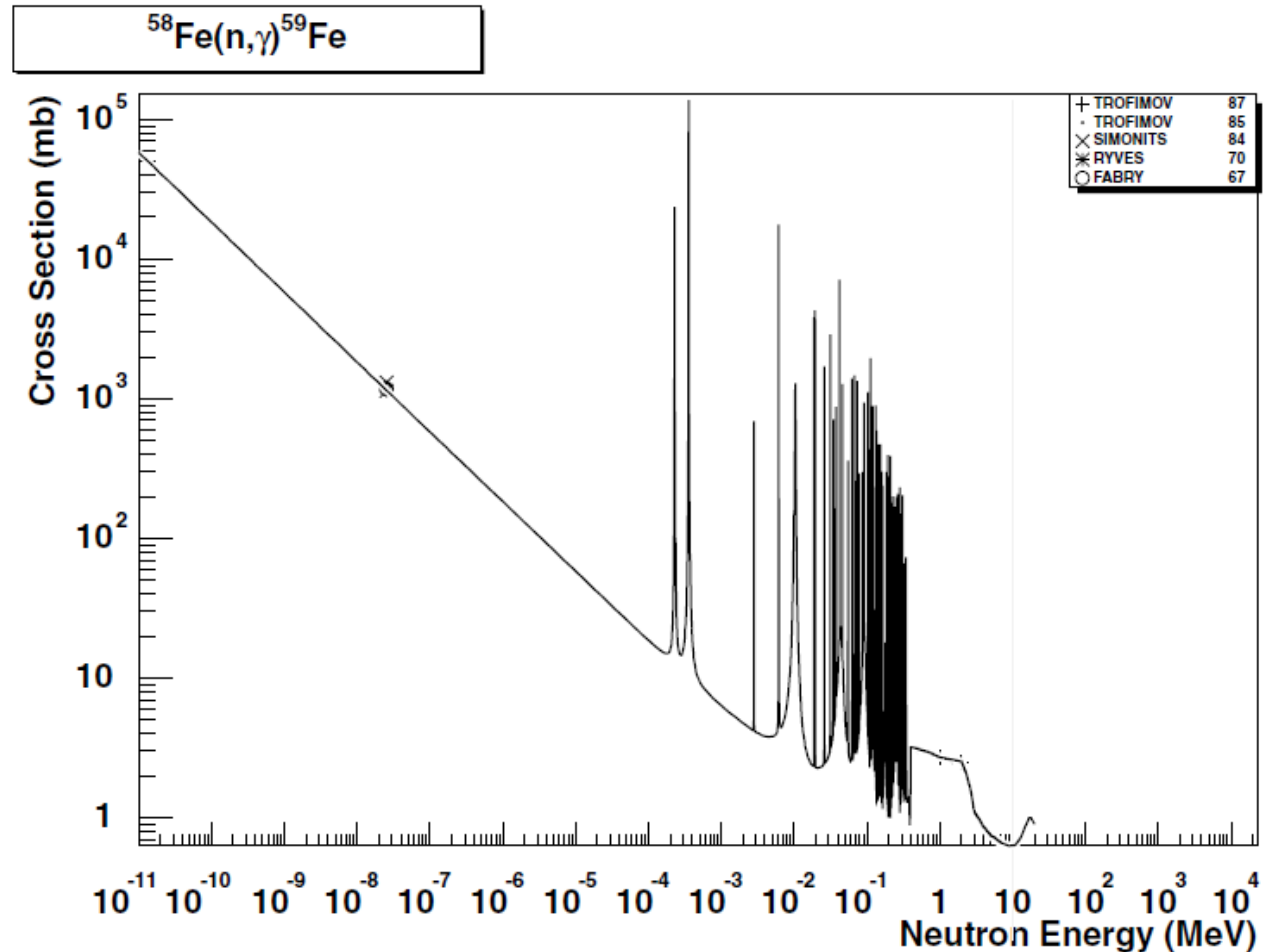
Low temperature in irradiation channels

Cross section

Expressed in 'barns' = 10^{-24} cm²

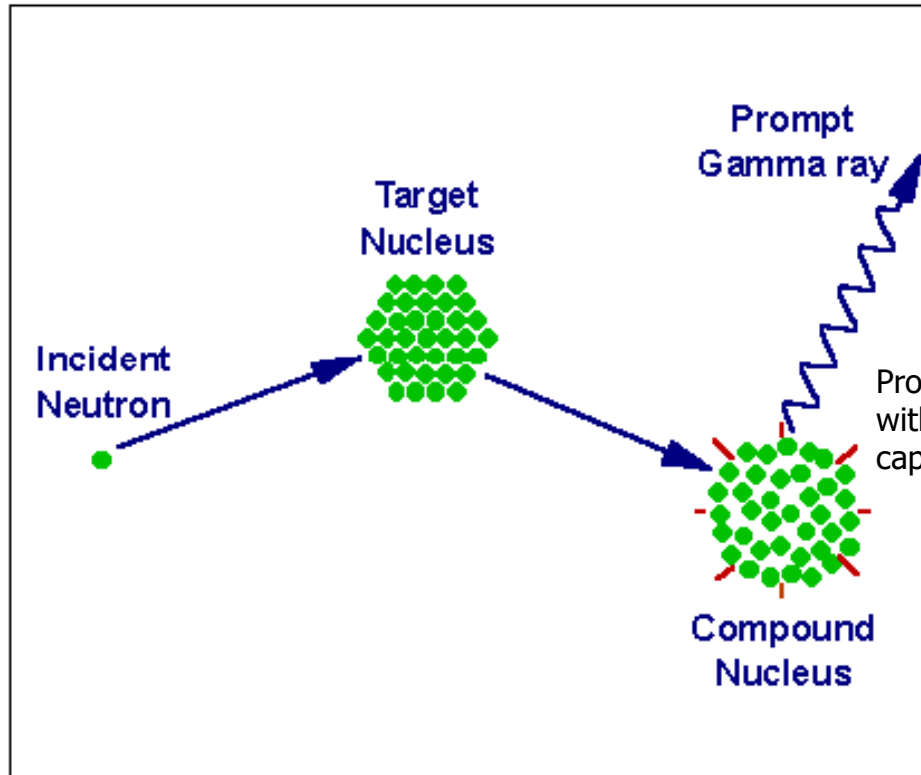
Cross section is
neutron energy dependent

Low values compensated by
high reactor neutron fluence rates
($10^{12} - 10^{15}$ cm⁻²s⁻¹)



Neutron Activation Analysis

Nuclear Reaction



Measurement of gamma-rays emitted by the **de-excitation** of the **compound nucleus** after the nuclear capture :

Prompt-gamma analysis (PGA)

Prompt radiation emitted within $\sim 10^{-12}$ s after neutron capture

Neutron Activation Analysis

Measurement of the prompt gamma is measurement of the de-excitation of the compound nucleus, and not a measurement of the **activity** of the radionuclide produced;

As such, the IUPAC compliant term for the technique is

Prompt gamma analysis

and

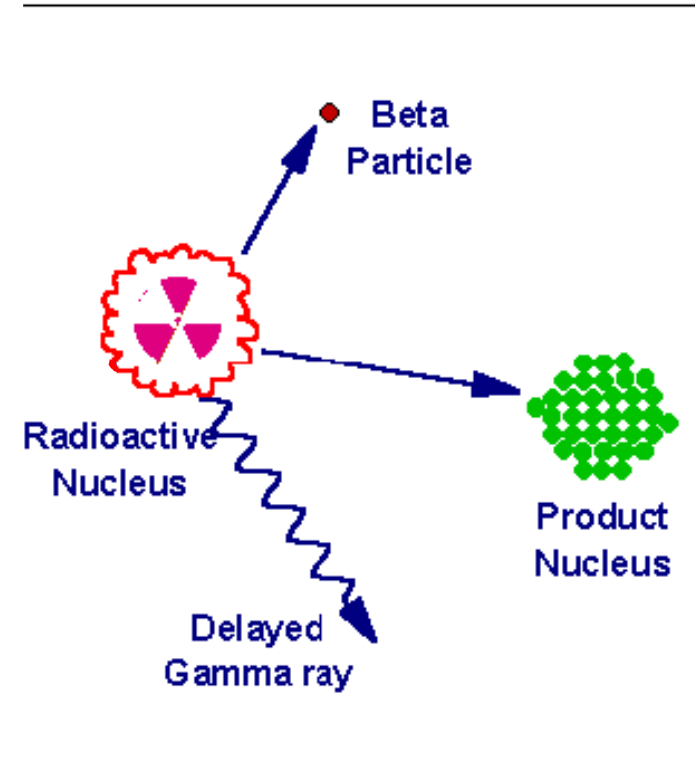
not **prompt gamma** (neutron) **activation** analysis
(see the definition of activation analysis).

Neutron Activation Analysis

Measurement of gamma-rays emitted by the 'activation' product and after the capture reaction is stopped:

"Normal" neutron activation analysis

Radioactive Decay



Nuclear reaction

Radioactive decay

