

PIXE and PIGE analysis of metallic and environmental samples at the 3 MV Tandetron of IFIN-HH

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Particle Induced X-Ray Emission (PIXE) is an ion beam analytical method based on inner-shell ionization of atoms by particle beam of MeV energy, followed by emission of characteristic X-rays. In our laboratory, PIXE could determine elements with $Z \geq 12$ in the investigated samples.

Particle Induced Gamma-ray Emission (PIGE) is able to determine light elements, such as B, Li, Na, Mg, Al, S, and Cl, based on (p,γ) , $(p,p'\gamma)$, or $(p,\alpha\gamma)$ nuclear reactions.

PIGE can also be applied to determine some medium and heavy elements (e.g. Cr, Mn, Fe, Co, Cu, Pt) based on (p,γ) , $(p,p'\gamma)$, and/or $(p,n\gamma)$ reactions.

Experiment proposal

Application of PIXE and PIGE techniques (3 MeV protons):

- To determine elemental contents in **nuclear grade graphite** using comparator **standards of similar matrix**, prepared as thick targets from high purity graphite and chemical compounds of elements to be determined (attention is paid to possible spectral interferences and overlap reactions).

The elements of interest for PIGE in graphite samples are Li, F, Na, Mg, Al, Si, P, Cl, S, Cr, Mn, Fe, and Cu. Except for Li and F, these elements can also be measured by PIXE, in addition to K, Ca, Ni, and Zn.

- To measure **excitation functions** for γ -rays yielded by PIGE on various comparator standards (metallic and environmental matrix) to determine $E_{1/2}$ for a certain element ($E_{1/2}$ is proton beam energy corresponding to half γ -ray yield); $E_{1/2}$ value is needed for stopping power corrections in the case of thick targets.

- To investigate different types of **thin target samples** using a new experimental set-up; biological samples (e.g. animal tissue and vegetation) are prepared by chemically digestion (Y is added as internal standard).

Detectors:

- For PIXE (X-ray detection): IGLET-X-06135-S High Purity Germanium (diameter 6 mm, depth 6 mm), with Be window of 0.0127 mm, placed in the reaction chamber.

- For PIGE (γ -ray detection): GEM10P4-70 High Purity Germanium (1.75 keV FWHM at 1.33 keV of ^{60}Co).

Quantitative analysis:

PIXE: Software program GUPIX (Guelph PIXE).

PIGE:

- Relative method, by using comparator standards.

$$c_T = (Y_T/Y_S) \cdot (S_T(E_{1/2})/S_S(E_{1/2})) \cdot c_S$$

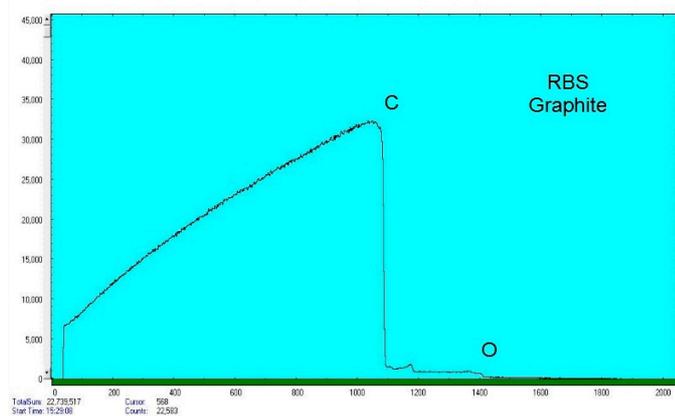
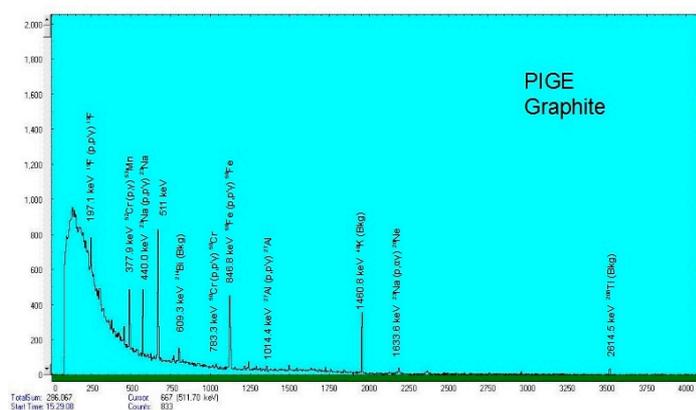
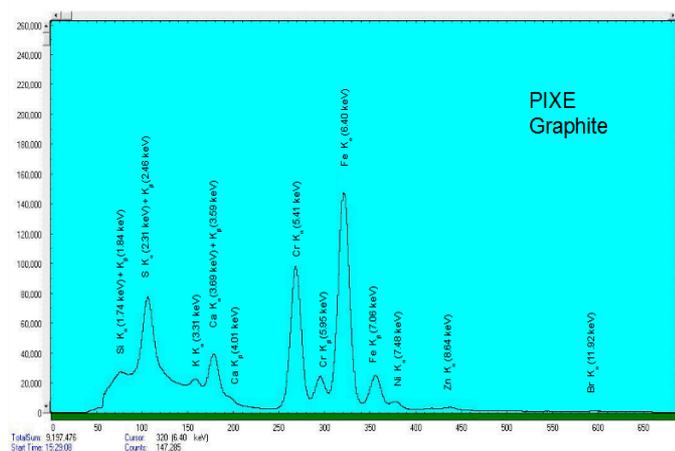
c_T and c_S are the element concentrations in sample and standard, respectively.

Y_T and Y_S are element yields for sample and the standards, respectively, normalized to the accumulated charge of the incident protons.

S_T and S_S are stopping powers for the proton energy $E_{1/2}$ ($E_{1/2}$ is defined as $Y(E_{1/2}) = Y(E_p)/2$).

- ERYA code (Emitted Radiation Yield Analysis) [1] (in progress), could be used in the future as a standard-free method for PIGE analysis on thick targets.

Example of spectra measured at the 3 MV Tandatron of IFIN-HH [2]:



References

- [1] P. Dimitriou, A. Pedro de Jesus, Summary Report 3rd Research Coordination Meeting Development of a Reference Database for Particle-Induced Gamma ray Emission (PIGE) Spectroscopy, IAEA Headquarters, Vienna, Austria, 7 – 11 April 2014, INDC(NDS)- 0625, <http://www-nds.iaea.org/publications>.
- [2] A. Pantelică, D. G. Ghita, D. Păceșilă, P. Ionescu, A. Scarlat, M. Drăgușin, PIXE and PIGE analysis of nuclear graphite, IBWAP-2014 Conference, 2-7 July 2014, Constanta, Romania.

BEAM REQUEST at Bucharest 3 MV TANDEM

Experiment Title: Application of PIXE and PIGE analytical techniques on nuclear graphite, metallic and environmental samples.

Experiment Responsible

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Short presentation of the scientific project (maximum four pages): see above

Beam time request (unit=8 hours)^{*}: 30 shifts; **Desired Period**^{*}:

Desired beam properties

Type^{*}: protons; Energy (MeV)^{*} 3; Intensity^{*} (p/nA): ~ 10 nA

Vacuum Requests^{*}: 10^{-6} torr

Special requirements for detectors, electronics, acquisition system:

Experimental set-up belonging to the PIXE-PIGE-RBS reaction chamber

Minimal information needed for the radiological risk evaluation :

- a) Source activity:^{*} -
- b) Use of open sources^{*}: -
- c) Estimate of the residual activity as a result of irradiation^{*}: -
- d) Means of storage/transportation for irradiated targets^{*}: -