NEUTRON ACTIVATION ANALYSES IN ROMANIA

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The history of activation analyses in Romania, starts way back in 1957 when a 2000 KW VVR-S Nuclear Reactor, and in 1958 when a U-200 Cyclotron have been put into function. The Institute for Atomic Physics has been developing its research activity around these two basic nuclear facilities. Soon after that a 30 MeV Betatron entered into operation and during the following years several 14 MeV neutron generators have been built or installed in various sites over the country. A king size High Voltage tandem Van de'Graaff accelerator joined later the nuclear facilities at the beginning of seventies.

At about the same time, the State Commettee for Nuclear Energy has organized nationwide Courses for Radioisotope Applications, training specialists in various fields as geology, biology, medicine, engineering, agriculture and so on, in the peaceful uses of nuclear energy. Teaching at this courses were the research workers and the university staff in this field. In this way the courses have become a kind of national forum debating the appropriate ways for a wide application of nuclear methods in technology, agriculture and the other related fields of science and economy. Soon has been found out that the most effective impact of the nuclear methods in the related fields, besids the overall problem of nuclear energy consists in the nuclear analyses and X-ray fluorescence methods.

THERMAL NEUTRON ACTIVATION ANALYSES (TNAA or INAA)

Historically the first thermal neutron activation analyses carried out at the romanian nuclear reactor, were in late fifties dealing with the analysis of the purity of silicon as semiconducting material. Since then, trace elements determinations in silicon has been a constant task for our researchers in various groups. The whole romanian industry of semiconducting devices, benefits greatly now of sistematic and routine purity analyses, as well as nuclear doping by irradiation of silicon lingots in the active core of our reactor.

In the early sixties, a pneumatic rabbit system has been set up into one of the horizontal channels of the reactor, enabling measurements on short lived isotopes. The transit time of a few seconds has allowed determinations on isotopes whose lifetimes range as short as tens of seconds. This rabbit system has been in operation along a period of more than twenty years and is still in service, being used by all the research groups dealing with thermal neutron activation analysis on short lived isotopes.

This rabbit system is also used for delayed neutrons measurements on the uranium content in ores. Taking into account the fact that lately, the demands for such analyses have greatly increased beyond the capacity of the present pneumatic system, a new and improved rabbit is under construction and is to be set up ontoanother horizontal channel of the reactor. This new air rabbit will have a six position revolving chargeable magazine and an intricate system of switches, to direct the sample in various positions, according to the irradiation programme. The whole system is designed to be before long controlled by the computer.

As one can see in the proceedings of this conference, a great deal of research and routine work is being carried on at this moment by an important number of working teams. As an example of some activities in thermal neutron activation analyses, the main domains will be be outlined as follows:

GEOLOGY AND MINING

Several groups in the Institute for Physics and Nuclear Engineering, in the Institute for Radiation Equipment, in the Institute for Geology and Geophysics and the Institute for Rare Metals have been and are doing research and routine work for the determination of useful minerals in ores, like iron, molibdenum, zirconium, platinic metals, uranium and thorium and all other metals as well as nonmetaliferous minerals like kaolins and refractory clays.

In the followings, a few works of this kind are mentioned:

- Determination of gold and platinic elements in Apuseni Carpathians ores.
- Analysis of some mineral salts by TNAA.
- Uranium contents measurements on U-phosphate ores.
- Neutron activation analysis of some zircon samples from the Apuseni Carpathians.
- Determination of alumina and silica contents in kaolins and refractory clays by a combined method of TNAA and FNAA.
- Rare-earths determinations in geological samples.

PROCESSING OF MATERIALS

The researchers of the Institute for Physics and Nuclear Engineering have carried out important work in co-operation with the scientists and technologists of the industry in the study and production of high purity and/or special materials. Units like the Enterprise for Electronic Components and Semiconductors, the Institute for Research in Electronic Components, the Institute for Metalurgical Research, and many others, order routine analyses, or co-operate in research programmes for high purity studies, in solving acute technological problems.

Here are some examples of works performed in these co-operations:

- Neutron activation analysis of semiconductor silicon.
- Neutron activation analysis of high purity CaF_2, GeO_2, Bi_2O_3 and $(NH_4)_2MoO_4.4\ H_2O$.
- P.p.m. level cobalt content in special steels.
- Glass powder purity studies by INAA.
- INAA on high purity quartz.
- INAA on high purity graphite.

ENVIRONMENT AND BIOLOGY

Studies have been carried out in co-operation with institutes for healths, for biology and for food processing. Examples of works in this fields are as follows:

- Analysis of algae and marine sediments on the romanian coastline of the Black Sea.
- Study on the possibility of using algae as detectors for environmental pollution.
- Analysis of human hair content.
- Determination of oligoelements in human serum.

ARCHEOLOGY

A great deal of the analysis work is being carried on in co-operation and for the benefit of the history museums all over the country. Here are a few of the characteristic works of this kind:

- INAA of prehistorical copper objects.
- A correlation between the XRF and NAA methods in numismatic studies.
- NAA studies on middle age pottery.
- NAA characterisation of bizantyne glass wares.

INTERCOMPARISONS

One of the intercomparisons, our nuclear analysts have taken part in, were those organised by IAEA's Analitycal Quality Control Service. Our most recent participation is connected with the determination of 32 elements at the p.p.m. level in SOIL-7, a reference material prepared of a soil collected near Ebensee in Upper Austria. We are glad to report good results in comparing our determinations with the certified values of the AQC Service. In the past years the same kind of intercomparison participations have to be mentioned on rye flour, human hair, and mussel tissue materials.

The same group of our most outstanding analysts have taken part in an intercomparison organised by the Institute of Radioecology and Applied Nuclear Techniques of Kosice - Czechoslovakia, on reference materials realized from fly coal ashes.

An intercomparison among the balkan countries would greatly increase the connections and the co-operation of our laboratories.

EPITHERMAL NEUTRON ACTIVATION ANALYSES (ENAA)

The determination of uranium and thorium in ores with high Th/U ratios or high rare earth contents special problems arise in TNAA methods. The problem has been solved using epithermal neutrons for activation. Participation in a IAEA intercomparison on S-14, S-15 and S-16 reference materials, has shown how good this method can be in such difficult matrices.

FAST NEUTRON ACTIVATION ANALYSES (FNAA)

Three low energy accelerators are used as 14.1 MeV neutron sources, one of them entirely specialised on FNAA.

This one, installed in the Institute for the Technology of Radiation Equipment is provided with special equipment for oxygen and low mass elements determinations. This equipment consists in an air rabbit having two parallel ways, one for the unknown sample and one for the standard, with simultaneous irradiation and also simultaneous measurement at two large NaI(Tl) measuring heads, appropriately equilibrated.

This installation carries on routine measurements on the determination

of oxygen content in steels and aluminium.

Also theoretical nuclear model calculations are being used to extent the neutron data basis available for applications. This computational method is based on the statistical model (Hauser - Feshbach STAPRE code) and the pre-equilibrium decay geometry dependent model. Thus an accurate theoretical description of the fast neutron induced reactions is an useful alternate way to support FNAA.

CHARGED PARTICLES ACTIVATION ANALYSES (CPAA)

The posibility of bringing out into the air of a proton beam at the cyclotron, raised the possibility to install a gravitational sample changer at the end of a beam line and to perform mechanized analyses for protein determinations in grains. Protons of 14 MeV are being used and a (p,n) reaction on nitrogen helps to make the quantitative analysis of this element, that is closely connected to the protein content in grains. The installation, already in routine operations, analyses thousands of samples yearly, each sample meaning as container of about 4 cubic centimeters of wheat, barley, corn, sorgum or whetever other cereal.

I include in the domain of charged particles activation analysis, a very interesting method of determination of the profiles of hydrogen content in the surface layers of solids, that has been put into work at the tandem Van de'Graaff accelerator. It uses the isolated narrow resonances that usually occur in heavy ion induced reactions. For instance, the reaction

$$N\text{-}15 + H\text{-}1 \longrightarrow O\text{-}12 + He\text{-}4 + \text{gamma } (4.43 \text{ MeV})$$

has a cross section that is outside the resonance three orders of magnitude lower than on the peak. By bombarding the sample with N-15 ions of energy greater than the resonance (6,385 MeV) and detecting the resulting 4.43 MeV gamma rays by the help of a large volume NaI(Tl) detector, the distribution in depth of the hydrogen concentration is scanned, by gradually increasing the incident heavy ions energy. Interesting applications in microelectronics, special glasses industry, archaeology, silicon thin layers production, steel alloys and superconducting materials, have been found out and co-operation with those fields are in process of being established.

As the Collective for Nuclear Analyses has been organized in the Institute for Physics and Nuclear Engineering starting with the year 1980, one hopes that before long all the activities connected to nuclear analyses of all kinds, activation included, to be better co-ordinated and put on a more professional basis.