

# RAPID ANALYSIS OF NON-GAMMA RADIONUCLIDES USING THE "ANABET" SYSTEM

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## ABSTRACT

Analysis of radionuclides that do not emit a gamma ray has traditionally been a difficult task. Where complex mixtures of isotopes are present extensive chemical separation usually has to be performed prior to radiometric analysis in order to achieve proper identification and quantitative analysis of the isotopes of interest. The ANABET system (ANalysis of Alpha, Beta and Electron-capture radionuclide Technology) is a method for achieving the separation and quantitative measurement in a single step. To do this ionic constituents of the sample are separated by ion exchange chromatography, and the resulting fractions or "peaks" of separated nuclides pass sequentially through an on-line scintillation detector for quantitative measurement.

## INTRODUCTION

Nuclear power generation of electricity results in the production of various radioactive waste forms of which some are accumulated awaiting disposal and some are discharged into the environment. The control of radioactive wastes and discharges for the protection of the environment is dependent on being able to analyze for the radionuclide content. Many nuclides are easily measured and identified by their characteristic gamma emissions, but others which decay by alpha particle, beta particle emission or electron capture and have no associated gamma emission require complex chemical separation procedures before individual measurements can be made which exclude interference from other nuclides. The radiochemical methods used for such separations are time consuming and labour intensive.

ANABET (Analysis of Alpha Beta and Electron-capture radionuclide Technology) is a system developed for the rapid separation and analysis of mixtures of non-gamma emitting nuclides. Examples of such radionuclides are given in Table I.

## THE ANABET TECHNIQUE

The ANABET system has been developed, over two years, by the Central Electricity Generating Board (National Power Division) at Berkeley Nuclear Laboratories in Gloucestershire, UK. The technique is a combination of ion chromatography and flow through scintillation detection capable of analyzing for many ionic radionuclides such as alkali metals, alkaline earths, lanthanides and halides.

## OPERATING PRINCIPLE

The principle of operation is that nuclides are collected in an ion exchange pre-concentration step, and are then separated by ion chromatography. The output from the ion chromatograph is passed to an on-line scintillation counter, which provides a quantitative analysis of each nuclide as it passes through. Where very high sensitivity is required the ion chromatography separation can be used to produce a series of separated fractions, which can then be analyzed by off-line techniques. This is particularly applica-

TABLE I

Common Isotopes Unsuitable for Gamma Spectrometry

Nuclide	Decay (MeV)	Half Life (y)
<sup>14</sup> C	Beta, 0.2	5730
<sup>35</sup> S	Beta, 0.2	0.24
<sup>45</sup> Ca	Beta, 0.3	0.44
<sup>55</sup> Fe	ec, X-Ray	2.7
<sup>59</sup> Ni	ec, X-Ray	80,000
<sup>63</sup> Ni	Beta, 0.07	100
<sup>90</sup> Sr	Beta, 0.5	28.5

ble to alpha-emitters, which are inefficiently detected by the on-line method.

The development of sophisticated chromatographic elution systems has enabled the separation of nuclide mixtures into individual nuclide fractions. Although the systems are not designed for the analysis of gamma nuclides (which can be analyzed by gamma spectroscopy) possible interference from gamma emitters is avoided by clean separation. Two separate systems can be used to analyze for cationic nuclides (e.g. Cs, Sr, 3-d transition metals, lanthanides) and anionic nuclides (e.g. Cl, I, S, Nb, Tc)

## OPERATING PROCEDURE

The sample is first prepared by appropriate treatments (if necessary) to convert it to the form of an aqueous solution of the correct chemistry. The solution is then passed through the cation and anion pre-concentration columns and the effluent liquid is discarded.

It is not possible to generalise about the appropriate sample preparation, but within certain limits any sample which is, or can be converted to, aqueous solution can be analyzed. There are limits on the burden of non-radioactive ions which can be present if the concentrator column is used, and materials which would alter the chemistry of the ions during the separation process must be excluded or destroyed before the analysis. Nuclides must be in or con-

verted to the common ionic species in aqueous solution (e.g. chloride, sulphate,  $\text{Sr}^{2+}$ ).

The cation and anion fractions are then individually separated on the ion chromatograph by the elution programmes specially developed for ANABET. For on-line use the detector is packed with a solid scintillant. There is no need to mix in liquid scintillant - each individual nuclide causes a scintillation signal or "peak" as it passes through the detector. A conductivity detector can in some cases be used in series to provide simultaneous information about the chemical concentrations present.

Very rapid analysis (50 minutes) can be achieved on routine samples of a uniform type once the methodology of preparing that sample type for analysis has been formulated. Where high sensitivity is required the analysis time is longer, and in any case is likely to be determined by the time necessary for good counting statistics.

#### ACCURACY AND STATISTICS

The system has been developed with a very high degree of attention to the statistical treatment of errors. Unlike gamma spectroscopy the chemical loading could in principle affect the linearity of the calibration curve. The behaviour of each ion over three orders of magnitude working concentration range has been examined.

Low limits of detection are obtained using a concentrator column, where radionuclides from large sample volumes can be collected and concentrated for analysis. Typical limits using the concentrator column can be as low as 3/100th Bq per ml ( $3 \times 10^{-12}$  Ci per ml) for a 100 ml sample (Table II). Further sensitivity and greater accuracy can sometimes be obtained by collecting specific output fractions and counting in a conventional scintillation counter system.

#### APPLICATION

The technique has a wide field of application, some of which are listed below:

- Analysis of Fuel Pond Water and Reactor Water for isotopes such as  $^{55}\text{Fe}$ ,  $^{90}\text{Sr}$ ,  $^{45}\text{Ca}$  and  $^{63}\text{Ni}$ .
- Analysis of Radioactive Effluents.
- Analysis of  $^{90}\text{Sr}/\text{Y}$  without waiting for secular

equilibrium.

- Analysis of radioactive waste materials after suitable sample preparation.
- Preparation of samples for alpha spectroscopy.
- Analysis of samples for environmental radioactivity.

TABLE II

Dynamic Efficiency and Lower Limits of Detection for Some Common Nuclides

Radionuclide	Dynamic Efficiency	Typical Lower Limit of Detection (Bq)
$^{14}\text{C}$	0.900	
$^{35}\text{S}$	0.637	
$^{36}\text{Cl}$	0.913	3.5
$^{45}\text{Ca}$	0.998	3.1
$^{55}\text{Fe}$	0.349	8.9
$^{60}\text{Co}$	0.800	
$^{63}\text{Ni}$	0.342	9.1
$^{90}\text{Sr}$	0.997	3.1
$^{90}\text{Y}$	0.999	
$^{99}\text{Tc}$	0.825	
$^{129}\text{I}$	0.758	
$^{147}\text{Pm}$	0.626	
$^{151}\text{Sm}$	0.310	
$^{152}\text{Eu}$	0.800	

(Lower Limit of Detection determined with the statistical procedures of Nix et al., Nuclear Data Inc., 1984, as used by US Environmental Protection Agency. 5% Probability of Type 1 and Type 2 errors).

#### CONCLUSION

The ANABET System represents a significant advance in the methodology for analysis of radionuclides that do not emit a gamma ray. Rapid and accurate analysis can be achieved for many of the radionuclides commonly of concern in environmental measurements or radioactive waste management.

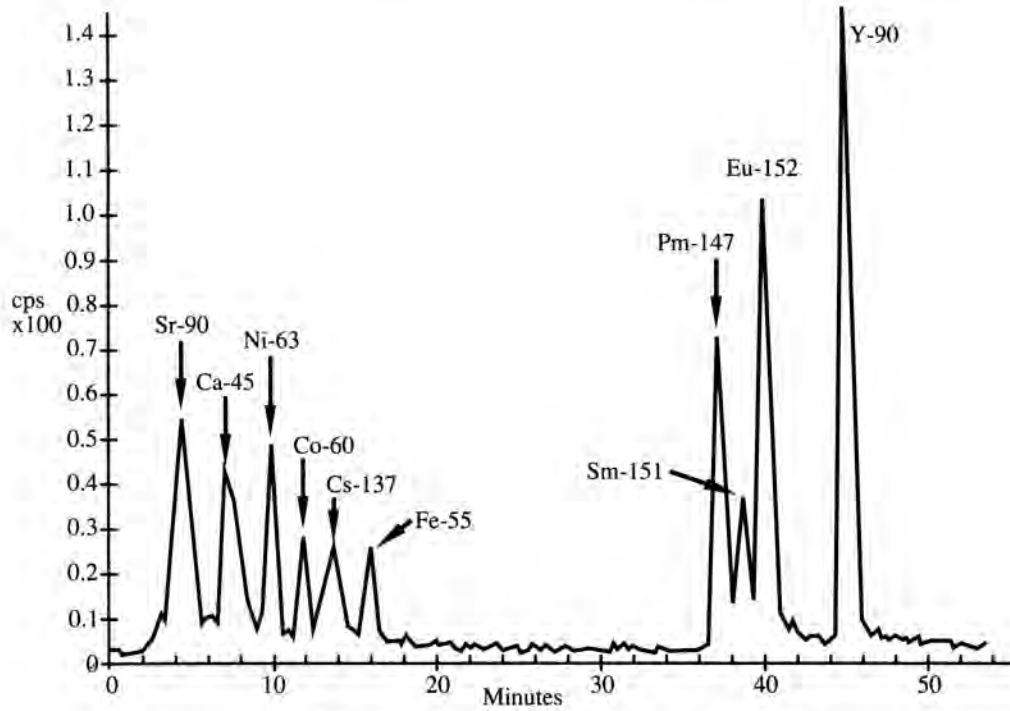


Fig. 1 A Typical Chromatogram of Cationic Nuclides.

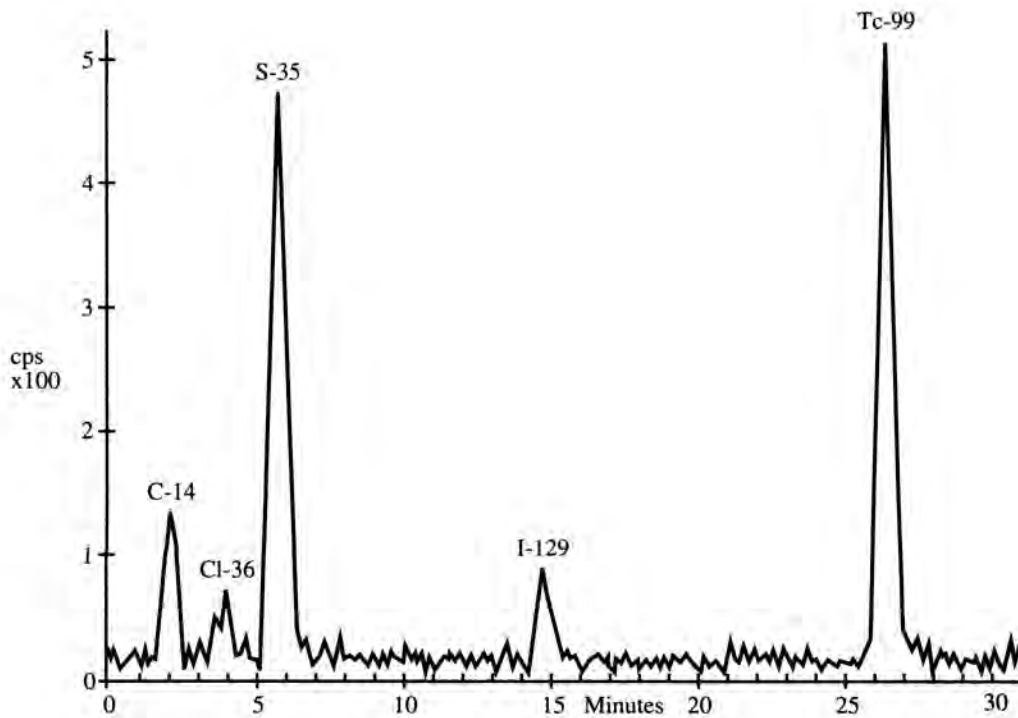


Fig. 2. A Typical Chromatogram of Anionic Nuclides.