14 MeV NEUTRON ACTIVATION ANALYSIS
APPLIED TO A NON-AQUEOUS FLOWING SYSTEM
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The feasibility and advantages of fast neutron activation analysis in a non-aqueous
flowing system, using economical irradiation techniques are outlined. The application
of the method to the determination in solution of elements producing isotopes with
half lives in the range 588 — 29.4 sec, the selection of the optimum flow rate to
minimise interferences for each element, and their limits of detection are also given.
A method for the prediction of the optimum flow rate, on a given system, for the
determination of any element producing an isotope of known half life is also given.

Introduction

The feasibility of neutron activation analysis in flowing systems, for a range
of elements, has been demonstrated by a number of authors, using both isotopic and
generator neutron sources. Little work has been published describing the
activation analysis of non-aqueous flowing systems, yet analysis in a non oxygen
containing (hydrocarbon) solvent is relatively uncomplicated by interferences
produced by activation of the solvent, and there are many potential applications
such as, for example, in the petroleum industry. Aqueous systems suffer the inher-
ent disadvantage of a solvent background consisting of a mixture of $^{16}$N ($T = 7.35$ sec) and $^{15}$N ($T = 600$ sec) from activation of the oxygen present; both
isotopes contributing to the large 0.51 MeV peak observed, whilst the Compton
continuum and higher energy peaks of $^{16}$N stretch from 7.12 MeV downwards.

The object of these investigations was to demonstrate the feasibility of routine
neutron activation analysis of non-aqueous flowing systems, using an economical
pulse technique where applicable. The solvent background from a variety of
hydrocarbons was first of all examined and as little difference was observed
between the more inflammable hydrocarbons, reagent grade colourless kerosine
was finally chosen as a suitable solvent for the present investigations. A flowing
system was then constructed of solvent resistant material, and the analysis of a
range of elements, giving product nuclei with varying half lives was attempted.
The results obtained demonstrated the feasibility of using economical techniques
for the activation analysis of a range of elements in hydrocarbon solvents.
Materials and method

A Kaman 1003A fast neutron generator, capable of generating $10^{11} \text{n} \cdot \sec^{-1}$ and a $75 \times 75 \text{ mm NaI(Tl)}$ crystal detector assembly coupled to a Laben 400 multichannel analyser were used in these investigations. A boron trifluoride counter coupled to a scaler and a ratemeter linked to a fairly fast pen recorder (chart speed $1.3 \text{ mm} \cdot \sec^{-1}$ balancing time at 95% of scale approximately 1 second) were used to monitor the output of the generator.

The flowing system described comprised a liquid reservoir connected to an irradiation cell with nylon tubing (6 mm internal diameter), which was coupled to a detector cell by narrower tubing (4 mm internal diameter). Liquids were forced round the system by nitrogen gas pressure; a needle valve and interchangeable flowmeters enabled a wide range of steady flow rates to be selected.

The irradiation cell (24 ml) was of soldered brass construction, cylindrical in section (100 mm diameter, 6 mm deep), with copper inlet and outlet pipes (5 mm internal diameter), and contained a brass double spiral (1 mm thick) so as to maintain, as far as possible, streamline flow through the cell. The demountable cell bottom was sealed by a PTFE gasket, the cell being clamped together between bolted dural plates. A hole in the upper plate, machined to fit the generator target cooling jacket provided positive location.

A three layer, nylon tubing (4.3 mm internal diameter) detector cell was wound on to a polythene former machined to crystal detector dimensions, so as to utilize the end face of the detector, as well as the sides. Layers were embedded in epoxy resin and the cell volume was 237 ml.

In these investigations a single pulse irradiation technique\(^\text{13}\) (resulting in short irradiations and hence in a relatively inexpensive procedure) was adopted except for the shortest half lives examined (<60 sec). After a steady flow rate had been achieved, the neutron generator was switched on, in our case by rapidly raising the accelerating voltage to the operating level for the duration of the irradiation. After a pre-determined delay, the total activity of the active plug of liquid passing through the detector cell was measured by counting for a pre-set time. The irradiation time was selected to be consistent with the flow rate (and hence transit time between irradiation and detection). The delay and counting times were determined using the multichannel analyser in the multiscaler mode and investigating the variation in the activity of the flowing solution in the detector cell with the time elapsed from the end of the irradiation. For half lives below 60 sec irradiation at constant flux was used with the subsequent counting of the saturation activity in the solution.

The total BF\(_3\) count recorded during the irradiation was taken as being proportional to the total number of neutrons passing through the irradiation cell. The dimensions of the system ensured that streamline flow conditions prevailed over the range of flow rates investigated, the decaying active plug of liquid being drawn out to a parabolic activity profile.

Irradiation of the chosen hydrocarbon solvent, colourless kerosine in the

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