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PRELIMINARY COMMUNICATION

Indirect neutron absorptiometry

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It is possible to utilise the absorption of neutrons for analysis just as the absorption of electromagnetic radiation is used for other methods. In the past few years, some work of this type has been reported in the literature[1–6] but in general this method has had little acceptance except for the analysis of boron.

The tendency for an element to absorb thermal neutrons is indicated by a "thermal neutron absorption cross-section". Table I lists these cross-sections for the 20 elements which are the best neutron absorbers. It is interesting to note that most of these elements, particularly those with the highest cross-sections, are rather exotic elements not often encountered in the majority of analytical laboratories.

TABLE I. THERMAL NEUTRON ABSORPTION CROSS-SECTIONS[7]

Element	Cross-section, *barns*
Gadolinium	46,000
Samarium	5,500
Europium	4,600
Cadmium	2,550
Dysprosium	1,100
Boron	750
Iridium	430
Mercury	380
Indium	190
Rhodium	150
Thulium	118
Hafnium	105
Lutetium	108
Gold	98
Rhenium	84
Lithium	71
Holmium	64
Silver	62
Neodymium	46
Terbium	44

The application of neutron absorptiometry to the analysis of boron appears to have filled a need for a rapid, non-destructive, and on occasion "in-line"[8,9] method for macro amounts of this element. From Table I we see, however, that there are several elements for which the method would be much more sensitive and for which there would be less potential interference. Indeed, the element gadolinium would be some 60 times more sensitive than boron and almost 10 times better than any other element in the periodic system.

We are studying a technique for utilising this unique neutron absorption property in the analysis of common elements such as fluorine. This technique, which we call "Indirect Neutron Absorptiometry", is analogous to radiometric analysis in that neutron absorbing elements are utilised in the determination of elements which do not themselves absorb neutrons.

In a typical procedure, fluoride ions in solution are precipitated with an excess of gadolinium ions. Gadolinium ions adsorbed on the precipitate are washed off or eliminated by a dissolution and reprecipitation. Neutron absorption measurements are then made either on the dissolved precipitate or on the liquid residue. The neutron-absorbing gadolinium measured thus represents a stoichiometric amount of fluoride.

The sensitivity obtainable is quite dependent upon the geometry of the neutron source, sample container and neutron detector within the assembly. At present a modified Nuclear-Chicago Neutron Howitzer is being used with a 5-curie plutonium-beryllium source. This permits a bottled liquid sample to be placed between the source and the detector. We are, however, assembling a modified apparatus in which the sample solution is contained in a Marinelli-type beaker surrounding the small neutron detector tube. This should eliminate much of the scattered neutron radiation which now reaches the detector without "seeing" the sample. By improving the geometry we should also increase the sensitivity of the method.

Preliminary results indicate that the idea of indirect neutron absorptiometry is sound and that values reproducible to within a few per cent can be obtained rapidly by this technique. Even with relatively poor geometry it is possible to analyse for milligram amounts of fluoride and it should be possible to improve this sensitivity with the new apparatus being assembled. This method should also be applicable to the analysis of other ions which form insoluble compounds with gadolinium. It may even be possible to analyse for potassium as the tetraphenylborate by this technique.

Indirect neutron absorptiometry is a non-destructive method which utilises encapsulated sources only and does not require handling of radioactive solutions. In this respect it presents no more problems than the thousands of thickness, density and level gauges used routinely in industry at the present time. Furthermore, it utilises the same principles of absorptiometry already so familiar to the analytical chemist—only the type of radiation is different.

Work is continuing on this method to elaborate the areas of analysis in which it will be most useful. Detailed evaluation of procedures and equipment will establish limits of sensitivity, as well as point up problems of contamination, manipulation, and the like. It appears now, however, that this indirect approach to neutron absorption has considerable potential for the average analytical laboratory.

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Summary—A preliminary account is given of the use of the neutron absorption of suitable elements (such as gadolinium) for the determination of non-absorbing elements (such as fluorine) by measuring the absorption of a dissolved precipitate (in the case quoted, gadolinium fluoride). This indirect determination by neutron absorption gives reproducible results rapidly and non-destructibly. The applications of the method are being studied.

Zusammenfassung—Eine Vorläufige Mitteilung über die Anwendung von Neutronenabsorbtion wird gegeben. Geeignete Elemente wie z.B. Gadolinium zönnen zur Bestimmung von nichtabsorbierenden Elementen z.B. Fluor herangezogen werden, indem die Absorbtion eines Niederschlages (im Beispielsfalle Gadoliniumfluorid) gemessen wird. Die Indirekte Bestimmung durch Neutronenabsorbtion gibt rasch reproduzierbare Resultate. Weitere Anwedungsmöglichkeiten der Methode werden studiert.

Résumé—L'auteur donne un compte-rendu préliminaire sur l'utilisation de l'absorption des neutrons par des éléments convenables (tels que le gadolinium) pour le dosage d'éléments non absorbants (tels

que le fluor) par la mesure de l'absorption d'un précipité convenable (dans le cas cité, fluorure de gadolinium). Le dosage indirect par absorption de neutrons donne rapidement des résultats reproductibles et n'altère pas l'échantillon. Les applications de cette méthode sont étudiées actuellement.

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