(ii) Only metals from the Groups IVA-VIA of the Periodic System give rise to this structure type. The phases include a chalcogen element in combination with metals from Group IVA; a pnigogen element in the case of metals of the Group VIA; while the Group VA metals form both pnictides and chalcogenides. Using valences corresponding to the periodic group numbers appropriate to the components, the structure type occurs in the valence electron concentration range 4.88 – 5.44 per atom.

(iii) As is perhaps to be expected, the relative sizes of the component atoms appear to exert control over the appearance of phases with this structure type. Thus the larger metal atoms (e.g. Zr) combine with the larger non-metal atoms Te and/or Sb, while the smaller (e.g. V) combine with S, Se, and/or As. As a limiting case of this trend it is to be noted that Cr does not form any phase of this class.

1. Hahn, H. and Ness, P. Z. anorg. allgem. Chem. **302** (1959) 136.
2. Grønvold, F., Kjekshus, A. and Raaum, F. Acta Cryst. **14** (1961) 930.
3. Raaum, F., Grønvold, F., Kjekshus, A. and Haraldsen, H. Z. anorg. allgem. Chem. **317** (1962) 91.
4. Grønvold, F., Haraldsen, H., Pedersen, B. and Tufte, T. Rev. Chim. Minér. **6** (1969) 215.
5. Røst, E. and Gjertsen, L. Z. anorg. allgem. Chem. **328** (1964) 299.
6. Meissner, H.-G. and Schubert, K. Z. Metallk. **56** (1965) 523.
7. Selte, K. and Kjekshus, A. Acta Chem. Scand. **17** (1963) 2560.
8. Furuseth, S. and Kjekshus, A. Acta Chem. Scand. **18** (1964) 1180.
9. Boller, H. and Nowotny, H. Monatsh. **95** (1964) 1274.
10. Rundqvist, S., Carlsson, B. and Pontchour, C. Acta Chem. Scand. **23** (1969) 2188.
11. Furuseth, S., Selte, K. and Kjekshus, A. Acta Chem. Scand. **19** (1965) 95.
12. Taylor, J. B., Calvert, L. D. and Hunt, M. R. Can. J. Chem. **43** (1965) 3045.
13. Jensen, P., Kjekshus, A. and Skansen, T. Acta Chem. Scand. **20** (1966) 403.
14. Jensen, P. and Kjekshus, A. Acta Chem. Scand. **20** (1966) 1309.
15. Grønvold, F., Hagberg, O. and Haraldsen, H. Acta Chem. Scand. **12** (1958) 971.

Epithermal Neutron Activation Analysis of Uranium in Rocks

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Several nuclear methods are now available for the analysis of uranium in rocks (e.g. Ref. 1).

A method using epithermal neutrons to promote a selective activation has recently been developed which allows an accurate and rapid determination of the uranium content in such samples.[2,3] The present study has as its aim the simultaneous analysis of several samples since this is of importance in connection with uranium prospecting.

The irradiation was performed on the upper core surface of a swimming pool-type reactor. In this position an "excess" epithermal neutron flux is available for the activation purposes and larger cadmium covers containing several uranium samples can accordingly be introduced into the reactor without any essential change in reactivity.

The general principles of epithermal neutron activation analysis have previously been described, and only a short resumé of the technique will therefore be given here. In the activation process epithermal neutrons favour those nuclides which exhibit a large epithermal neutron cross-section, i.e. a high resonance integral. It is accordingly possible to enhance the activity of a specific nuclide for which analysis is desired by supressing the activity of interfering nuclides with lower resonance integrals. Quantitatively the advantage of epithermal activation as compared with thermal activation including an epithermal contribution is expressed by the ratio:

$$F = (R_{Cd})_d / (R_{Cd})_D \qquad (1)$$

$(R_{Cd})_D$ denotes the cadmium ratio of the nuclide to be determined; $(R_{Cd})_d$ denotes the cadmium ratio of the interfering nuclide. The factor F may be described as the "advantage" factor.[4] The cadmium

ratio for gold is often known for a certain irradiation position. It is then possible to calculate the cadmium ratio for another nuclide by means of eqn. (2):

$$R_{Cd} = I + \frac{\sigma_0}{\sigma_0{}^{Au}} \times \frac{0.44\ \sigma_0{}^{Au} + I^{Au}}{0.44\ \sigma_0 + I} (R_{Cd}{}^{Au} - 1)$$
(2)

σ_0 denotes the thermal neutron cross-section and I denotes the resonance integral ($1/v$ contribution excluded).

Experimental. Samples. The samples consisted of alluvial sediments, and amounted to about 100 mg each. The samples were wrapped in aluminium foils.

Irradiations. Ten samples and two standards were irradiated together in a cadmium cylinder, 5.5 cm long and 3 cm in diameter with a wall thickness of 0.5 mm. The standards were located at each end of the container. The cadmium container was placed on the top of the core of the I.A.N. reactor. In the irradiation position used the thermal neutron flux amounted to about 10^{10} n/cm² sec.[5] The measured cadmium ratio for gold in this position was 1.90. The samples were irradiated for periods of 10—20 min.

Measurements. The analysis was assayed by the nuclide ^{239}U with a half-life of 23.5 min. The 74 keV gamma ray was measured by a 2″ × 2″ NaI(Tl) crystal attached to a 512 channel pulse height analyser of Nuclear Data manufacture.

Results and discussion. Table 1 gives the results of a study comprising the simultaneous analyses of 10 uranium samples at the ppm concentration level from the same ore. The mean value with the standard deviation is 4.5 ± 0.2 μg/g, which is in good agreement with the value of 4.3 μg/g obtained by fluorometric analysis.[6]

In this study a large irradiation volume was used and the effects of epithermal flux gradients could not be neglected. In the irradiation position used this gradient was measured for each sample in the geometrical array by means of uranium standard samples. In the samples studied the main interference was due to ^{56}Mn in accordance with previous experience.[3]

An enhancement factor of 19 is obtained for the ^{239}U activity using epithermal neutrons as compared with the conventional thermal irradiation with an epi-

Table 1. Study of the uranium content in ten rock samples of the same quality.

Sample	Uranium content (μg/g)
1	4.2
2	4.3
3	4.3
4	4.3
5	4.4
6	4.4
7	4.5
8	4.7
9	4.8
10	4.9
	Mean value: 4.5 ($\pm$ 0.2)

thermal contribution, taking into account the ^{56}Mn interference.[3]

The epithermal neutron activation technique for uranium is favourable in the analysis of samples containing the 0.1—50 ppm concentration range. Above 50 ppm epithermal neutron activation analysis is not necessarily superior to thermal activation analysis.

The detection limit of uranium in rocks was estimated to be 0.1 ppm in agreement with previous results.[3]

In this study ten samples were irradiated simultaneously, and the whole analysis was completed in a time interval of less than one hour. The method seems favourable for routine applications in connection with the prospecting of ores for uranium.

1. Brownlee, Jr., J. L. *Modern trends in activation analysis*, Proc. Intern. Conf. Gaithersburg, Md. October 7—11, 1968, **1** (1968) 495.
2. Steinnes, E. and Brune, D. *Talanta* **16** (1969) 1326.
3. Meyer, H. G. *J. Radioanal. Chem.* **7** (1971) 67.
4. Brune, D. *Anal. Chim. Acta* **46** (1969) 17.
5. Casabianca, M. *Personal communication* (I.A.N. Institute).
6. Torres, R. *Personal communication* (I.A.N. Institute).