# Radioanalytical chemistry in Denmark. A bibliography 1936-1977

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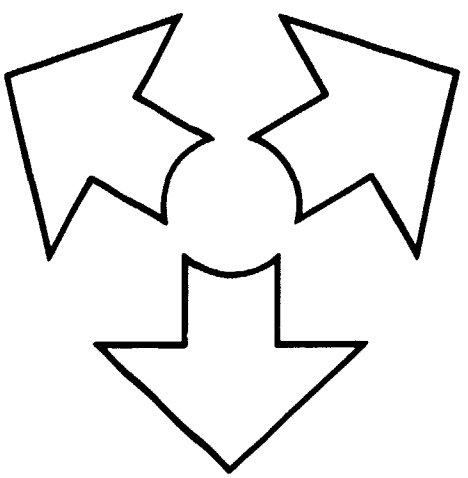

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# RADIOANALYTICAL CHEMISTRY IN DENMARK
## A Bibliography 1936-1977

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Abstract. Publications from Denmark in the field of radioanalytical chemistry are presented in 2 groups, one involving neutron activation and similar techniques, and one for other radioanalytical work. Altogether 258 references including books are given for the period 1936-1977, and the overall doubling time is 5.2 years. A significant deviation from a purely exponential growth was caused by the Second World War.

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## PREFACE

In November 1977 the Editor of the Journal of Radioanalytical Chemistry proposed a world-wide radioanalytical bibliography to be prepared for the period 1936-1977. Scientists in the different countries were approached, and a guide for compilation and presentation of national bibliographies was provided.

The present work is carried out with this aim in mind, and the material is organized in agreement with the above-mentioned recommendations. Many colleagues have helped us locate relevant publications so that nothing of importance should be overlooked.

We have carefully studied all candidate publications before deciding whether or not to include them; however, many borderline cases exist between radioanalytical work and other scientific disciplines, and some of our distinctions are based on discussions with other scientists.

The final responsibility for omissions whether intentional or not must remain ours.

K. Heydorn Hilde Levi

## 1. INTRODUCTION

The contribution to radioanalytical chemistry from Denmark before the Second World War is closely related to the work of Georg von Hevesy. During his stay in Copenhagen in the years from 1935 to 1940, he carried out work with radioactive indicators in collaboration with scientists at the Niels Bohr Institute and several other institutions.

Part of this work could be classified as radioanalytical chemistry, although this term was not yet coined, and the present bibliography is headed by his famous publication which gave birth to neutron activation analysis.

All publications involving neutron activation analysis and other particle-induced reactions, as well as capture γ-rays and X-ray emission, have been placed in Category A.

Other radioanalytical methods are placed in Category B; here we find analytical radiotracer methods and associated subjects such as radiochemical separations, instrumentation and detectors, computer programs, and theory.

We have included methods based on nuclear absorption and scattering, but excluded nuclear magnetic resonance, X-ray fluorescense, and Mössbauer spectroscopy.

Methods for environmental monitoring of radioactive pollution have been included, whereas prospecting methods based on measurements of natural radioactivity have not.

Radio-immuno assay is included as an analytical method, but measurements of flow, clearance, or other diagnostic tools are not considered.

For all these radioanalytical methods we have selected only papers which represent the methodological aspect, while the

routine application of the analytical methods for medical, industrial, or other purposes are omitted.

## 2. COMPILATION

### 2.1. Activation, prompt and other methods using neutron and charged-particle bombardment

1936-1940

G. Hevesy and Hilde Levi (Inst. Theoretical Physics, Copenhagen): The action of neutrons on the rare earth elements. K. Dan. Vidensk. Selsk., Math. Fys. Medd. 14, No. 5 (1936) 34 pp.

G. Hevesy and Hilde Levi (Inst. Theoretical Physics, Copenhagen): Artificial activity of hafnium and some other elements. K. Dan. Vidensk. Selsk., Math. Fys. Medd. 15, No. 11 (1938) 18 pp.

1958-1962

Bent R. Petersen (Danish Isotope Centre, Copenhagen): Activation analysis - methods and perspectives. Kem. Månedsbl. 41, No. 7/9 (1960) 61-64 (in Danish).

1963-1967

B. Gregers Hansen (Agricultural Res. Dept., DAEC Res. Establ. Risø, Roskilde): Activation analysis. Ugeskr. Landm. 109 (1964) 231-237 (in Danish).

B. Gregers Hansen (Agricultural Res. Dept., DAEC Res. Establ. Risø, Roskilde): Application of radioactivation analysis for the determination of selenium and cobalt in soils and plants. In: 8. International Congress of Soil Science, Bucharest,

1964. Transactions. Vol. 3 (Publishing House of the Academy of the Socialist Repoblic of Romania, Bucharest, 1964) 63-70.

K. Heydorn (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Graphical representation of double neutron capture in gold and tantalum. Radiochim. Acta 3 (1964) 161-166.

S. Sølvsten (Dept. Diagnostic Radiology, Isotope Lab., Rigshospital, Copenhagen): Determination of gold in serum and urine by neutron activation analysis. Scand. J. Clin. Lab. Invest. 16 (1964) 39-44.

Kirsten Rald (Royal Danish School of Pharmacy, Copenhagen): Introduction to activation analysis. Principles and utilization. Farm. Tid. 75 (1965) 845-855 (in Danish).

H.R. Lukens, *K. Heydorn, and T. Choy (*Isotope Div., DAEC Res. Establ. Risø, Roskilde): Determination of vanadium in blood by neutron activation analysis with pre-irradiation separation. Trans. Amer. Nucl. Soc. 8 (1965) 331.

F.M. Graber, H.R. Lukens, and *K. Heydorn (*Isotope Div., DAEC Res. Establ. Risø, Roskilde): The determination of Tb, Er, Yb and Y by neutron activation analysis. Trans. Amer. Nucl. Soc. 9 (1966) 87.

B. Gregers Hansen (Agricultural Res. Dept., DAEC Res. Establ. Risø, Roskilde): Activation analysis. Dan. Kemi 47, No. 3 (1966) 41-45 (in Danish).

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K. Heydorn (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Multiple carrier addition followed by reirradiation yield measurement for the determination of arsenic in hair and biological material. Trans. Amer. Nucl. Soc. 9 (1966) 70-71.

K. Heydorn (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Improvement of accuracy in activation analysis by multiple carrier addition followed by reactivation yield determination. Trans. Amer. Nucl. Soc. 9 (1966) 86.

K. Heydorn and H.R. Lukens (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Pre-irradiation separation for the determination of vanadium in blood serum by reactor neutron activation analysis. Risø Report No. 138 (1966) 20 pp.

K. Heydorn (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Improvement of accuracy by multiple carrier addition followed by reirradiation yield determination in a simple method for the determination of arsenic in biological material. In: Nuclear Activation Techniques in the Life Sciences. Proceedings of a Symposium, held in Amsterdam, 8-12 May 1967 (IAEA, Wien, 1967) 179-188.

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Birte Bisbjerg (Agric. Res. Dept., DAEC Res. Establ. Risø, Roskilde): Studies on selenium in plants and soils. Risø Report No. 200 (1972) 150 pp (Dissertation).

E. Damsgaard, K. Heydorn, and B. Rietz (Isotope Div., DAEC Res. Establ. Risø, Roskilde): Determination of vanadium in biological materials by neutron activation analysis. In: Nuclear Activation Techniques in the Life Sciences, held at Bled, 10-14 April 1972 (IAEA, Wien, 1972) 119-130.

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## 2.2. Other radioanalytical methods

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## 3. DISCUSSION

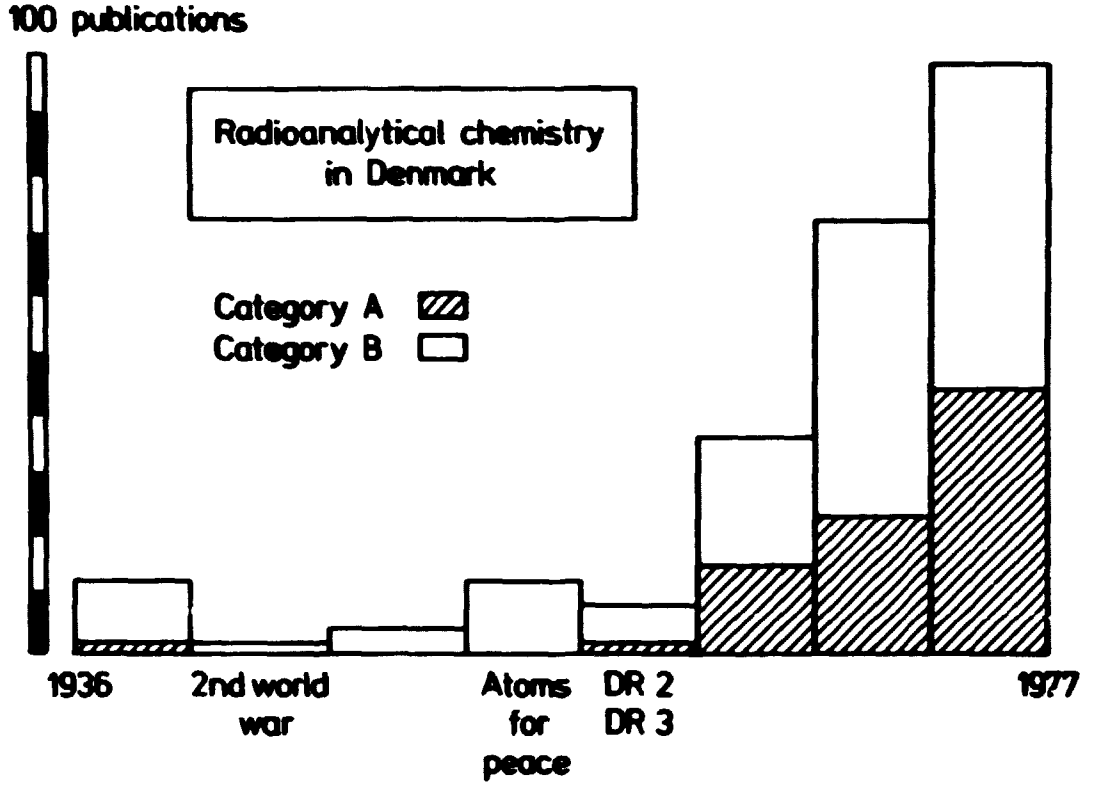


Fig. 1. Histogram showing the distribution of 244 publications over the years 1936-1977.

Figure 1 shows a histogram of the publication activity during the period 1936-1977 excl. books. The general shape of the distribution is characteristic of a developing scientific activity, and the irregularities can be attributed to special events.

The departure of Georg von Hevesy from Denmark because of the German occupation during the Second World War had a dramatic effect on the activity in radioanalytical chemistry, and it took more than 15 years to reach the same level. At the 1st Geneva Conference in 1955 the peaceful uses of atomic energy such as in the application of isotopes and radiation were made available to the international scientific community, and the Danish Atomic Energy Commission was created with Niels Bohr as chairman.

In the following years the Research Establishment Risø was built with the reactors DR 2 and DR 3, and radioanalytical chemistry based on the use of reactor neutrons has been responsible for a considerable fraction of the growth over the past 15 years.

During the last 10 years of the period the development of radioimmunoassay has been the largest single contribution to the field, and at the same time the development of new radioanalytical methods has spread from the universities to the hospitals and their clinical laboratories.

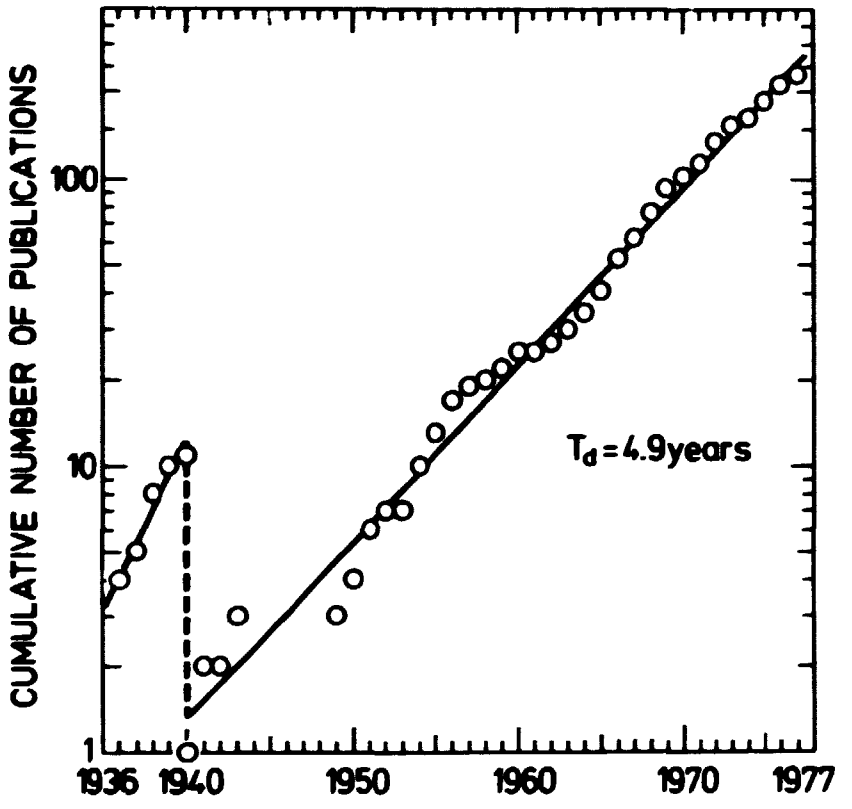


Fig. 2. Cumulative distribution of 233 publications from the period 1940-1977 is approximately exponential with a doubling time of 4.9 years. Publications by Hevesy during the period 1936-1940 belong to a different distribution.

Figure 2 shows the cumulative number of publications in both categories up to 1977, having an overall doubling time of 5.2 years. It is clear, however, that only the second half of the

period is reasonbly well approximated by an exponential function, and therefore in the figure the development is described by 2 exponential functions. The first exponential with a doubling time of ∿2.6 years is associated with the name Hevesy and ends in 1940. The present exponential starts in 1940 and has a doubling time of 4.9 years; the degree of approximation is very similar to the exponential growth curves for activation analysis given by Braun et al. [1977], whereas the growth rate is somewhat lower. This is in agreement with the comparatively low Danish publication output in radioanalytical chemistry observed by Braun and Bujdosó [1979].

However, with the increasing applicability of radioanalytical methods in widely different fields, the development of new methods and techniques will probably be distributed over many types of laboratories. It is therefore possible that radioanalytical publications then appear in other specialized journals, where the radioanalytical chemist is not likely to find them.

The need for bibliographical services in the field of radioanalytical chemistry is therefore bound to become even greater in the future than it is today.

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APPENDIX A

Budapest, November 21, 1977

Dr. K. Heydorn
Atomic Energy Commission
Research Establishment RISO
DK-4000 Roskilde
Denmark

Dear Dr. Heydorn,

The unexpected great success of the National Issues so far published in our Journal incited the idea to initiate a world-wide maping of the whole field of radioanalytical chemistry and the evaluation of radioanalytical research effort all over the world. Such a task, of course, could be realized only by means of serious international co-operation.

As first step, exhaustive national bibliographies covering the period between 1936-1977 ought to be compiled.

In view of this suggestion I should like to ask you to join us in this work as the representative of your country. Could you compile within about 6 months the complete radioanalytical bibliography of your country?

The material ought to be compiled in chronological order and divided into two major categories: 1. Activation analysis; 2. Analytical use of radioisotopes and nuclear radiation.

The complete material would be published in the JRC and the bibliographies of the different countries would be headed by the name of the compiler.

Should you be prevented from accepting this proposal of ours, I would much appreciate if you could suggest a colleague who would be ready to accomplish this task.

Yours sincerely,

T. Braun

(Dr. T. Braun)

APPENDIX B

## COMPILATION OF NATIONAL BIBLIOGRAPHIES

## /GUIDE/

### Coverage

The National Bibliography on Radioanalytical Chemistry should contain all the papers, reports and books written by scientists of the institutions of the country in question and published both in/by domestic and foreign periodicals/publishers going back in time as far as possible in order to make the compilation complete and up to December 1977.

The Radioanalytical Bibliography should contain all papers being "nuclear" aiming "analysis".

### Cathegories

The papers should be divided into two groups:

1. Activation, prompt and other methods using neutron, charged particle and photon bombardment,
2. Other radioanalytical methods

Because of the very broad context of "radioanalytical", this cathegorization is only a division of the items in which the former can be better outlined. The latter should contain the analytical radiotracer methods, separation techniques, isotope dilution, environmental monitoring, i.e., determination of radioactive substances, analysis by nuclear absorption and scattering, etc.

The cathegories should contain also papers promoting the use of the method in question such as instrumentation, sensitivity calculations, computer programs, liquid scintillation counting, quantitative autoradiography, etc.

### Listing

The listing of the items should be grouped according the year of publication only indicating the year at the beginning in each cathegory.

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