Photographic Emulsion Method Applied to the Investigation of Radioactive Deposits from Atmospheric Air

By REINHARDS SIKSNA

Institute of High Tension Research, University of Uppsala

(Manuscript received 6 December 1949)

Abstract

This article describes a combined activation-photographic detection method applied in the investigation of radioactive deposits from atmospheric air. It is shown that with this simple and convenient method it is possible to obtain many fine details of the phenomenon also in case of quite weak activity. It is also shown that the method can be employed with success in the investigation of the mobility of radioactive carriers in atmospheric air.

Introduction

The incentive to this investigation arose out of observations carried out in connection with the introduction of measurements of small-ion density of atmospheric air at the Institute of High Tension Research, University of Uppsala (NORINDER a. SIKSNA 1949). An abnormally high ion-density was observed in the rooms of the Institute building (50,000—60,000 n/cm^3 in the transformer-room, 3,000—20,000 n/cm^3 in other rooms; in the open air in the environments of the Institute the ion-density was usually 900—1,500 n/cm^3, more rarely it increased to 3,000—3,500 n/cm^3). It was assumed that the source of the higher ion-density in the Institute building was the transformer-room, and the cause of it—the radioactivity of the air.

Therefore, a method was sought with which it would be possible to carry out investigations of the radioactivity of atmospheric air without incurring too great expenses.

The photographic emulsion method seemed to us to meet these requirements. In recent times this method has found large application in many investigations (POWELL and OCCHIALINI 1947, YAGODA 1949), but as far as we know, it has not yet been applied to the investigation of the radioactivity of atmospheric air.

Method employed

The technique used was as follows: a freely suspended body is connected to the negative terminal of a high tension rectifier and exposed in the room where the measurements are to be made. After several hours of electrical exposure photo-plates are placed on the plane surfaces of the body with their emulsions touching the metal surfaces, after which photo-exposure follows. After the development of the plates the tracks of α-particles produced in the emulsion are measured microscopically.

The method employed can be regarded as the activation method of ELSTER and GEITEL (1902, 1903) combined with the photo-emulsion method for the determination of induced activity.

With this simple and convenient combined *activation-photographic detection* method it is possible:

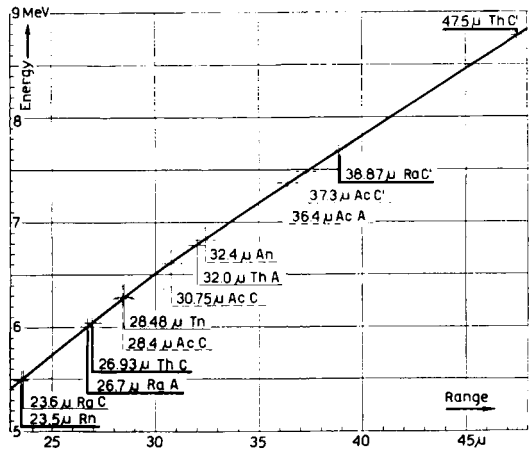

Fig. 1. Range-energy curve for α-particles of radon (Rn), thoron (Tn) and actinon (An) and their decay products in Ilford "Nuclear Research" emulsions.

1. to determine individual tracks of the radioactive deposit from atmospheric air,
2. to identify from the ranges the origin of individual α-particles; the range-energy relation of α-particles of emanations and all their decay products is given in fig. 1 (LATTES, FOWLER, CUER 1947),
3. to obtain many of the details of the phenomenon also in cases of quite weak activity,
4. to derive conclusions concerning the relation of contents of different kinds of active atoms in the atmospheric air from the relation of number of tracks.

Experiments

Corresponding to the method outlined above experiments were carried out according to the following arrangement:

1. The test body—a brass disc, 1 cm thick and 5 cm in diameter, with rounded edges—was connected with the negative terminal of a high tension rectifier (4.5 kV) and exposed in the room where it was to be tested.

Activation in such a manner was carried out in the transformer-room, in a work-room on the first floor of the Institute building and in the open air in one of the observation huts which had been built especially for the ion-density measurements at the Institute. The duration of the electrical exposure was 8—11 hours. After the electrical activation photo-plates were placed on plane surfaces of the brass disc with the emulsion layers in contact with the metal surfaces, whereupon photo-exposure followed. The photo-plates employed were Ilford "Nuclear Research Plates" Type E 1 with a 50 μ emulsion. The duration of the photo-exposure was 60—135 hours.

2. On the inside electrode of an Ebert ion-aspirator, connected permanently with the negative terminal of a dry battery (117 V respectively 240 V), a thin paper hull was slid. By aspirating with an air-stream through the aspirator, the hull was then activated for 9—11 hours. After this electrical exposure the hull was removed cautiously from the electrode, pressed flat between the emulsions of two photo-plates and held in that position for photographic exposure.

3. Already on the first plates exposed tracks could be traced which were identified as originating from Rn α-particles. Therefore the brass disc was grounded and exposed in this state in the transformer-room with a view to examine the possibility of obtaining an activation by the occlusion of radon in the metal without an electrical field.

Results

With the method described above the following has been established:

1. *The absence of anticipated RaA—RaC' stars.* The explanation of this fact may, perhaps, be understood from the following consideration: when a RaA-atom, situated on the surface of an activated body, has ejected its α-particle towards the emulsion it will be moved by the recoil into the body and the α-particle ejected afterwards from RaC' would not be directed towards the emulsion.

2. *Stars of successive decay* $Rn \xrightarrow{\alpha} RaA \xrightarrow{\alpha} (RaB) \rightarrow \rightarrow (RaC) \rightarrow RaC' \xrightarrow{\alpha}$. 1—2 % of all measured tracks are such radon stars, with the starting points of the stars located 10—20—30 μ deep in the emulsion.

3. *Range spectra by means of which it is possible to analyse active substances present.* Figures 2, 3 and 4 contain examples of spectra of the ranges of α-particles as obtained in the present investigation. The spectra from the inside rooms of the Institute building (fig. 2) show a distinct maximum with R = 39 μ, which corresponds to RaC', a second with R = 27 μ, correspond-

ing to RaA, and a third with R = 24 μ, corresponding to Rn. The spectra obtained by activation in the open air (fig. 3) also show maxima which might be attributed to the above mentioned ranges of Rn, RaA and RaC' α-particles, but they are more blurred since two more intensive maxima with R = 47 μ and R = 27 μ (corresponding to ThC' and ThC) have been superposed across them. Similar spectra are obtained by activating the paper hull over the negatively charged inside electrode of the Ebert ion-aspirator. The spectrum (fig. 4) obtained when the test-disc was grounded and exposed in the transformer-room has also the three maxima for the Rn-series, but for Rn the maximum is greater than it was when electrically activated.

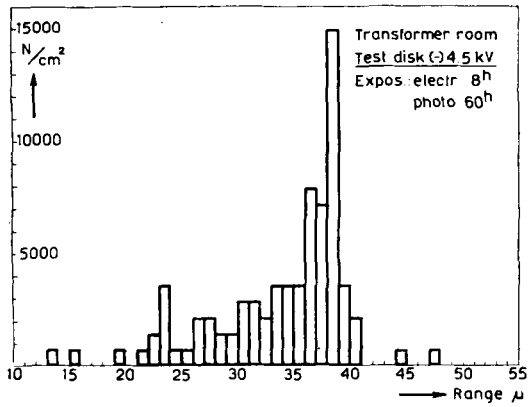

Fig. 2. Range spectrum of α-particles obtained from the transformer-room by activating the test-disc connected with a 4.5 kV negative tension.

4. Tracks of Tn decay products at very small rates of Tn in the atmosphere. It can be shown that also in those cases when the equilibrium state for the Tn series is not reached, the number of collected atoms of Tn decay products to be expected can be of the same order as that of the Rn products even with a ratio Tn : Rn = = 10^{-4} (Fig. 3), a number which may be accepted as a middle value in atmosphere. The reason for this is the difference in the half-lives of *Rn* and *Tn*, and of *RaB* and *ThB*.

5. Possibilities for detecting the presence of An decay products in the atmosphere. It can be shown that also for a ratio An : Rn = 5.5×10^{-7}, estimated from the relative abundance of the two principal uranium isotopes U I and AcU

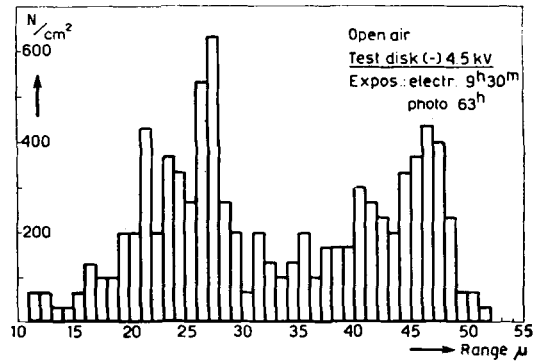

Fig. 3. Range spectrum of α-particles obtained in the open air by activating the test-disc connected with a 4.5 kV negative tension.

and their rates of disintegration, the ratio of the number of corresponding RaC and AcC atoms in equilibrium with their emanations will be RaC : AcC $\approx$ 200. In all the range spectra one can see a small maximum at 31—32 μ and, perhaps, another at 28—29 μ. It seems probable that tracks with these ranges may be interpreted as resulting from AcC, for in fig. 1 we have for AcC ranges 30.75 μ and 28.4 μ.

6. The presence of Rn atoms on the activated body. Direct arguments in favour of this are: the stars of successive decaying $Rn \xrightarrow{\alpha} RaA \xrightarrow{\alpha} \rightarrow (RaB) \rightarrow (RaC) \rightarrow RaC' \xrightarrow{\alpha}$ and the group of tracks with ranges around 23 μ; as indirect argument may also be considered the occurrence of a relatively large number of RaA tracks on several plates.

7. The deep penetration of active atoms into the activated bases. The spectral lines of range distribution are asymmetrical, spreading toward

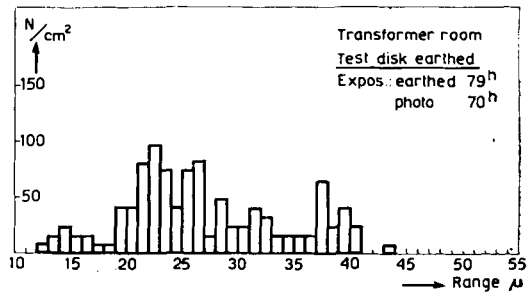

Fig. 4. Range spectrum of α-particles obtained from the transformer-room when the test-disc was grounded.

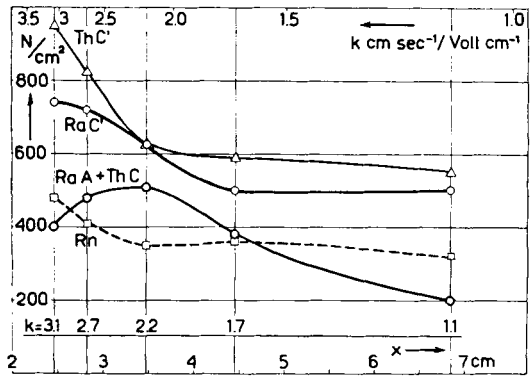

Fig. 5. Area density of a particular kind of active atoms deposited on the hull slid over the inside electrode of the Ebert ion-aspirator as a function of the distance x from the top end of the electrode. k — the limit mobility.

smaller ranges; one may suppose that many of the active atoms deposited must be hammered into the base by the electrical field or by the recoil, and that the α-particles ejected during the following decay therefore must follow a path through the material of the base.

8. The possibility to activate a hull slid over the inside electrode of the Ebert ion-aspirator applying the usual tension, in order to detect activity on the photographic emulsion. This convenient arrangement makes it possible to determine the mobility of the different active carriers in the atmospheric air and to distinguish between them. The area density of a particular kind of active atoms deposited on the hull slid over the inside electrode of the Ebert ion-aspirator, expressed as a function of the distance x from the top end of the electrode, is shown in fig. 5. We must desist from calculating the distribution of active carriers with respect to mobilities since this would require additional experiments in order to enlarge the measuring interval and to clear up several phenomena referred to above, for example the occlusion of radon. We have thereby wished to demonstrate that the method can be used for investigating mobility.

Acknowledgement

The author is very grateful to Professor H. NORINDER for his suggestion to investigate the radioactivity in atmospheric air, in connection with the observations made in our common investigation of small-ion density, for his liberal willingness to support this investigation, and for his interest throughout the study.

Professor NORINDER has kindly supported this investigation by funds available for experimental researches at the Institute of High Tension Research of Uppsala University, and by grants received from the Swedish Natural Science Research Council for the investigation of atmospheric electricity.

The author likewise wishes to express his thanks to Professor A. LINDH for placing at his disposal Ilford "Nuclear Research" plates, and to Professor E. NORIN and fil. lic. M. FRIES for permitting the use of microscopes for the first measurements.

REFERENCES

ELSTER, J. und GEITEL, H., 1902: Beschreibung des Verfahrens zur Gewinnung vorübergehend radioaktiver Stoffe aus der atmosphärischen Luft. *Phys. Z.S.*, **3**, p. 305—310.

ELSTER, J., 1903: Ueber gemeinsam mit Herrn GEITEL konstruierte transportable Apparate zur Bestimmung der Radioaktivität der Luft. *Phys. Z.S.*, **4**, p. 96—97.

ELSTER, J. und GEITEL, H., 1903: Ueber die radioaktive Emanation in der atmosphärischen Luft. *Phys. Z.S.*, 4, p. 522—530.

LATTES, C. M. G., FOWLER, P. H., CUER, P., 1947: A Study of the Nuclear Transmutation of Light Elements by the Photographic Method. *Proc. Phys. Soc.* **59**, Part 5, p. 883—900.

NORINDER, H. and SIKSNA, R., 1949: The measurements of the variation characteristics of the density of small-ions. *Arkiv för Geofysik*, **1**, 1, p. 1—32, Stockholm.

POWELL, C. F., OCCHIALINI, G. P. S., 1947: *Nuclear Physics in Photographs*, London, Oxford University Press.

YAGODA, H., 1949: Radioactive Measurements with Nuclear Emulsion, New York. John Wiley and Sons, Inc.