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ELECTRICAL CHARGE OF THORON PROGENY

J. BIGU (ELLIOT LAKE LABORATORY)

MINING RESEARCH LABORATORIES
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ELECTRICAL CHARGE OF THORON PROGENY

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ABSTRACT. The electrical charge carried by the short-lived decay products of thoron (i.e., thoron progeny) has been measured in an underground uranium mine using an electrical elutriator of the split-flow type. The results show that about 65% of the thoron progeny are electrically charged. This fraction is significantly lower than that corresponding to recently formed thoron progeny (80-85%) measured by some workers.

Key words: Electrical charge; Thoron progeny.

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INTRODUCTION

The short-lived decay products of radon (^{222}Rn) and thoron (^{220}Rn) are formed initially in an atomic, positively charged state which rapidly combines with submicron aerosols. As aerosols are found in positively, negatively and neutrally charged states, the resulting atmosphere consists of a complex mixture of charged and neutral particles. The charge associated with radioactive submicron aerosols is of interest from both health physics and occupational standpoints since it influences the deposition of these particles in the human respiratory system.

The electrical characteristics of ^{222}Rn and ^{220}Rn progeny aerosols have been investigated by several authors[1-7]. Because of the electrical charge associated with these radioactive particles, they can be influenced by external electric and magnetic fields[6,8,9].

This technical note deals with the electrical characteristics of the ^{220}Rn progeny in an underground uranium mine. Work on the electrical characteristics of ^{222}Rn progeny and Long-Lived Radioactive Dust (LLRD) has been published by the author elsewhere[10].

EXPERIMENTAL PROCEDURE

Electrical charge measurements were conducted using an electrical elutriator of the split-flow type (heretofore referred to as the split flow elutriator or SFE, for short), and a graphico-analytical procedure, both developed by Johnston[11]. Although the original method was intended, and has been used extensively, for electrical charge characterization of industrial dusts, the method has been adopted here to measure the electrical charge of airborne submicron radioactive aerosols, collected on a suitable filter, as follows. The (two) sampling ports of the SFE were connected together and then split into two independent flows: one flow (0.3 L min^{-1}) was directed to a condensation nuclei counter (CNC), whereas the other flow (2.7 L min^{-1}) went through an absolute filter (where the ^{220}Rn progeny were collected), housed in an in-line filter holder, by means of a servo-controlled flow-adjustable sampling pump. This experimental arrangement permitted monitoring of aerosol concentration as well as measurement of the ^{220}Rn progeny deposited on the filter by gross α-particle counting and/or α-particle spectrometry. The experimental arrangement used is shown in Figure 1.

Thoron progeny samples were taken at different voltages, V, on the SFE (0 to 5000 V DC) and the normalized α-particle activity measured by gross α-particle counting was plotted against V. This procedure is illustrated in Figure 2. Furthermore, particle size distribution data were obtained by sampling air (concurrently) with a 10-stage cascade impactor which provided MMAD (mass median aerodynamic diameter) and AMAD (activity median aerodynamic diameter) data for LLRD as well as for ^{220}Rn progeny (see Figure 3).

THEORETICAL BACKGROUND

It can be shown that the electrical charge, n, of a particle of size D_p (meter) is given by[11]:

$$n = 7.036 \times 10^9 \; (D_p/V_o) \qquad (1)$$

where V_o is a voltage defined as follows: particle concentration (or ^{220}Rn progeny activity on the filter as in the present case) is tabulated as a function of voltage difference, V, applied to the SFE. The data are then normalized to zero volt concentration and plotted against V. A tangent passing through the 50% normalized concentration (or activity) point defines V_o by drawing a vertical line to the x-axis (i.e., voltage) from the tangent contact point (see Figure 2). Condensation nuclei and cascade impactor data permitted determination of D_p and from Figure 2, V_o could be obtained. These two variables enable the electrical charge of LLRD[12] and ^{220}Rn progeny to be determined by means of Equation 1.

EXPERIMENTAL RESULTS

The experimental results obtained for a typical run are shown in Figures 2 and 3. Figure 2 shows percentage cumulative α-particle activity for LLRD and ^{220}Rn progeny, abbreviated TnP, versus Equivalent Aerodynamic Diameter, EAD ($D_{p,50}$). Also shown in the same graph is the percentage cumulative dust mass versus EAD for LLRD (labelled Total Dust). From Figure 2, the ^{220}Rn progeny AMAD can be obtained, i.e., ~0.2 μm.

Figure 3 shows the normalized ^{220}Rn progeny (TnP) activity versus V for a typical experiment. The value obtained for V_o is about 3200 V. Applying the values obtained for D_p and V_o to Equation 1, the electrical charge can be calculated as n ~0.45. Because the electrical charge carried by ^{220}Rn progeny must be either 0 or an integer, n<1 indicates that a fraction of the ^{220}Rn progeny cloud carries no electrical charge. Furthermore, Figure 3 suggests that about 65% of the ^{220}Rn progeny is either positively or negatively charged whereas the remaining fraction is in a neutrally charged state. These data are consistent with other measurements by the author[6,12].

CONCLUSIONS

The average electrical charge corresponding to ^{220}Rn progeny measured in an underground uranium mine was less than unity. This suggests that only a given fraction of these radioactive aerosols are electrically charged (~65%). This fraction is significantly lower than that measured by several authors[3-5], i.e., 80-85%, for recently formed ^{220}Rn progeny under laboratory controlled conditions. The difference between the data presented here and the results for recently formed radioactive aerosols is ascribed to electrical neutralization processes partly due to the attachment of the ^{220}Rn progeny to mine air aerosols.

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LIST OF ILLUSTRATIONS

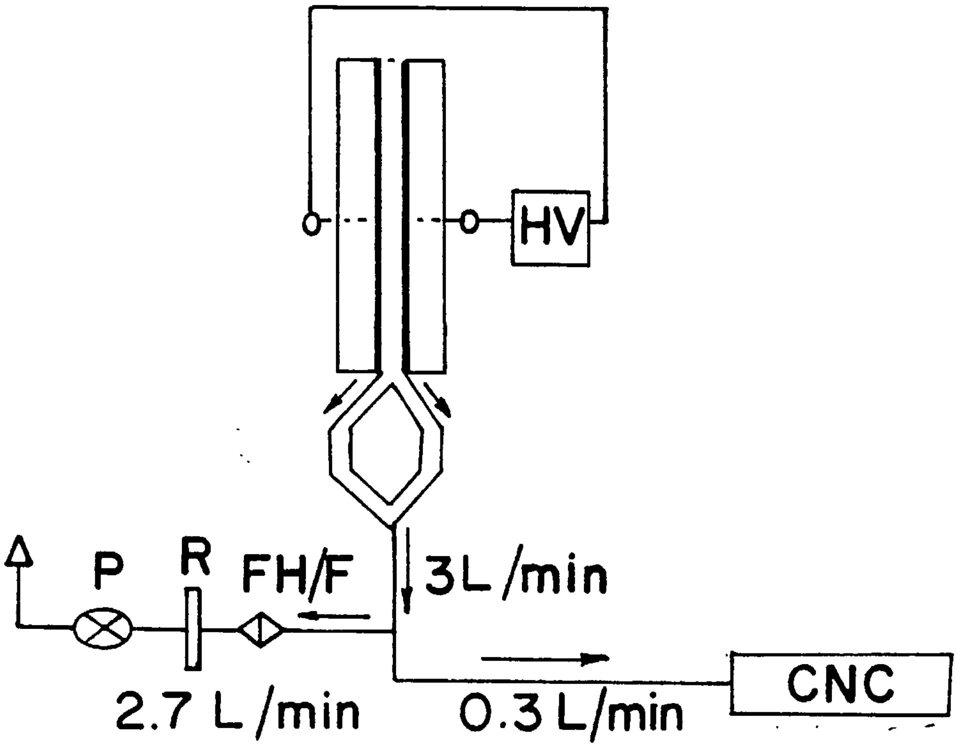


Figure 1.

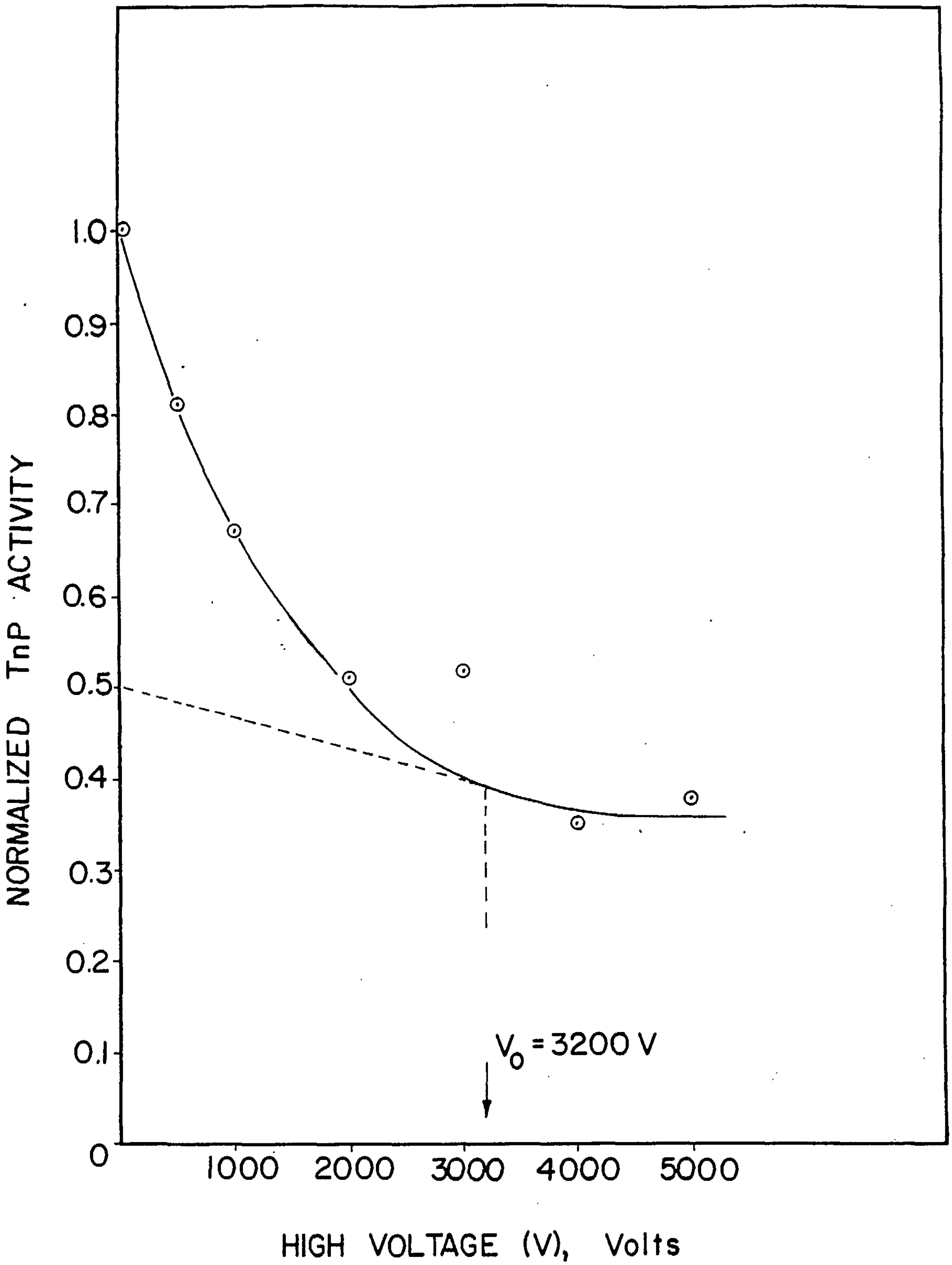
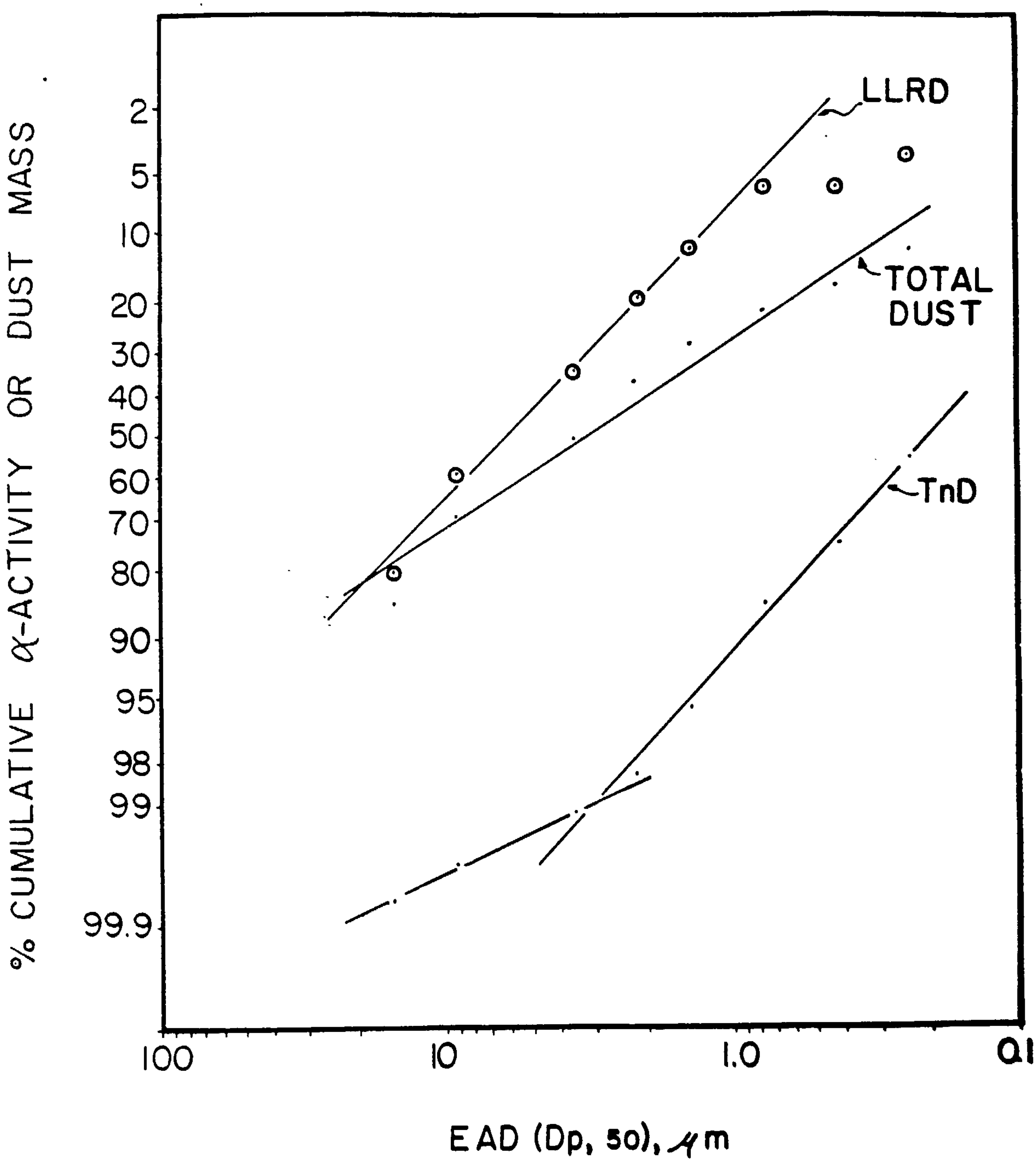

NORMALIZED TnP ACTIVITY
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1000
2000
3000
4000
5000
V_0 = 3200 V
HIGH VOLTAGE (V), Volts

Figure 2.



LLRD
TOTAL DUST
TnD
% CUMULATIVE α-ACTIVITY OR DUST MASS
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.9
100
10
1.0
0.1
EAD (Dp, 50), μm

Figure 3.