LETTERS TO THE EDITORS

PHYSICS

Self-quenching Geiger Counters containing Mixtures of Permanent Gases

We have investigated the characteristics of Geiger–Müller counters containing mixtures of argon with small quantities of xenon (0–7 per cent), oxygen (0–0·5 per cent) and nitrogen ($\sim$ 1 per cent), to total pressures of 700 mm. mercury. That counters filled with this mixture would behave as 'fast' counters in a manner similar to organically quenched counters was first reported by Shore[1], although Riedel[2] reported that using the filling recommended by Shore produced no Geiger region. Using counters of the conventional 'gamma' type, glass bodies with cylindrical cathodes of various materials together with a 4·7 megohm series resistor and a linear amplifier of a gain of about 25, we find that optimum proportions of the gas mixture to produce the best plateaux are: xenon (3·5 per cent), oxygen (0·3 per cent), nitrogen (1·2 per cent), with argon added to give a total pressure of 700 mm. mercury. Such a mixture gave a plateau about 170 V. in length, with a starting voltage of 1,460 V. and a plateau slope of 0·02 per cent/V.

Some fairly general conclusions can be reached as to the role of the various components in the mixture in producing the Geiger plateau. It is evident that the oxygen makes possible the rapid spread of the discharge along the counter anode, chiefly by photo-ionization, in the manner described by Huber[3]. This was made clear when fillings of pure argon and argon plus 1 per cent xenon were investigated, by examination of the discharge by oscilloscope. It was found that with both these mixtures there was no Geiger region, the discharge passing abruptly from the proportional to the corona region, the voltage at which this occurred being lowered from 1,850 V. to 1,260 V. with the addition of xenon. Addition of 0·1 per cent of oxygen to pure argon altered the character of the discharge entirely, the familiar Geiger pulses being observed although a plateau of only a few volts was obtained with many spurious pulses.

Although Shore reported that, if nitrogen were not present in the mixture, the plateau became extremely short, we have not found this to be so. The addition of about 1 per cent of nitrogen improves the performance of the counters but is not essential. For example, a counter containing the optimum quantities of xenon and oxygen had a plateau of 102 V. in length with a slope of 0·064 per cent/V. Refilling and adding 1 per cent of nitrogen resulted in an increase in length to 130 V. and the slope improved to 0·025 per cent/V.

It is also clear that the presence of the xenon inhibits the formation of the many spurious pulses found in the argon–oxygen–nitrogen mixtures. Adding small quantities of xenon to the latter results in an improvement in length and slope of the plateau together with a very sharp fall in the starting voltage, from 2,124 V. for zero quantity to 1,460 V. for the optimum amount of xenon (3·5 per cent). Adding further xenon results in an increase in the starting voltage, and a deterioration of the slopes and lengths of plateaux.

In an endeavour to understand this mechanism we have investigated the time incidence of spurious pulses by pulse-interval analysis[4] for mixtures containing increasing quantities of xenon with fixed amounts of nitrogen (1 per cent) and oxygen (0·3 per cent). At the same time we have measured the transit times of the front of the positive-ion sheath from examination of the cathode-current pulse. In all the many fillings investigated we have found that the maximum number of spurious pulses occur at the end of the counter dead-time and only a negligible proportion are recorded after the front of the positive-ion sheath has reached the cathode. It is apparent, at any rate with these counters, that the positive-ion effect at the cathode, often quoted as the reason for the generation of spurious pulses in Geiger counters, is unimportant.

The other possible mechanism is that the spurious pulses are due to hard photons, delayed relative to the main Geiger pulse, releasing photo-electrons at the cathode. Such hard photons could arise as a result of the quenching of argon metastables by collision with gas molecules. In fact, pulse-interval analysis of mixtures containing zero or less than optimum quantities of xenon shows large numbers of small spurious pulses occurring in as short a time as 15 μsec. after the main Geiger discharge. With optimum quantities of xenon such small pulses do not appear and the counters have a clear dead-time of about 150 μsec., indicating that the argon metastable states are rapidly quenched by collisions with xenon atoms. That this occurs, and with the formation of ions, is also indicated from the considerable lowering of starting voltage with addition of xenon, while the charge per pulse remains of the same order. The ionization potential of xenon (12·127 V.) is higher than both metastable levels of argon (11·53, 11·72 V.) so that direct ionization of xenon atoms by collision with argon metastable states is not possible; but in spite of this it seems fairly evident that some mechanism exists involving interaction between xenon atoms and argon metastable states giving rise to an increase in the number of ions produced in the avalanches.

A more detailed report of the work described in this communication is to be published elsewhere.

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[1] Shore, L. G., *Rev. Sci. Instr.*, **20**, 956 (1949).
[2] Riedel, O., *Z. Naturforsch.*, **5a**, 331 (1950).
[3] Huber, E. L., *Phys. Rev.*, **97**, 261 (1955).
[4] Putman, J. L., *Proc. Phys. Soc.*, **61** 312 (1948).