325. *The Composition of the Mixture of Rare Gases from the Hot Springs of Bath.*

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The gases from the King's Well and the Cross Spring of Bath have been analysed. The rare-gas fraction consists in each case of argon with about 12% of helium and 0·1% of neon. The helium is certainly the product of radioactive change; the argon and neon are probably of atmospheric origin, the neon content being about half of that in the atmosphere on account of its lower solubility.

In 1894 the late Lord Rayleigh determined the density of the rare-gas residue from the Bath Springs, and later examined the gas spectroscopically (*Phil. Trans.*, 1895, *A*, **186**, 227; *Proc. Roy. Soc.*, 1895, **59**, 207). Calculation based upon a determination of the density of the mixture of nitrogen and inactive gas, as obtained from the well, and an analysis of it, suggested that the helium–argon ratio might be as large as $\frac{1}{3}$, but a comparison of the spectrum of the gas with that of an artificial mixture of helium and argon indicated that the helium content of the Bath residue was somewhat greater than 10%. In 1912 Masson and Ramsay made a further examination of the gases from the Bath Springs, and attempted to separate the constituents by fractional absorption in charcoal cooled with liquid air, liquid hydrogen not being at that time available at University College, London. Their experiments led to the conclusion that the inactive residue contained a considerable quantity of neon, the residue from 1 l. of the gas, which originally contained no oxygen, and was freed from carbon dioxide, consisting of argon 7·33 c.c., neon 2·36 c.c., and helium 0·30 c.c. The presence of helium can of course be attributed to radioactive change, and the argon might be derived from the atmosphere. As to why the gas should contain so large a quantity of neon, since the solubility of that gas in water is less than that of argon, was a problem which remained unexplained.

Last year, I was asked by the Management of the Hot Springs to make a re-examination of the gases given off from the wells, and, knowing that the method employed by Masson and Ramsay was an unsatisfactory one, though it was the only method available, I agreed to do so, since, through the courtesy of Professor A. M. Tyndal and Dr. L. C. Jackson of the Department of Physics, University of Bristol, liquid hydrogen was available for the separation of the helium and neon from the argon. Mr. John Hatton, the Director of the Hot Springs, kindly made arrangements to enable me to collect samples of gas from the King's Well and from the Cross Spring.

It is not necessary to describe the method of operation in detail. The gases were collected in zinc gasholders, filled with water from the springs. In the case of the King's Well the gas from a chamber below the pool, which is filled with water, passed through a pipe to a small gasholder, in which it was collected. This pipe was disconnected from the gasholder, plugged with a rubber stopper, with a glass T-tube from which the sample was taken. In the case of the Cross Spring the gas was collected by placing a zinc funnel over a point in the floor of the pool from which bubbles of gas rose. In the first case the operation was complete in a few minutes; in the second it occupied several days. The gases were found to contain carbon dioxide and no trace of oxygen, showing that there was no contamination by air. In the first place 500 c.c. of each of the pure dry nitrogen–rare gas mixtures were analysed; they were found to contain:

King's Well, 12·8 c.c. of rare gas per l.
Cross Spring, 13·7 c.c. of rare gas per l.

Then, approximately 15 l. of the gas from each of the springs were passed over heated calcium, and yielded in each case about 335 c.c. of inactive gas. These samples of gas were used for the determination of the composition of the rare-gas residue. The gas samples were, in each case, then submitted to fractionation, liquid nitrogen being used as a cooling agent, seven approximately equal fractions being obtained. These were condensed in turn in a bulb cooled with liquid hydrogen, and separated into a volatile part containing helium and neon, and a non-volatile residue of argon. That the preliminary fractionation had been effective was shown by

the fact that of the first fraction about 75% was volatile, of the second about 5%, and of the third hardly a trace. The residues were refractionated, liquid oxygen being used as a cooling agent, and each fraction was again treated with liquid hydrogen, but only a trace of gas was obtained. Finally, the volatile fractions were mixed, and cooled with liquid hydrogen to freeze out any trace of argon contained in them.

The density of the lightest fraction showed that it consisted in each case of helium with no more than a trace of neon, indeed so little, that, using a 30 c.c. density bulb, it was only possible to determine the amount of it approximately. The non-volatile gas, after sparking with oxygen, was found to consist of pure argon. The following is the result of the analysis in c.c. per l. of the gas from the wells, dry and freed from carbon dioxide :

	King's Well.	Cross Spring.
Argon	11·12	12·22
Helium	1·66	1·47
Neon	0·01	0·01

The neon/argon ratio is then about one half of that found in the case of atmospheric air. As the argon and neon are probably dissolved in water when they find their way into the springs, this is to be expected.

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