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Ramsay and the Electric Lamp

An exhibition to mark the centenary of the birth of Sir William Ramsay is now open at the Science Museum in London. The importance of Ramsay's work to the lighting industry is shown in the following article.

By J. N. ALDINGTON,
B.Sc., Ph.D., F.I.E.S.,
and B. WITHRINGTON.

The electric lamp industry owes a particular debt of gratitude to the work of Sir William Ramsay. Receiving his early education at Glasgow University, he was fortunate in then being able to work under Fittig at Tubingen. After a tutorial appointment in technical chemistry on his return to Glasgow, he received the Chair of Chemistry at University College, Bristol, in 1880. His distinguished work at Bristol was followed by a long period as Professor of Chemistry at University College, London, where he succeeded A. W. Williamson.

In these days when, in the authors' opinion, young men are caused to specialise in some branch of science at much too early a stage, it is interesting to reflect that whereas Ramsay's contribution to the discovery of the rare gases and to determining their properties lay largely within the field of physics, by training and profession he was a chemist with a particular bias to the organic side.

Following his work on quinine and its decomposition products, he directed his attention to questions of physical and inorganic chemistry. While at Bristol he investigated the critical state and various properties of liquids, including vapour-pressure relationships, and carried out his work with John Shields on the relationship between the molecular complexity of a liquid and its surface tension.

His interest in the gases of the atmosphere was stimulated by Lord Rayleigh's famous

Sir William Ramsay

(With acknowledgment to "Vanity Fair")

letter to "Nature" in 1892, from which the following is an extract:—

"I am much puzzled by some recent results as to the density of nitrogen, and shall be obliged if any of your chemical readers can offer suggestions as to the cause. According to two methods of preparation, I obtain quite distinct values. The relative difference, amounting to about 1/1000 part, is small in itself; but it lies entirely outside the errors of experiment, and can only be attributed to a variation in the character of the gas."

Following that letter, on April 19, 1894, Lord Rayleigh reported at a meeting of the Royal Society the results of his further work on the density of nitrogen but without suggesting an explanation. Immediately following the meeting in a private discussion Lord Rayleigh told Ramsay that, in his view, the cause of the difference in density between chemically prepared nitrogen and that prepared from the air was the existence of a light gas in non-atmospheric nitrogen. Ramsay, however, after considering Rayleigh's results, thought that the most probable cause was a heavy gas in atmospheric nitrogen.

A few days after this conversation Ramsay began work on the treatment of atmospheric nitrogen with heated magnesium. The results were apparently so definite that after a meeting of the Royal Society on May 24 he reported privately to Lord Rayleigh that the density of the atmospheric nitrogen was further increased after the magnesium treatment, and he later wrote: "Has it occurred to you that there is room for gaseous elements at the end of the first column of the periodic table?"

Posterity is fortunate in that the original letters between Lord Rayleigh and Ramsay and between Ramsay and his wife have been preserved, as they disclose many details of his experimental work.

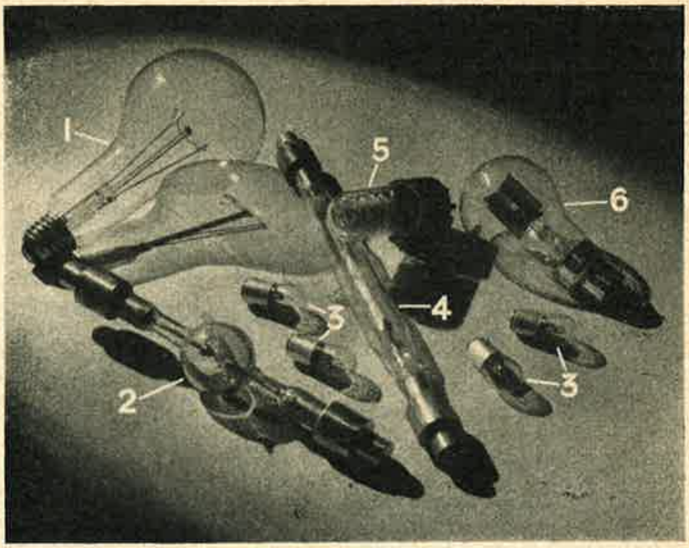
Eventually, by repeated passing of atmospheric nitrogen over heated magnesium turnings and copper oxide, the volume contracted and the density rose to about 19. A sample of the residual gas was sent to William Crookes, who reported that it gave an entirely new spectrum. In August, 1894, only a few months after Ramsay began his work on the subject and following confirmation by Rayleigh of Ramsay's results, they jointly announced the discovery of a new gas, afterwards called argon, which was present to the extent of almost 1 per cent. in the atmosphere. A full account of the work together with measurements of the properties of the new gas was given to a meeting of the Royal Society in January, 1895, the density being given as 19.95 against oxygen 16. It was stated that the gas appeared to be a completely inactive element.

In the same year Ramsay's attention was drawn to the fact that many minerals containing uranium gave off a gas on treatment with acid, and it was suggested that this gas might be argon. Ramsay obtained samples of the mineral cleveite and confirmed that when heated with acid a gas was evolved which had a powerful yellow spectral line identical with that detected in the sun's spectrum by Sir J. N. Lockyer and Sir E. Frankland in 1868, to which the name of helium had already been given. This extremely light gas with a density of 2 also appeared to be chemically inert and it was later found to be present in the earth's atmosphere to the extent of about one part in 250,000. On March 27, 1895, Ramsay communicated its discovery to a meeting of the Chemical Society. The matter is of such interest that the actual words of Ramsay, published in the Transactions of the Society, are quoted below:—

"In seeking a clue to compounds of argon I was led to repeat experiments of Hillebrand on cleveite, which, as is well known, when boiled with weak sulphuric acid, gives off a gas hitherto supposed to be nitrogen. This gas proved to be almost free from nitrogen; its spectrum in a Plücker tube showed all the prominent argon lines, and in addition a brilliant line close to, but not coinciding with, the D lines of sodium. There are, moreover, a number of other lines, of which one in the green blue is especially prominent. Atmospheric argon shows, besides, three lines in the violet which are not to be seen, or, if present, are excessively feeble in the spectrum of the gas from cleveite. This suggests that atmospheric argon contains, besides argon, some other gas which has as yet not been separated and which may possibly account for the anomalous position of argon in its numerical relations with other elements.

"Not having a spectroscope with which accurate measurements could be made, I sent a tube of the gas to Mr. Crookes, who has identified the yellow line with that of the solar element to which the name 'helium' has been given. He has kindly undertaken to make an exhaustive study of its spectrum.

"I have obtained a considerable quantity of this mixture and hope soon to be able to report concerning its properties. A deter-



Group of electrical lamps in which rare gases are used.

(1) *Argon gas-filled lamp.*

(2) *Xenon gas arc.*

(3) *Krypton miners' bulb.*

(4) *Xenon gas arc.*

(5) *Krypton or Xenon flash tube.*

(6) *Neon glow lamp.*

mination of its density promises to be of great interest."

Two new elements had thus been discovered and a study of their position in the Periodic Classification supported the belief that at least three more such gases should exist. It was at this time that Ramsay's fruitful collaboration with Dr. Morris Travers began. Many different minerals were examined, including meteorites, in an attempt to locate the supposedly missing elements revealed by a study of the Periodic Table, but up to early 1898 no positive results had been obtained. By then, however, the British Oxygen Company were able to make available a substantial quantity of liquid air. Ramsay and Travers fractionated this material and eventually spectroscopic examination of the residues revealed the existence of another distinct element, to which they gave the name krypton. It is a remarkable fact that by the end of July, 1898, by the continued fractionation of liquid air they eventually found that in addition to argon atmospheric air contained four other gases. Krypton and xenon were readily liquefied or even solidified and could be obtained in a reasonably pure state although the amount of xenon in the atmosphere is so astonishingly low. The hitherto unknown gas, named neon, which has such a characteristic red spectrum, was more difficult to isolate in any quantity but it was eventually separated in July, 1900, from the argon and helium by means of liquid hydrogen. It is good to recall that Ramsay's discovery of the rare gases brought to him many honours, including the Nobel Prize for Chemistry in 1904, and that at the same time Rayleigh was honoured by receiving the Nobel Prize for Physics.

We must now turn to the impact of these developments on the electric lamp industry. At first sight it would appear that a group of chemically inactive elements and particularly rare gases capable of being isolated from the air in only relatively small quantities would be of purely academic interest, but Langmuir's work on the causes of blackening in the electric lamp, however, had shown that this was due to normal evaporation of the tungsten from the filament surface during the life of the lamp, a process similar to that in nature of the gradual evaporation of ice without a visible liquid phase on a cold winter's day.

Even before Langmuir's time Edison had suggested surrounding his early lamp filaments with a chemically inert gas. He tried nitrogen, but the results were not too happy due to the severe additional thermal losses incurred by conduction and convection in the gas. Langmuir, however, showed how this difficulty could be overcome by compacting the filament into a tightly wound helix. He further suggested substituting argon for nitrogen and thus stimulated the large-scale production of argon from liquid air plants in various parts of the world. As is well known gas-filled lamps contain a mixture of argon and nitrogen with the argon content generally being predominant. It is interesting to reflect that no other element except one of the other rare gases discovered by Ramsay and his collaborators can be substituted for argon in practical lamps of the gas-filled type without loss of efficiency. It has always been clear since these gases were first applied, however, that the heavier ones, particularly krypton and xenon, would produce even more advantageous results than argon if they could be used to provide the inert atmosphere surrounding the filament. That they are not used for general lighting service lamps is due to their extreme rarity and therefore high cost. Nevertheless, British lamp makers a year or two before the last war developed krypton-filled miners' lamp bulbs which could be operated at a materially higher efficiency than argon-filled bulbs of the same rating and for the same life. Experimental work was also carried out on krypton fillings for low-wattage gas-filled lamps of other types both in this country and elsewhere. It was found, however, that for larger lamps the economic factors were adverse and therefore at the present time the only practical light sources using krypton as an inert atmosphere are the miners' lamp bulbs.

Neon has always enjoyed a special position in the discharge-lamp field due to the beautiful crimson spectrum which is emitted when it is electrically excited. Notwithstanding subsequent developments in high-voltage electric-discharge tubes utilising mercury and fluorescent powders and mixtures of other gases, the plain discharge through neon still holds a prominent position in the sign industry. Neon has also proved to be the most useful gas filling for many forms of cathode-glow indicator lamps.

Helium has not found extensive use as a source of light when excited by the electric discharge, but some interesting early experimental installations made use of the buff-white colour, which is produced at a suitable current density.

During the last war use was found for both krypton and xenon in new forms of electric-discharge lamp, thus completing the first impact of Ramsay's discoveries on the electric lamp industry. (See Fig. 2.)

Krypton was first used in discharge tubes of the continuously burning type, but its properties did not appear very promising. When, however, it was subject to a very high-current-density discharge white light at high efficiency was produced, and this property was utilised in the development of a whole range of repeating-flash tubes. These tubes are designed to have a high breakdown voltage, which may, for example, be greater than 2,000 volts. For the production of single flashes of light at very high intensity, as is necessary in certain photographic applications, a tube is connected across the terminals of a large capacitor which can be charged to 2,000 volts. No current passes through the discharge tube until an ionising voltage or other influence is brought to bear on the krypton within the tube. Immediately, however, this ionised condition is reached, the tube discharges at very high power with the production of a pulse of light of great intensity.

From this development has come another new industry—the production of portable and stationary repeating-flash equipments, which can either produce single flashes at will or a multiplicity of flashes in synchrony with, say, a moving machine part. Soon after this work had borne practical results for war purposes, it was found that xenon gave nearly 50 per cent. more light than krypton under the same discharge conditions, and the best repeating-flash tubes are now filled with pure xenon. In studying the high efficiencies and most desirable colour of the light produced in this way, it was considered possible that continuously burning sources with similar characteristics might be developed, and the xenon gas arc was announced in 1947. The first lamp was a 5-kw. water-cooled device emitting more than 100,000 lumens of white light. It was suitable for photography in both colour and in black and white, and for many other purposes. Development is still proceeding, not only in England but in lamp research laboratories in many other places, and several different high-current-density xenon gas arc lamps have been engineered into practical forms. The rarest of Ramsay's rare gases has thus taken its place in a marketable light source.

While all the rare gases have, therefore, now been brought into use, the story of the influence of Ramsay's work on the electric-lamp industry will probably never be complete, as research within the industry is constantly producing either new or improved light sources employing these remarkable elements.

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