SCIENCE

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*ON A NEW CONSTITUENT OF ATMOSPHERIC AIR.**

THIS preliminary note is intended to give a very brief account of experiments which have been carried out during the past year to ascertain whether, in addition to nitrogen, oxygen and argon, there are any gases in air which have escaped observation owing to their being present in very minute quantity. In collaboration with Miss Emily Aston we have found that the nitride of magnesium, resulting from the absorption of nitrogen from atmospheric air, on treatment with water yields only a trace of gas; that gas is hydrogen, and arises from a small quantity of metallic magnesium unconverted into nitride. That the ammonia produced on treatment with water is pure has already been proved by the fact that Lord Rayleigh found that the nitrogen produced from it had the normal density. The magnesia, resulting from the nitride, yields only a trace of soluble matter to water, and that consists wholly of hydroxide and carbonate. So far, then, the results have been negative.

Recently, however, owing to the kindness of Dr. Hampson, we have been furnished with about 750 cubic centimeters of liquid air, and, on allowing all but 10 cubic centimeters to evaporate away slowly, and, col-

*Paper read before the Royal Society on June 9th by Professor William Ramsay, F. R S., and Morris W. Travers. Received by the Society June 3d. Reprinted from *Nature*.

lecting the gas from that small residue in a gas holder, we obtained, after removal of oxygen with metallic copper and nitrogen with a mixture of pure lime and magnesium dust, followed by exposure to electric sparks in presence of oxygen and caustic soda, 26.2 cubic centimeters of a gas, showing the argon spectrum feebly, and, in addition, a spectrum which has, we believe, not been seen before.

We have not yet succeeded in disentangling the new spectrum completely from the argon spectrum, but it is characterized by two very brilliant lines, one almost identical in position with D_3, and almost rivalling it in brilliancy. Measurements made with a grating of 14,438 lines to the inch, kindly placed at our disposal by Mr. E. C. C. Baly, gave the following numbers, *all four lines being in the field at once:*

D_1	... ...	5895.0
D_2	... ...	5889.0
D_3	... ...	5875.9
D_4	... ...	5866.65 + 1.7 to correct to vacuum.

There is also a green line, comparable with the green helium line in intensity, of wave-length 5566.3, and a somewhat weaker green, the wave-length of which is 5557.3.

In order to determine, as far as possible, which lines belong to the argon spectrum, and which to the new gas, both spectra were examined at the same time with the grating, the first order being employed. The lines which were absent, or very feeble, in argon have been ascribed to the new gas. Owing to their feeble intensity, the measurements of the wave-lengths which follow must not be credited with the same degree of accuracy as the three already given, but the first three digits may be taken as substantially correct:

Violet	... ..	4317	Blue	... ...	4834
"	... ...	4387	"	... ...	4909
"	... ...	4461	Green	... ...	5557.3
"	... ...	4671	"	... ...	5566.3
Blue	... ...	4736	Yellow	... ...	5829
"	.. ...	4807	"	... ...	5866.5
"	... ...	4830	Orange	... ...	6011

Mr. Baly has kindly undertaken to make a study of the spectrum, which will be published when complete. The figures already given, however, suffice to characterise the gas as a new one.

The approximate density of the gas was determined by weighing it in a bulb of 32.321 cubic centimeters' capacity, under a pressure of 521.85 millimeters, and at a temperature of 15.95°. The weight of this quantity was 0.04213 gram. This implies a density of 22.47, that of oxygen being taken as 16. A second determination, after sparking for four hours with oxygen in presence of soda, was made in the same bulb; the pressure was 523.7 millimeters, and temperature was 16.45°. The weight was 0.04228 gram, which implies the density 22.51.

The wave-length of sound was determined in the gas by the method described in the 'Argon' paper. The data are:

	i.	ii.	iii.
Wave-length in air	34.17	34.30	34.57
" " gas	29.87	30.13	

Calculating by the formula

$$\lambda^2_{air} \times \text{density}_{air} : \lambda^2_{gas} \times \text{density}_{gas} :: \gamma_{air} : \gamma_{gas}$$
$$(34.33)^2 \times 14.479 : (30)^2 \times 22.47 :: 1.408 : 1.666$$

it is seen that, like argon and helium, the new gas is monatomic and therefore an element.

From what has preceded, it may be concluded that the atmosphere contains a hitherto undiscovered gas with a characteristic spectrum, heavier than argon, and less volatile than nitrogen, oxygen and argon; the ratio of its specific heats would lead to the inference that it is monatomic and therefore an element. If this conclusion turns out to be well substantiated we propose to call it 'krypton,' or 'concealed.' Its symbol would then be Kr.

It is, of course, impossible to state positively what position in the periodic table this new constituent of our atmosphere will occupy. The number 22.51 must be taken as a minimum density. If we may hazard a conjecture it is that krypton will turn out to have the density 40, with a corresponding atomic weight 80, and will be found to belong to the helium series, as is, indeed, rendered probable by its withstanding the action of red-hot magnesium and calcium on the one hand, and on the other of oxygen in presence of caustic soda, under the influence of electric sparks. We shall procure a larger supply of the gas and endeavor to separate it more completely from argon by fractional distillation.

It may be remarked in passing that Messrs. Kayser and Friedlander, who supposed that they had observed D_3 in the argon of the atmosphere, havê probably been misled by the close proximity of the brilliant yellow line of krypton to the helium line.

On the assumption of the truth of Dr. Johnstone Stoney's hypothesis that gases of a higher density than ammonia will be found in our atmosphere, it is by no means improbable that a gas lighter than nitrogen will also be found in air. We have already spent several months in preparation for a search for it, and will be able to state ere long whether the supposition is well founded.

LIQUID HYDROGEN.

PRELIMINARY NOTE ON THE LIQUEFACTION OF HYDROGEN AND HELIUM.*

IN a paper entitled 'The Liquefaction of Air and Research at Low temperatures," read before the Chemical Society, and published in their 'Proceedings,' No. 158, an account is given of the history of the hydrogen problem and the result of my own experiments up to the end of the year 1895. The subject is again discussed in a Friday Evening Lecture on 'New Researches on Liquid Air,'* which contains a drawing of the apparatus employed for the production of a jet of hydrogen containing liquid. It was shown that such a jet could be used to cool bodies below the temperature that could be reached by the use of liquid air, but all attempts to collect the liquid in vacuum vessels failed. No other investigator has so far improved on the results described in 1895. The type of apparatus used in these experiments worked well, so it was resolved to construct a much larger liquid air plant, and to combine with it circuits and arrangements for the liquefaction of hydrogen, which will be described in a subsequent paper. This apparatus, admirably constructed by the engineers, Messrs. Lennox, Reynolds, and Fyfe, took a year to build up, and many months have been occupied in testing and making preliminary trials. The many failures and defeats need not be detailed.

On May 10th, starting with hydrogen cooled to —205° C., and under a pressure of 180 atmospheres, escaping continuously from the nozzle of a coil of pipe at the rate of about 10 cubic feet to 15 cubic feet per minute, in a vacuum vessel double-silvered and of special construction, all surrounded with a space kept below —200° C., liquid hydrogen commenced to drop from this vacuum vessel into another doubly isolated by being surrounded with a third vacuum vessel. In about five minutes, 20 cc. of liquid hydrogen were collected, when the hydrogen jet froze up from the solidification of air in the pipes. The yield of liquid was about 1 per cent. of the gas. The hydrogen in the liquid condition is clear and colorless, showing no absorption spectrum, and the meniscus is as well defined as in the case of liquid air. The liquid has a relatively high refractive index and dispersion, and the density appears to be in excess of the theoretical density, viz., 0.18 to 0.12, which we

*Read before the Royal Society, London, May 12, 1898.

*'Roy. Inst. Proc.,' 1886.