ACTIVE NITROGEN.[1]

EVERYONE has heard of ozone, the active modification of oxygen which is produced when this gas is subjected to electric discharge. I hope to show you to-night that nitrogen can also be made to assume an active state under suitable experimental conditions. We will begin with an experiment (Fig. 1) which will serve to introduce the subject.

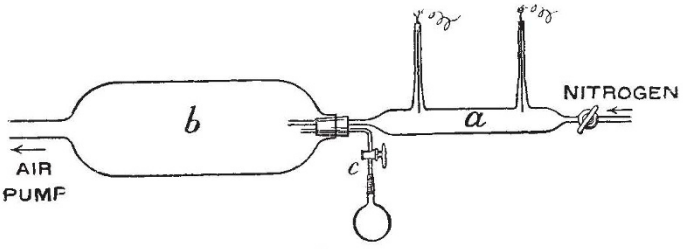

FIG. 1.

A rapid stream of rarefied nitrogen gas passes through the tube *a* at a pressure of a few mm. of mercury, and on its way the gas is sparked through by a series of high-tension electric discharges from a Leyden jar. It then issues as a jet into the large vessel *b*, where it is seen to be brilliantly luminous, the stream of gas being visible as a whirling cloud of brilliant yellow light. Notice that this light is of a different colour from that of the electric discharge in the former vessel.

Why does the gas remain luminous in this way for an appreciable time after the electric discharge has passed through it? The view which I shall develop this evening is that the discharge has split the nitrogen molecules into single atoms. Nitrogen atoms in this condition are uneasy, and are anxious to find partners again. But to do this takes time. The reunion of the nitrogen atoms is attended with the emission of the yellow light which you see, and this continues so long as the process of pairing off is incomplete.

Preliminary even to considering this theory, we must be certain that nothing but nitrogen is necessary to the success of the experiment, and that no other substance intervenes. Some experimenters in Germany have recently expressed the opinion that traces of oxygen are concerned. I am satisfied, however, that they are entirely mistaken. The nitrogen used in the experiment you have just seen has been standing in contact with phosphorus until the phosphorus no longer glows in the dark. If I added a 1/100,000th part of oxygen to the nitrogen, the phosphorus would begin glowing again quite perceptibly. So we may be sure that there is not that amount of oxygen present: and I do not think it is reasonable to attribute these brilliant effects to a smaller amount. Again, we may inquire what is the effect of adding oxygen intentionally? I find that the addition of 2 per cent. of oxygen is enough to obliterate the phenomena altogether. Much more might be said on the subject, but we must pass on.

It is convenient for some purposes to experiment in a different way. We have here two similar glass globes containing rarefied nitrogen. I can induce an electric discharge in them without electrodes by putting them in this coil of wire, through which a Leyden jar is constantly discharging. When I withdraw them you see that they are brilliantly luminous, and that they remain so for several minutes after stimulation. By holding them alternately in the exciting coil we can get them about equally bright, and you see that the luminosity of each decays at about the same rate. Now I stimulate them equally again, and cool one down by immersing it in liquid air. It shines brightly for a moment, but soon becomes quenched. I withdraw it, and you can compare it with the other, which is still brightly luminous.

This experiment shows that cooling the gas shortens the period of luminosity. Let me show you next that the brilliance is increased by cooling. I have exhausted this bulb to a suitable degree, and cool the neck by immersion in liquid air, contained in a transparent vessel (Fig. 2). You see how much brighter the cooled portion is after excitation than the rest of the bulb. There is no doubt a certain ambiguity in this form of experiment, because cooling a portion of the vessel causes a local concentration of the gas in that portion. I must ask you to take it from me that special experiments have proved that this cause is not enough to explain the greatly increased brightness you have seen. The reunion of nitrogen atoms occurs, then, more quickly the lower the temperature. This is a unique instance of a chemical action being quickened by cooling. In all other cases heating accelerates the action. Plausible objections may be made to this statement, but I must content myself now with saying that they admit of answer.

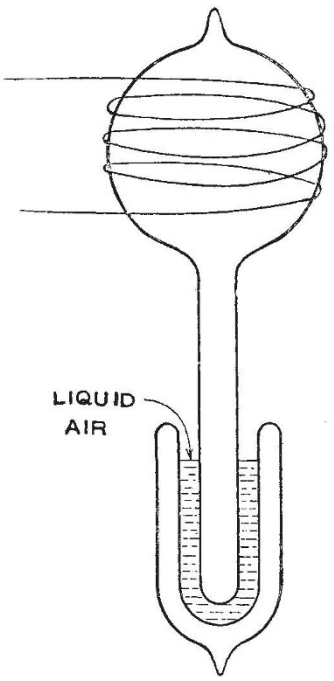

FIG. 2.

When oxygen and hydrogen unite, the union may occur in two distinct ways. It may occur with luminosity throughout the volume of the mixture, as when the gases are exploded, or, again, it may occur at the surface of a solid such as clean platinum. In the latter case there is no luminosity.

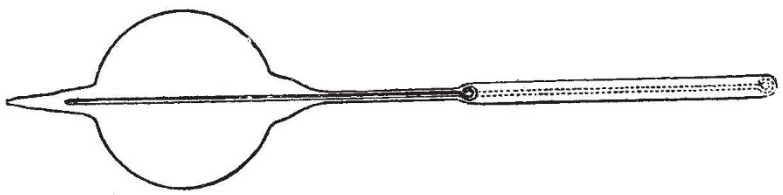

FIG. 3.

Similarly, active nitrogen atoms may reunite in the volume of the gas with luminosity—this we have seen already—or the combination may occur without luminosity at a suitable surface. Oxidised copper

[1] Discourse delivered at the Royal Institution on Friday, February 28, by the Hon. R. J. Strutt, F.R.S.

affords such a surface. This bulb (Fig. 3) can be made to glow like those you have seen before, by inserting it into a coil; and if the copper wire is situated in the side tube the glow lasts a long time, for the gas has as yet no access to it. But if I excite the gas again, and turn the bulb round so as to drop the oxidised wire into it, you see that the luminosity is extinguished in a fraction of a second. Combination of the nitrogen atoms occurs much more quickly at the surface, so that the whole quantity of active nitrogen present is almost instantly used up. Incidentally, the experiment illustrates the extremely rapid diffusion of the gaseous residuum in an exhausted vessel, for every particle of the active nitrogen must evidently find its way to the surface of the wire in the fraction of a second.

We pass now to consider the effect of nitrogen in this condition on other substances. The yellow glow we have studied so far is due to the recombination of nitrogen atoms, and accordingly it shows a nitrogen spectrum, though with very curious modifications.

If we offer to the monatomic nitrogen other substances, it will often unite chemically with them, which, of course, cold ordinary nitrogen will not do. I go back to the apparatus used in the first experiment, and admit some acetylene by a stopcock (*c*, Fig. 1). The jet of active nitrogen now enters an atmosphere of acetylene, and you see that the character of the light is at once changed; it has become lilac. I turn off the acetylene and substitute chloroform vapour. We now get an orange light. This may appear very different, but the difference is unessential. The spectrum is in each case that characteristic of cyanogen and its compounds, only the violet portion of this spectrum is more intense with acetylene, the red portion with chloroform.

Since we get the cyanogen spectrum without having any cyanogen compound originally present, we may suspect that some such compound has been formed. Let us pass from suspicion to proof. Using chloroform vapour from a bulb containing the liquid (see Fig. 1), we pass the gases through a vessel in which a test-tube is inserted. This test-tube contains liquid air, and any condensable constituent is frozen out on to its external surface (Fig. 4). After a few minutes' run, we take out the test-tube and dip it in a solution of potash. I now add a mixture of ferrous and ferric salts and excess of hydrochloric acid. I pour out the liquid on to this white porcelain dish, and you see that abundance of prussian blue has been formed. This proves the presence of some cyanogen compound.

We can get the same result with pentane, ether, benzene, or almost any other organic vapour. With these the amount of cyanogen formed is much the same, but the cyanogen spectrum, curiously enough, is far less conspicuous. Benzene, for instance, almost quenches the nitrogen glow, and little can be seen of the cyanogen spectrum either. In most cases it appears that hydrocyanic acid is formed, but the orange cyanogen glow, only obtained in compounds containing much chlorine, is probably due to the formation of chloride of cyanogen in addition. This, when absorbed in potash, forms a cyanate, which has been detected chemically.

In the case just considered, the spectrum observed, when active nitrogen is mixed with another substance, is that of the product of the action. In some cases, however, the spectrum developed is that of the substance originally introduced. I admit some of the vapour of perchloride of tin: you see the brilliant blue glow. I introduce a drop of the liquid chloride on a wire loop into the flame of a Bunsen burner, and you see the same blue colour, though less advantageously. The brilliance of the luminous effect does not seem to give any trustworthy indication as to whether much chemical action is going on. If, for instance, we admit bisulphide of carbon vapour to the active nitrogen stream, we do not get very brilliant effects of luminosity—nothing striking enough to be worth showing you—but none the less interesting chemical actions are going on. The tube in which the action occurs gets covered with the dark blue transparent deposit, which I show by projection on the screen. This substance is a known compound of nitrogen and sulphur, originally investigated by Mr. Burt in 1910. If the gases are condensed farther on in the tube by liquid air, we get a second deposit of brown colour, which can be identified as the brown polymeric carbon monosulphide studied by Sir James Dewar and the late Dr. H. O. Jones. You see, then, that the chemical action is completely traced. Active nitrogen takes part of the sulphur from carbon disulphide, leaving carbon monosulphide.

The behaviour of active nitrogen with metallic vapours is of interest, though it has not yet been very

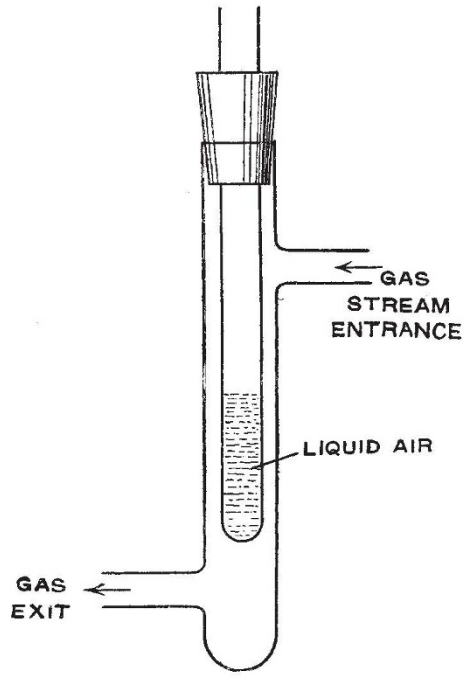

FIG. 4.

completely studied. I select the case of mercury to show you. We pass the stream of glowing gas through this tube, which contains a small pool of mercury. While the mercury is cold, the yellow glow passes on unaffected. I apply heat, and green mercury light, of the colour familiar in the mercury-vapour lamps used in electric lighting, is apparent, when active nitrogen mingles with mercury vapour. Soon the tube gets obscured, except when I am actually heating it, by a dirty-looking solid deposit containing much metallic mercury.

I wish to convince you that an explosive compound of nitrogen and mercury has been formed. For this purpose, to save the trouble of dismounting the tube already used, we will take a similar one prepared beforehand. I heat the mercurial deposit moderately over a Bunsen burner, and, if you will kindly be quite still for a moment, we shall hear a distinct crackling sound, as the explosive compound decomposes. At close quarters it is easy to see flashes of light accompanying the minute explosions, but these can scarcely

be shown to an audience, as the opaque deposit over the greater part of the tube obscures them.

It has only been possible this evening to bring forward a selection of the results of two years' work on this subject at the Imperial College, with generous help from colleagues, and facilities provided by the governors.

Let me conclude by reading to you a prophetic passage from one of Faraday's letters to Schönbein :—"What of nitrogen? Is not its apparent quiet simplicity of action all a sham? Not a sham, indeed, but still not the only state in which it can exist. If the compounds which a body can form, show something of the state and powers it may have when isolated, then what should nitrogen be in its separate state? You see I do not work; I cannot. But I fancy, and stuff my letters with such fancies (not a fit return) to you."

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

A NEW chair of bacteriology is to be founded in Edinburgh University under a bequest from Mr. Robert Irvine, of Royston, Granton. At his death, eleven years ago, Mr. Irvine bequeathed 230 shares of 10*l.* each in a company for developing the resources of Christmas Island for the purpose of establishing the chair when the interest from the shares should reach 25,000*l.* or 30,000*l.* The accumulated dividends on these shares now reach more than 30,000*l.* It is understood that 25,000*l.* will go towards the maintenance of the professorship, and that the remaining 5000*l.* will be used in providing the class-rooms, laboratories, and the necessary equipment.

ATTENTION has already been directed to the progress which has been made in the provision of well-equipped laboratories for the study of electrical technology and kindred subjects in the University of Hong Kong. Prof. C. A. Middleton Smith has sent us an exhaustive list of engineering and other equipment which has been presented to the University by public-spirited manufacturing firms. Their generous support of the cause of higher technical education in the distant parts of the Empire is sure to be productive of excellent results, and is worthy of emulation by other firms. The greatest support seems to have been received for the department of heat engines, and the authorities in Hong Kong hope that more offers of apparatus will be received from firms interested in electrical engineering. A complete equipment is required for experiments in all branches of electrical work, and an appeal is made to manufacturers that this branch of engineering shall be represented worthily in the equipment presented to the University. It is impossible here to mention each of the gifts which have been made, but as indicative of the substantial character of the gifts, the complete spectrographic outfit presented by Messrs. Adam Hilger and Co., and the Sankey's hand-bending testing machine given by Mr. Casella, may be mentioned.

SOCIETIES AND ACADEMIES.

LONDON.

Physical Society, April 25.—Prof. C. H. Lees, F.R.S., vice-president, in the chair.—W. R. **Bower**: A graphical method of optical imagery. The paper contains a development of optical imagery based on elementary geometry, including limiting positions, but excluding cross-ratios, centres of perspective, &c. The method adopted is useful for teaching the properties of optical systems to those who are not essentially students of pure mathematics, and can be satisfactorily used by those capable of draughtsmanship with mathematical instruments.—Dr. C. V. **Burton**: The spectroscopic resolution of an arbitrary function. An ordinary grating has periodic rulings, and a spectrum obtained by means of it is characteristic of the radiation entering the spectroscope-slit. But if the radiation is homogeneous, while the distribution of the rulings is arbitrary, we obtain a spectrum characteristic of the grating. It is thus found to be theoretically possible to resolve spectroscopically a given arbitrary function $\phi(x)$ into its harmonic constituents. The theory of the proposed method of resolving functions is discussed, and is as complete as that of ordinary spectroscopy, while in one respect it is more simple; for, since the light entering the spectroscope-slit is entirely of one wave-length, the comparison of intensities of spectral lines (whether visually or photographically) is facilitated.

Linnean Society, May 1.—Prof. E. B. Poulton, F.R.S., president, in the chair.—Prof. P. **Groom** and W. **Rushton**: The structure of the wood of East Indian species of Pinus.—Dr. Winifred **Brenchley**: Branching specimens of *Lyginodendron oldhamium*, Will.—A. C. F. **Morgan**: A problem in Weismannism.—Mrs. L. J. **Wilsmore**: *Sphenopus marsupialis*.—Papers on collections made by the Percy Sladen expedition to the Indian Ocean:—Miss Helen L. M. **Pixell**: Polychæta of the Indian Ocean, with some species from the Cape Verde Islands. The Serpulidæ, with a classification of the genera Hydroides and Eupomatus.—S. **Hirst**: Report on the Arachnida of the Seychelles.—Miss Marjorie **Lindsay**: *Gypsina plana*, Carter.—A. **Grouvelle**: Nitidulæ, Heterocidæ.—A. **Raffray**: Pselaphidæ de l'Archipel des Seychelles.—Dr. K. **Jordan**: Anthribidæ of the Seychelles.—S. **Maulik**: Hispinæ from the Seychelles.—Dr. K. **Jordan**: Certain changes in nomenclature of Lepidoptera proposed by Dr. Verity.

Zoological Society, May 6.—Dr. Henry Woodward, F.R.S. vice-president, in the chair.—Dr. F. E. **Beddard**: The anatomy and systematic arrangement of the Cestoidea. This paper, the tenth of the series, contained an account of two species of tapeworms found in a Dongolan genet, both of which were described as new, one being made the type of a new genus.—J. A. **Milne**: Pacific salmon: an attempt to evolve something of their history from an examination of their scales. Reasoning from the similarity of their appearance to the scales of the other Salmonidæ, the author pointed out that all the migratory species except *Onchorhynchus kita* remain for at least a year in fresh water before proceeding to the sea—in the Fraser River district, at any rate. He also showed the scale of a quinnat, and pointed out that it was scarcely possible to avoid the conclusion that that fish had already spawned once before it was captured.—Miss Kathleen **Haddon**: Notes on *Peripatoides woodwardii*, Bouvier. This paper was based on material collected in Western Australia, consisting of twenty specimens, male and female, ranging in size from 17 to 46 mm., thus considerably exceeding in length those described by Prof. Bouvier. Various types of coloration are exemplified, some being blue-green with small yellow spots, while others have the yellow pigment increased so as to give a tawny appearance to the animal; a dark variety of this latter type also occurs.—J. C. F. **Fryer**: Field-observations on the enemies of butterflies in Ceylon. It was concluded (1) that in Ceylon, with the exception of the