XXIII.—*On the Synthesis of Ammonia.*

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(Second Notice.)

MY demonstration of the synthetical production of ammonia from the nitrogen evolved by heating a solution of nitrite of ammonium by passing it mingled with hydrogen over spongy platinum, after removing adhering ammonia from it by sulphuric acid (demonstrated to this Society January 20th, 1881), having been objected to on the ground that the vapour of some ammoniacal salt might be carried by the rapid stream of gas through the absorbing apparatus and the first Nessler solution, and might then be dissociated in the hot platinum-tube and yield ammonia which would tinge the Nessler solution be-

yond, I made the following experiment with a view to elucidate this matter:—

I passed hydrogen through the apparatus described in my last paper and over the spongy platinum, heating the latter till it gave off no ammonia, as shown by the absence of precipitation in a Nessler solution through which the gas was made to pass; I then allowed the platinum to cool in the hydrogen, and introduced a current of *nitrogen* from a mixture of nitrite of potash and sal-ammoniac, with the intention of displacing all the hydrogen from the apparatus whilst the platinum remained *cold*, and then heating the platinum, so that the ammonia salt (if present) might be dissociated and yield the ammonia, which would then show itself in the second Nessler bulb, though no hydrogen was passing through the apparatus. I was surprised, however, to find that a copious precipitate appeared in the Nessler bulb immediately after the admission of the nitrogen into the apparatus, though the platinum remained cold; and on adjusting a set of bulbs containing decinormal sulphuric acid and passing the mixed gases for one hour, I found that acid had been neutralised corresponding with a production of 24 mgrms. of ammonia. The dissociation of vapour of an ammoniacal salt in *cold* spongy platinum does not seem probable.

It was desired that I should make some experiments with nitrogen obtained from a non-ammoniacal source, and accordingly I attempted to synthesise ammonia with nitrogen procured from atmospheric air by the action of heated copper. In this I was not successful.

I next passed the nitrogen from ammonium nitrite over heated copper, and subsequently through spongy platinum with hydrogen, and obtained no ammonia whatever.

This result might be due either to the nitrogen being rendered inactive by heat, or to the removal by the red-hot copper of some *oxide of nitrogen* which had previously yielded the ammonia.

Now it has long been known that the nitrogen obtained by heating a solution of ammonium nitrite is liable to be contaminated with nitric oxide whenever, as frequently happens, the evolution of gas becomes unusually violent, red fumes being constantly observed upon contact of the rapidly evolved gas then produced with atmospheric air.

But I have found that in all cases, and however carefully regulated the temperature and rapidity of evolution of gas may be, the nitrogen from this source is invariably accompanied by small quantities of nitric oxide, and the complete removal of this impurity is a matter of no little difficulty.

I employed a solution of *ferrous sulphate* for this purpose, and passed the nitrogen through a counterpoised tube containing freshly reduced copper, the copper being heated to redness, allowed to cool in the nitrogen, and weighed at intervals of one hour.

The increase in weight of the copper was reduced to 5 mgrms. per hour, when the absorbing apparatus consisted of three French drying-tubes containing pumice soaked with acid ferrous sulphate, two potash-bulbs containing acid solution of ferrous sulphate, and one Woulffe's bottle containing the same absorbent.

The copper increased in weight *not at all* when heated for one hour in a constant current of the gas from a solution of nitrite of potash and ammoniac, which has been passed through (1) a long tube, (2) two French drying-tubes, all packed with fragments of pumice-stone soaked in a saturated acid solution of ferrous sulphate; (3) two potash-bulbs containing acid solution of ferrous sulphate; (4) two more French drying-tubes prepared in the same way as the first; (5) a Woulffe's bottle containing acid ferrous sulphate; (6) a Woulffe's bottle containing potash and pyrogallin; and (7) a French drying-tube containing pumice soaked in oil of vitrol.

A. Solution of Nitrate of Potash and Sal-ammoniac. B. Hydrogen Apparatus.
C. Solution of Nitrate of Silver. D. Nessler test. E. Spongy Platinum.

Having, by means of this elaborate absorbing apparatus, removed all traces of oxides of nitrogen, and obtained a gas which gave up nothing to red-hot copper (evidently perfectly pure nitrogen), I now admitted hydrogen into the apparatus through a solution of nitrate of silver, and the same absorbing apparatus as the nitrogen from (4) onwards; and, on passing the mixed gases over spongy platinum, I obtained ammonia as before.

I first passed the mixed gases over the *cold* spongy platinum for one hour, and absorbed the ammonia by normal sulphuric acid. Acid was neutralised corresponding with a production of 3 mgrms. of ammonia.

In a subsequent experiment in which the platinum was heated to dull redness, and the gas was passing at the same pace, an exactly equal weight of ammonia was produced in one hour.

It was impossible in these experiments to pass the gas very rapidly through the apparatus, owing to the great pressure to be overcome by the various liquids it had to traverse. Hence the comparatively small formation of ammonia. I next passed the nitrogen through the same absorbing apparatus, and mixed with hydrogen over heated asbestos, then over cold spongy platinum, and finally through a Nessler solution.

Traces of ammonia were produced in the hot asbestos,* but these were retained by a tube containing pumice and sulphuric acid placed between the asbestos and spongy platinum tubes. It was found that *no* ammonia was produced as long as the asbestos-tube remained hot, but the Nessler solution began to become turbid as soon as this tube could be touched by the fingers, and then soon showed evidence of the formation of ammonia.

In order to ascertain whether the absorbing apparatus still retained its efficiency, the nitrogen was now allowed to displace all hydrogen from the front of the apparatus, and the copper tube was again heated for half an hour to redness, and allowed to cool in the gas. Its *weight was unchanged*.

Having thus obtained ammonia by synthesis from hydrogen, and a gas evolved from a solution of nitrite of potash and sal-ammoniac, and which yielded nothing to red-hot copper (presumably pure nitrogen), and having found that the formation of ammonia is arrested by passing this gas through a red-hot tube, the evidence seems very strong that nitrogen, like phosphorus, is capable of existing in two forms, an active one and an inactive one, the latter produced by heat.

I hope to pursue this subject by investigating the behaviour of nitrogen from other sources, and especially of atmospheric nitrogen obtained without the aid of heat, when brought in contact with spongy platinum in presence of hydrogen.