III.—*On some Nuclei of Cloudy Condensation.* By JOHN AITKEN, F.R.S.
(With a Plate.)

(Read 3rd May, 1897.)

I have to apologise for placing this communication before you in a somewhat incomplete form. My work has been much interrupted in the past, and it will again shortly be stopped for a considerable time. I have therefore decided to place before you the results so far as they are worked out.

PART I.

IONS AND CLOUDY CONDENSATION.

ROBERT VON HELMHOLTZ published in 1887 the results of "Experiments with a Steam Jet."* This investigation was continued, and he and Professor RICHARZ joined forces, and the result of their investigation will be found in the same journal for 1890, under the title—"On the Influence of Chemical and Electrical Action on the Steam Jet, and on the Dissociation of Gases, particularly of Oxygen."†

HELMHOLTZ seems to have begun his work under a wrong impression as to the conclusions of other investigators. In the first of these papers, after describing some results, he says they *cannot* be explained on the dust theory; and after stating that some observers had rejected the dust theory, he adds that "AITKEN, on the other hand, has attempted to explain everything by it." In the second of the papers referred to, the authors say: "We hold that the earlier assertions that cloud is never formed without dust is incorrect." I have great difficulty in understanding how these authors could have made this mistake, because in my first paper it is distinctly stated that cloudy condensation can take place without dust; and a number of experiments are described in which condensation takes place in the presence of the vapours of different substances, such as sulphuric acid, hydrochloric acid, and a number of others,—the very substances one of the authors uses to prove that condensation can take place without dust. I had also shown, that if the supersaturation be great enough, that condensation can take place without nuclei of any kind.

In my first communication on the subject in 1881 I even went further, and said that it was probable that sunshine might cause the formation of nuclei, and allow cloudy condensation to take place where there was no dust. On this point I shall have something further to say in this paper.

* *Weid. Ann.*, xxxii. pp. 1-19, 1887.

† *Weid. Ann.*, xl. pp. 161-202, 1890.

The principal object of the two papers by HELMHOLTZ and RICHARZ is to prove that cloudy condensation may take place without dust, and the authors describe a great number of very beautiful experiments made with the steam jet, showing the change which takes place in its appearance when mixed with air charged with the products of combustion either from flames or from slow combustion, such as damp phosphorus slowly oxidising in the air, or when the jet is mixed with air which had been exposed to the electric discharge. In all these cases the authors show that something is produced which, when it meets the steam jet, causes an increase in the density of the condensation, evidently due to an increase in the number of small water drops. That there is something produced which causes an increase in the density of the steam is evident; but whilst one may go thus far with these authors, yet it is difficult to accept their explanation of the phenomenon. They attribute the condensation not to nuclei, but to the molecular shock produced by the chemical processes going on in the neighbourhood of the jet, or, to use a translation of the authors' words, "The collapse of the unstable condition of the supersaturated water vapour from the jet is determined less by the particular nature of the chemical action than to a far greater extent by the molecular shocks set up in the jet, molecular dissociations and associations, and on the presence of unsaturated compounds, molecular groups with free valencies or 'ions.'"

Whilst accepting the facts of the experiments, namely, that something is produced in these chemical processes which determines dense condensation in the steam jet, yet one has great difficulty in accepting the above explanation. Supposing we even admit that a molecular shock of the kind described could determine condensation in a supersaturated vapour, it must be remembered that the degree of supersaturation in a steam jet in the open air where there is dust is extremely slight,—the particles of water are so close that any strain easily relieves itself. Further, it must be remembered that the vapour in the jet is nearly in equilibrium with the drops of the size present in the jet, and it is very doubtful if it will be at all supersaturated to extremely minute particles of water, as the vapour tension at the surface of extremely small particles is higher than at the surface of larger particles. For these reasons it seems more probable that whatever it is that is produced in these chemical processes, it acts somehow in forming nuclei, and is itself engaged directly in the formation of the centres of condensation.*

Near the end of the second paper already referred to, the authors put in a claim for the importance of these "ions" in producing ordinary cloudy condensation. They

* There is another way of considering the whole question, from which it would appear that there is no such thing as supersaturation in a vapour; that is, no strain in the vapour which either dust or "molecular shocks" can relieve. What is generally called a saturated vapour is one whose tension is equal to the tension of the vapour at a flat surface. Now this tension is not so high as the tension at a surface of extremely small convex curvature; and vapour that is in equilibrium with the vapour at a convex surface is supersaturated to the flat surface; so that saturation is a relative and not an absolute quantity, relative to the curvature of the condensing surface, and a vapour that is supersaturated to a flat surface is not necessarily saturated to a surface of very small curvature. It would thus appear that there is no strain in a vapour till a surface makes its appearance; but after it is formed the lower tension at its surface determines a movement of the vapour molecules towards it.

say: "Apart from the explanation, the fact remains that by rapid and slow combustion an agent is called forth which sets up condensation, and which does not disappear immediately on the cessation of the originating process. Now so much oxidation takes place in so many different ways, that the idea is at once suggested that this agent which is formed by oxidation will be always present in small quantities in the air. We consider it quite possible that the faint condensation which the steam jet suffers in the open air may quite as well be due to the presence of this agent as to that of dust."

This conclusion seemed to be of sufficient importance to demand further investigation. Admitting the existence of these "ions" in the products of combustion, the question resolves itself into this: Do these "ions" persist for any length of time, and so come to play some part in the condensation of a steam jet or of a cloud, or is their action very short-lived? The difficulty of arranging an experiment for testing this point is, that during combustion so many different products are thrown into the air as well as an enormous number of fine dust particles. It is, therefore, difficult to find, by testing this complex mixture, many of the constituents which cause cloudy condensation, whether any particular one is more affected by time than the others. Because, if we keep the gases, new chemical combinations are formed, and the number of dust particles also decreases, and it would be difficult to determine how much of the decrease was due to loss of activity of the "ions." If, therefore, we are going to test the length of time the "ions" of combustion retain their activity, we must use some form of combustion in which no dust is formed, and the products are free from any substance that can form on cooling solid or liquid nuclei. Hydrogen burned in oxygen seemed particularly suitable for the purpose, but as this would involve considerable difficulties, it was determined to try the effect of burning it in filtered air. It was, however, kept in view that the presence of the nitrogen might give rise to complications, but fortunately there was no trouble due to its presence; nor did hydrogen peroxide, ozone, or ammonium nitrate, which are said to be produced when hydrogen is burned, produce any effect. Further, the products from hydrogen burning in air are stated by HELMHOLTZ to be very powerful in increasing the density of the steam jet, and they, therefore, seemed the most suitable substance for an experiment of this kind.

In carrying out this experiment the following arrangement was adopted (see Plate). The hydrogen was prepared from zinc and sulphuric acid placed in the flask, *A*. After being purified, it was burned at the platinum jet, *B*, having a diameter of 1 mm. The air for combustion was drawn through the large cotton-wool filter, *C*, and brought in at the lower end of the tall cylindrical glass combustion chamber, *D*, and taken off at the top. The combustion chamber used for these experiments was a Fresenius Chloride of Calcium Cylinder placed in an inverted position. For the present the flask, *U*, is supposed to be removed, and the combustion chamber, *D*, connected directly by its branch pipe, *V*, with the long glass tube, *E*, through which the products of combustion are carried to the gasometer, *F*, by means of which the air and products of combustion

are drawn through the apparatus. On the pipe, *E*, at a point about 1 m. from the combustion chamber, there is a branch pipe, *G*, which leads through the stop-cock, *H*, into the test-flask, *I*. This flask is provided with an air-pump, *K*, and a filter, *L*. By means of this part of the apparatus a sample of the air passing from the combustion chamber can be tested when desired. To make this test, the flask, *I*, is first cleared of all dust particles by means of the pump, *K*, and filter, *L*. After the air is free from nuclei, the stop-cock, *H*, leading to the pipe from the combustion chamber is opened, and a sample of the products passing in the pipe are drawn into the flask, *I*. The stop-cock, *H*, is then closed, and the air in the flask expanded by means of the pump, when the density of the condensation observed indicates the number of nuclei in the air from the burning hydrogen. For observing the amount of condensation in the flask, *I*, the dark lantern, *R*, was used, the light being focussed on the contents of the flask by means of the condensing lens, *S*, whilst the cloudy particles were observed through the lens, *T*. When making these experiments the room should be darkened, as the phenomena are then most easily observed.

At first the results were unsatisfactory: there was always considerable clouding, but the density was far from being constant. Efforts were, therefore, made to get everything as perfect as possible. Pure redistilled zinc and the purest sulphuric acid were used for generating the hydrogen, and, to prevent sulphur compounds from coming over with the gas, cupric sulphate* was added to the sulphuric acid, which was used very weak, and mixed with water and cooled before being put in the flask, *A*. The flask, *A*, in which the hydrogen was generated was kept cool by a bath of water, *M*. The hydrogen after leaving the generating flask was passed through the wash-bottle, *N*, filled with solution of lead nitrate. The gas then passed through a plug of cotton-wool, *O*, saturated with a strong solution of lead nitrate, then through a dry cotton-wool filter, *P*. It then passed through a small but very tight cotton-wool filter, *Q*, to regulate the pressure of the gas, as without this obstruction the light was apt to go out, owing to irregular pressure due to the bubbling of the gas. The gas was burned at the platinum jet, *B*, which was made red-hot with a blow-pipe before each experiment to thoroughly cleanse it, and prevent nuclei being driven off by the heat. The combustion chamber was kept cool by surrounding it with a wet cloth.

We shall now turn to the question of filtering the air. This looks a simple matter, but it was found to be one of the most troublesome parts of the experiment. In the apparatus a large cylindrical metal box, *C*, filled with cotton-wool, was used, with a pipe leading off it at the end. This pipe was at first connected with the combustion chamber by means of a short length of india-rubber tube. When the pure hydrogen was burned in this apparatus the flame was scarcely visible, and quite invisible if there was any daylight in the room, even if the combustion cylinder was surrounded with a black surface. Watching the burning hydrogen on one occasion, suddenly a little bright spark

* It was necessary to be constantly adding cupric sulphate to the acid in *A*. If this was not done, considerable condensation took place in the products.

made its appearance in the flame; on now testing the products they were found to have greatly increased in impurity. This at once suggested that some piece of solid matter had got into the flame. I now gently tapped the india-rubber tube by which the filtered air was brought to the combustion chamber, when the flame at once responded, showing a few bright sparks in succession, and the test-flask showed the air to be very full of nuclei. The india-rubber tube was therefore removed, and the filter connected direct to the combustion chamber. On now testing the apparatus, I gently tapped the filter itself, with the result that matters were as bad as before—dense clouding made its appearance in the test-flask. The arrangement of the apparatus was now slightly altered. The combustion chamber, filter, and gas-generating apparatus were put on one table, while the test-flask, with its pump, were put on another, to prevent the vibrations produced by working the pump from shaking the other parts of the apparatus. Further, the cotton in the filter was damped by passing damp air through it the reverse way, and when in use a wet cloth was hung over the entrance end of the filter. This was done to prevent dust rising from the dry wool or metal case.

It may be asked why all these precautions are necessary, when a cotton-wool filter is found to act quite satisfactorily without them when used in the ordinary dust experiments. The reason is very simple. If a little bit of any kind of matter happens to be carried with the air out of the filter in making the ordinary experiments, this means only one centre of condensation, and that drop may not meet the eye of the observer; but when the same bit of matter, particularly if it be organic, passes through the hydrogen flame, at once there are created thousands of centres of condensation, and what in the one case may escape detection gives rise in the other to a very manifest effect.

After many failures, and many alterations and improvements in the apparatus, the result is that, when everything is working right, the test-flask shows the products of combustion of pure hydrogen in dust-free air to be free from nuclei of all kinds. The air remains clear on expansion, and only a few drops are seen falling rapidly; the air is in fact far freer from condensation than the purest air met with in the country. The air was never absolutely free from a single nucleus on expansion, but frequently only a very few drops appeared, and all in view could be easily counted.

From this experiment it may be concluded, 1st, that pure hydrogen burning in dustless air gives rise to no solid or liquid form of dust; and 2nd, that any activity the "ions" may have is extremely short-lived, as they are inactive by the time they are cooled.

Whilst the apparatus, as described, shows that pure hydrogen when burning in dustless air gives rise to no permanent nuclei of condensation, we can, by making a slight alteration in the conditions, show the great importance of dust in the cloudy condensation produced by the products of combustion. If we remove the filter, *C*, and allow the air of the room to go unfiltered to the hydrogen flame, we get very different results, according to the condition of the air. If the day be calm, and the air of the room be but little disturbed, we get a great increase in the density of the condensation

when tested in the flask, *I*, but the density is not very much greater than what the air of the room would give if it had not passed through the hydrogen flame. The concentrated light from the lantern produces a luminous cone shining in the flask. If now, however, we move about things in the room, so as to stir up some dust, the result is remarkable. On now testing the products from the hydrogen flame in the flask the cone of light is no longer visible. So dense is the condensation that the whole flask is filled with a dense white fog, the flask looking like a white ball, the intense heat of the hydrogen flame having produced an enormous number of nuclei out of some of the dust floating in the air.

The conditions of the experiment, in which it is shown that hydrogen burning in filtered air gives rise to no nuclei of condensation, is not, however, quite the same as that in which HELMHOLTZ found these products to be very active, as he mixed them much more quickly with the re-acting agent. The products in his experiment were carried direct to the steam jet. To test the condensing power of the products immediately after combustion, the following alterations were made in the arrangement already described in the apparatus shown in the Plate :—The test flask, *U*, was introduced into the circulating system at a point close to the combustion chamber, so that the products might be tested immediately after combustion. For testing them in this case the steam jet method was employed as in HELMHOLTZ' experiments, only no unfiltered air was allowed to mix with the products. Steam was generated in the flask, *W*, and conveyed by means of a glass tube to the interior of the test-flask, *U*. This tube terminated in a fine jet. With the hydrogen burning and unfiltered air, there was a dense condensation, but when filtered air was used the condensation was extremely slight, and if the flame was low on some trials, it was difficult to say whether there was any condensation or not. In each test the steam was allowed to enter only for a very short time, as the test-flask got heated, and had, therefore, to be cooled before each test. It is evident from these experiments that the products of combustion from pure hydrogen and dustless air are far from being very active in the condensation of the steam jet, even when they are newly formed.

There are other reasons for leading us to conclude that the action of these "ions" is extremely short-lived. It is generally admitted that these "ions" are the cause of electrical conduction in gases, that it is to their presence in the products of combustion that these gases owe their power of discharging electrified bodies. Now we know that the products of combustion soon lose this power; if we bring the products from the flame to the electrified body by means of a short tube, the discharge is rapid, but as we lengthen the tube, the power very rapidly decreases. Again, the air of a room where gas is burning has very little, if any, power of discharging electrified bodies, yet it has enormous numbers of nuclei of condensation, due to the products of combustion. Lord KELVIN and Dr MAGNUS MACLEAN, in a recent communication to the Royal Society of Edinburgh, show that the products of combustion lose their power of discharging bodies in less than fifteen seconds. Further, we know that air

is nearly freed of all nuclei of condensation by the electric discharge, which, while it deposits the dust, rather increases the "ions." It may also be remembered that air passed through the Thermic filter is freed of all nuclei.

But whilst all experimental tests indicate that these "ions," or whatever it is that is produced during combustion, and which gives rise to condensation, are extremely short-lived, and do not play any important part in cloudy condensation in the atmosphere, it would be rash to say that they never do play any part. The conditions of combustion of a laboratory experiment are different from those under which combustion usually takes place; and further, whilst hydrogen may not give any long-lived "ions," some other forms of combustion may, and though they lose their power of discharging electrified bodies, they may yet be capable of causing cloudy condensation.

From many hundreds of observations on the dust and the transparency of the atmosphere, it has been shown that, for the same *relative humidity*, the transparency is proportional to the number of dust particles in the air, except at one place of observation, and under exceptional conditions.* Now this is not likely to be the case if "ions" played any important part in the condensation, as we can hardly expect their action to bear a constant proportion to that of the dust. For the reasons above given, it therefore does not appear at all likely that "ions" play any important part in the ordinary cloudy condensation in the atmosphere.

PART II.

SUNSHINE AND CLOUDY CONDENSATION.

In 1894 there was communicated to this Society Part III. of a paper "On the Number of Dust Particles in the Atmosphere." It is there shown that under certain conditions the sun gives rise to a great increase in the number of nuclei. The observations made at Kingairloch show, that when the wind is from the N.W. the number of particles is always very low, being generally under 500 per c.c., and often very much lower when the sky is clouded, but that when the sun came out the numbers rapidly increased as the day advanced, and if the sun kept shining all day, the numbers rose to many thousands in the afternoon, after which the numbers decreased, and again were very low next morning if the wind continued to blow from the N.W. These observations entirely justify the prediction which was made in 1881 on the probable action of sunshine in producing nuclei of condensation.

This action of sunshine on our atmosphere evidently deserves further investigation. A few of the ordinary constituents and impurities of our atmosphere have therefore

* *Proc. Roy. Soc., Edin.*, vol. xx. pp. 66, 93; *Trans. Roy. Soc., Edin.*, vol. xxxvi., Part III., pp. 621, 693.

been tested to see if sunshine acted on them in such a way as to make them active as producers of nuclei of cloudy condensation.

The gases tested were ammonia, nitric acid, nitrous acid, peroxide of hydrogen, sulphurous acid, sulphuretted hydrogen, hydrochloric acid, and chlorine. The result of these tests is that the gases or vapours of all these substances give rise to nuclei of condensation after being acted on by sunshine.

The apparatus used for these experiments consisted of a glass flask, in which the gases were sunned and tested. This flask was provided with an air-pump and a cotton-wool filter, the arrangement being the same as that shown on the right-hand side of the Plate, with the centre tube removed. Different methods were used for getting the gases into the flask; in some cases a little of their solutions in water was introduced into the flask, in others the gases were drawn into the flask through the cotton-wool filter.

In making a test, the first thing to be done was to wash the flask and connecting tubes, and put new cotton-wool into the filter. Filtered air was then pumped in till no drops appeared on expanding the air. If a solution of any of the gases was in the flask, the apparatus was then removed to an open window and exposed to sunshine, generally for one minute, after which it was brought back, the air expanded by means of the pump, and the density of the condensation noted. If the gas was introduced into the flask through the filter, it was sometimes necessary to pass a considerable quantity of vapour when making the first test, as it was found that the vapour that first entered the filter did not pass through, but seemed to combine with the cotton-wool, or perhaps only condensed on it, as after a filter was saturated it acted for some time, supplying nuclei without a fresh quantity of vapour being passed into it.

I regret that the experiments on the action of sunlight on the vapours mentioned are far from being as complete as I could wish; but for the reasons already given, and on account of the difficulty of getting plenty of sunlight, it has not been found possible to get the work done. The following notes are, therefore, very incomplete.

It should be noted at the outset that ordinary air, after being filtered and exposed to sunshine, does not show any cloudy condensation on expansion, only occasionally a drop or two may appear; but when any of the above-named gases are in the air a very different result is obtained. Ammonia has been experimented with both by placing a weak solution in the test-flask, and by drawing the vapour into the flask through the filter. If one drop of ammonia be added to 100 c.c. of water, and put in the flask and sunned for one minute, a great deal of condensation takes place on expansion with even this very weak solution, and if we expose it for five minutes the condensation is much more dense. If we put a weak solution of nitric acid in the flask, say two drops to 100 c.c. of water, we get cloudy condensation on expansion after being sunned; but the action of nitric acid is not so powerful as ammonia; that is to say, that though the solution of nitric acid was double the strength, it did not give so dense a condensation as the vapour from solution of ammonia.

The experiments made with nitrous acid must be looked on with considerable doubt, owing to the uncertainty which hangs round the existence of this gas when produced by the ordinary methods. I shall, therefore, only describe the experiments made, and leave the reader to draw his own conclusions. In experimenting with this gas it was always made outside the test-flask, and drawn in through the cotton-wool filter. The gas was prepared by means of nitric acid and arsenious anhydride. With gas prepared in this way, it is probable some of the effect might be due to nitric acid passing over with the nitrous acid. Another sample of nitrous acid was prepared from weak sulphuric acid and sodium nitrate. Both these samples of nitrous acid gave dense condensation after being exposed to sunshine.

The hydrogen peroxide was tested by placing a little of the ordinary 10 per cent. solution in the test-flask and sunning the contents. It proved to be a powerful generator of nuclei.

Sulphurous acid is one of the most puzzling of all the gases tested, its action is so uncertain. Unlike the others, it almost always gives rise to condensation in the dark. On some days, with even a weak solution in the test-flask, it was impossible to get the condensation to cease entirely. When attempting to clear the air in the flask, even in the dark, a few drops fell at each expansion, and on most days, though the drops nearly ceased to appear, yet on standing a few minutes a considerable number made their appearance when the air was expanded; but in all cases the cloudy condensation was very greatly increased after sunning. The products of combustion from household gas in some cases gave rise to slight condensation after sunning, whilst the products of combustion from anthracite coal, which probably contained a good deal of sulphur, gave dense condensation after being exposed to sunshine. This test might possibly be used for the detection of sulphur compounds in household gas.

The sulphuretted hydrogen tested was prepared from sulphide of iron and weak sulphuric acid. The gas was generated in a glass bottle, and drawn into the test-flask through the cotton-wool filter. This gas gave dense condensation after being exposed to sunshine. In order to see that the effect was not due to vapour of sulphuric acid, the acid used was tested alone before adding the sulphide of iron, and was found to be inactive.

Vapour from hot hydrochloric acid was drawn into the test-flask through the filter and sunned, after which it gave dense condensation on expansion, whilst the same vapour was inactive whilst kept in the dark.

Chlorine is one of the most interesting of the gases tested, as it caused condensation to take place without supersaturation. The gas was prepared from potassium bichromate and hydrochloric acid; it was drawn into the test-flask through the filter. Whilst this gas gave no condensation on being expanded, if kept in the dark, it became fogged on exposure to sunlight without being expanded, and the density of the condensation was but little increased by expanding it.

A point of some importance connected with these nuclei due to the action of light

on gases in the atmosphere is: after they are formed, do they remain active for any length of time, or are they short-lived? Unfortunately, for reasons already given, this point has not been thoroughly worked out; but this much has been ascertained: some of them, such as the hydrogen peroxide nuclei, are very short-lived—fifteen minutes to half-an-hour being sufficient for the air in the flask to lose its power of cloudy condensation; whilst the nuclei from sulphurous acid remain active for a long time, half an hour having no appreciable effect on the density of the condensation when that substance forms the nuclei. In this case the nuclei are probably particles of fine sulphur dust, and their action seems to be as permanent as that of ordinary atmospheric dust.

As might be expected, all the gases do not respond to light rays of the same rate of vibration; but no extensive experiments have been made in this direction. It may, however, be mentioned that whilst sulphurous acid is easily made active by means of the light of burning magnesium, on many of the other gases that light has little if any action. The action of burning magnesium on sulphurous acid makes a convenient lecture experiment, the flask being shown free from cloudy condensation when the moist air and sulphurous acid vapour are expanded, if the room be lit with gas. On now burning two or three inches of magnesium ribbon, and expanding, the air in the flask becomes densely white with cloudy condensation.

Whilst these experiments show that many gases which are frequently found in the atmosphere form nuclei of condensation after being acted on by sunlight, yet it must be admitted that they throw but little light on the abnormally high dust readings got at Kingairloch, when the wind blew from a pure direction and the sun shone. On looking for a source of impurities in the atmosphere at Kingairloch, I found there was a "mineral well" to the north-west of the place of observation, at a distance of about three miles; and on inquiry I found that there are a number of these wells in the district. The water in these wells contains sulphuretted hydrogen, and it seemed possible that this gas under the action of sunlight might be the cause of the abnormal number of nuclei; but as yet I have not been able to get evidence sufficient to bring in a verdict against it. Since I discovered that the sunlight was in some way connected with the production of these nuclei of condensation in N.W. winds, I have only been once at Kingairloch to test if the mineral springs supplied the gas out of which the nuclei were produced, but unfortunately the weather was never favourable for a test. If the sun shone, the wind was in the wrong direction, and when the wind was N.W., there was no sunshine. Only on one day did I get a minute or two of weak sunshine while the wind was N.W., but on that occasion I got no evidence against the well. The numbers were the same in the air coming to the well as in the air leaving it. The test, however, was too imperfect to put any reliance on, as by the time I got to a small distance to the lee side of the well, to get the air after the sun had time to act on it, the sun was under a cloud. I have also had some of the water bottled and brought here, where it was tested by placing some of it in the test-flask, and sunning

the air and gases over it, but obtained little indication of nuclei being formed. It should, however, be kept in view that it is quite possible the sun may produce the nuclei found at Kingairloch in some other way than from gaseous impurities in the atmosphere, and the phenomenon will require to be further investigated at that place.

These experiments on the effect of sunshine on the gases in the atmosphere show that it is possible for cloudy condensation to take place in the absence of dust. That is, supposing there is any part of the upper air free from dust, it is possible, if any of the gases referred to be present, for the sun to convert them into nuclei of condensation, and permit of clouds forming in dustless air. In the lower atmosphere there always seems to be plenty of nuclei to form cloudy condensation whether the sun shines or not. The only case where almost no nuclei were detected in the air was at the Ben Nevis Observatory, where on one occasion, at least, Mr Rankin found the air nearly free from dust, whilst the top of the mountain was in cloud. All the nuclei there at the time seemed to have been used up to form fog particles, and the air was then in a peculiarly supersaturated condition.

Though it is here shown that the impurities in the atmosphere when acted on by sunshine may permit of cloudy condensation taking place in the absence of what is commonly known as dust, we are not yet in a position to say that they do act in this way, because the impurities may not be in sufficient quantity to give a large enough number of nuclei to produce the cloudy form of condensation ; there may be only nuclei sufficient to produce the rainy form of condensation.

MR. JOHN AITKEN ON SOME NUCLEI OF CLOUDY CONDENSATION.