Number of Ions in the Free Atmosphere near Hot Springs.

By D. ISITANI.

[Read July 4, 1908]

§ 1. Introduction. It is a well-known fact that the atmosphere owes its electric conductivity to the presence of positive and negative ions wandering in it. There are several possible causes for the production of these ions: (1) radioactive substances may exist everywhere in the earth-crust, and ionise the surrounding air; (2) emanations developed in the earth-crust may come out into the atmosphere, either by direct diffusion, or by being first collected in cavities and capillars of the earth-crust and thence diffusing into the atmosphere, and these emanations as well as induced radioactive substances may ionise the atmosphere; (3) the strongly ionised air in the cavities and capillars of the earth-crust carrying ions may come out as the consequence of the lowering of the barometric pressure and give up the ions; (4) gases, waters, oils etc. emerging from the earth may be endowed with radioactivity and ionise the air; (5) extremely penetrating radiation, which has ionising action may come from the earth or heavenly bodies; (6) the sunlight may have ionising and electrifying action; (7) corpuscles with high velocities and therefore having ionising power may come from heavenly bodies; and so on.

From the fact that many thermal springs contain radioactive substances, as has been experimentally proved by many observers in Europe, especially in Germany, it may be imagined that the observation of ionic densities in the atmosphere near hot springs and comparison with corresponding quantities at ordinary places may lead to an indirect estimation of the quantities of radioactive substances contained, if any, in the springs. The ionic density in the free atmosphere, however, differs not only by locality, but also by the meteorological conditions, so that the above idea is by no means an easy matter to realise. On the other hand, the relation of ionic density in the atmosphere and the hygienic as well as therapeutic action of the air has lately drawn attention of physicians. This circumstance makes it
desirable, apart from the estimation of radioactive substances contained, to investigate the ionic densities in the free atmosphere, especially near thermal springs.

During the winter and spring vacations in 1907 and 1908, I made observations of the ionic densities in the free atmosphere at several mineral springs: Shuzenji and Itō in the province of Izu, Isobe, Kusatsu and Kawara-yu in the province Kōtsuke, and Nasu in the province of Shimotsuke. For the sake of comparison, I made also similar experiments in Tokyo at different places and at different epochs, especially at the Central Meteorological Observatory in May and June, 1908.

The observations were carried out with Ebert’s aspiration-apparatus, made by Günther & Tegetmeyer, the method of working being the usual one. It may here be remarked that, in Kusatsu and at the Central Meteorological Observatory, I measured the natural leak, i.e. the leak when the aspirator was not working, both before and after each individual experiment, while in the other cases similar measurements were made at irregular intervals in the course of a series of experiments.

The following is a short report of these observations, together with brief geographical sketches of places of observation.

§ 2. Ionic Densities at Tokyo. Although the atmosphere of Tokyo, being contaminated by dust and smoke, can not be a suitable standard medium for comparison of ionic densities, still it was considered interesting to examine the numbers of ions in the atmosphere in which we live, and to compare them with those of other places. In the following list, \( n_+ \) and \( n_- \) denote the mean numbers of positive and negative ions respectively in a cm\(^3\), and \( q' \) the ratio \( n_+:n_- \). The number of measurements from which each number has been obtained, varies greatly, from one in the cases designated with * to a hundred or more in some cases.

<table>
<thead>
<tr>
<th>Place</th>
<th>( n_+ )</th>
<th>( n_- )</th>
<th>( q' )</th>
<th>Date</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Toky University, near the Pond, under trees.</td>
<td>532</td>
<td>677</td>
<td>0.72</td>
<td>Jan. 11, '08</td>
<td>fog, calm.</td>
</tr>
<tr>
<td>2. Prof. Nagaoa's room</td>
<td>1852*</td>
<td>1900*</td>
<td>0.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. A Lecturer's room (measured by Dr. T. Terada)</td>
<td>760</td>
<td></td>
<td></td>
<td>Apr. 5, '06</td>
<td>fine</td>
</tr>
<tr>
<td>4. Nakatomisaka, Koishikawa</td>
<td>674*</td>
<td>663</td>
<td>1.02</td>
<td>March 23, '08</td>
<td>120-130</td>
</tr>
<tr>
<td>5. Central Meteorological Observatory</td>
<td>498</td>
<td>318</td>
<td>1.56</td>
<td>May 24 and June 5, 7, 10, '08</td>
<td></td>
</tr>
</tbody>
</table>
Prof. Nagaoka’s room contains a radium-specimen, which probably accounts for the strong ionisation.

As may be expected, \( q' \) is in most places approximately equal to unity, only at the Central Meteorological observatory \( q' \), as deduced from nearly a hundred observations, exceeds considerably that value. This may be accounted for as follows: the observatory is situated in the central part of Tōkyō, near the Imperial Palace, on the extremity of a ridge, 20m. above the sea-level. In the compounds of the observatory, which was formerly a part of Tokugawa Castle, there now remains a foundation-mound which is protected on all sides with large granite blocks piled up to a height of 11 meters above the ground. It was upon this granite wall, near the western edge, that I carried out my observations. Since the potential gradient of the earth’s electric field is very steep near an edge of a high peak, there will be a greater number of positive ions than negative, thus giving to \( q' \) a value greater than unity.

§ 3. Ionic Densities at Shuzenji. My first journey with Ebert’s apparatus was attempted in the winter vacation of 1906, to Shuzenji Hot Springs which lie in the north-western part of the Province of Izu. These hot springs are situated in a very narrow valley of the Katsura Stream, which comes from Darumayama, and running eastwards through the narrow valley, pours into the River Kano. Although the valley is only 100m. high above the sea-level, it is wholly surrounded by hills and mountains with the exception of its narrow eastern opening. The hot water comes out at several spots both on the banks and at the bottom of the Katsura Stream, over a length of a few hundred meters. It is transparent, colourless, and odourless alkaline water, containing mainly sodium chloride, sodium sulphate and calcium carbonate, the temperature being about 60°. There are some thirty sources there, none of which, however, produces any considerable quantity. The following is the result of observations made in the vicinity:

<table>
<thead>
<tr>
<th>Place</th>
<th>( n_+ )</th>
<th>( n_- )</th>
<th>( q' )</th>
<th>Date</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dakko-no-Yu</td>
<td>904</td>
<td>900</td>
<td>1.00</td>
<td>{Jan. 2.07}</td>
<td>covered with thin cloud, east wind.</td>
</tr>
<tr>
<td>2. Yanagiya Hotel</td>
<td>881</td>
<td>1010</td>
<td>0.88</td>
<td>Jan. 2.3.07</td>
<td>do</td>
</tr>
<tr>
<td>3. A slope on the south side</td>
<td>959</td>
<td>991</td>
<td>0.37</td>
<td>Jan. 4.07</td>
<td>fine, calm</td>
</tr>
<tr>
<td>near the village under trees.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Uncovered slope in the north hill.</td>
<td>449°</td>
<td>150°</td>
<td>2.99°</td>
<td>Jan. 4.07, 15°–16°</td>
<td></td>
</tr>
</tbody>
</table>
Dokko-no-yu, the first place of observation, is the most famous of the springs, and dates from the middle of the 15th century. The hot water issues from a fissure of a large rock in the middle of the Katsura Stream, and is collected in a cavity bored in the rock, for bathing purposes. It was on this rock that the aspiration-apparatus was set; the densities of both ions were nearly equal to each other.

The second place of observation was a room, situated near to the reservoir of the natural hot water, in the hotel Yanagiya. The hotel has no source of its own, and the thermal water is led with pipes from two sources some 100 meters off. Observations showed that n was greater than n+.

The third place of observation is a spot on the slope on the southern side, near to the east end, of the valley. It is situated, only a little elevated from the bottom of the valley, where hotels and bath-houses stand, and is in the lower marginal part of a forest. The table shows that the ionic densities were nearly equal to those at Dokko-no-yu, the only difference being that n− was slightly greater than n+.

The fourth place of observation was an uncovered spot, on the east-side slope of a small branch valley running northward from the east end of the main valley, the distance from the main valley being about 400 meters. Having observed low numbers of ions, I gave up the observation, since, at that time, my principal object was to find out places with high values of ionic densities.

§ 4. Ionic Densities at Ito Hot Springs and Atami Geyser.

<table>
<thead>
<tr>
<th>Place</th>
<th>n−</th>
<th>n+</th>
<th>q'</th>
<th>Date</th>
<th>Weather</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Dekiyu</td>
<td>555</td>
<td>574</td>
<td>0.97</td>
<td>Jan. 6, pm.'07</td>
<td>&quot;</td>
</tr>
<tr>
<td>3. Coast of Ito</td>
<td>793</td>
<td>706</td>
<td>1.12</td>
<td>Jan. 67,'07</td>
<td>&quot;</td>
</tr>
<tr>
<td>4. Atami</td>
<td>524</td>
<td>535</td>
<td>0.98</td>
<td>Apr. 2,19-,'06</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

The measurements were on the way from Shuzenji to Itō, near a tunnel at the top of a mountain pass called Kashiwata-ga, which is at the level of 430 meters above the sea. The table shows that the ionic densities were much less than those at Shuzenji, and that the positive ions were more numerous than the negative, as was to be expected.

On the eastern side of the mountain, there extends a plain, which, with an area of ¼ sq. km., is one of the largest plains in the mountainous province of Izu. This plain is surrounded on three sides by
mountains, the remaining northeast side being bounded by sea. The town Itō is situated on this part of the sea coast. There are great many hot springs in the town, each of which pours out large quantities of hot water, which is transparent, colourless and odorless, has a slightly saline taste, and contains principally chlorides of sodium, potassium and magnesium, and silicic acid. The most famous sources are Shishido, Dekiyu, Wada and Me-no-yu. The temperature of the hot water is different in different sources; that of Dekiyu was about 50° C.

The second place of observation was at the bank of a hot-water pond, which serves for washing the horses, and which is on one side of Dekiyu. The ionic densities were nearly equal for both ions and was of the same order as those at Kashiwa-tōge, much less than those at Shuzenji.

The third place of observation was chosen immediately near to the coast, near Ryūgū-shrine at the north end of the coast line at the foot of the mountain, which is about 600 meters distant from Dekiyu. The sea was calm, except that there was usual rolling at the shore, and splashes were occasionally formed by the wave breaking against numerous large round rocks. The ionic densities observed were greater than those at Dekiyu, and as might be expected, the positive ions were more numerous than the negative.

It may be noticed that the number observed at the coast was of the same order of magnitude as those \( n_+ = 761, n_- = 743, q' = 1.02 \) obtained by Eve\(^*\) at the Gulf in United State of America, on his voyage from America to England.

The fourth line of the above table gives the result as obtained by Dr. Terada, at Atami, which is noted for its geyser, and has a similar geographical feature as Itō, only in a much smaller scale. I take this opportunity of expressing my sincere thanks to Dr. Terada for his kindness in giving to me his numbers and other valuable informations.

§ 5. Ionic Densities at Isobe Mineral Springs.—Isobe mineral springs are situated at the end of the valley of the river Usui, where the valley opens into the great plain of Kwanto. There are two sources, from which issues muddy, cool, effervescing mineral water, that leaves, on evaporation, beautiful cubic crystals of sodium chloride. The

\(^*\) Phil. Mag. 13, p. 251, 1907.
observations made at one of the sources in the forenoon of the 6th March, '08, in a cloudy weather, gave \( n_+ = 460, n_- = 399, q' = 1.15 \); thus

the ionisation did not much differ from that in Tōkyō, and the positive ions were in excess. Experiments made in the afternoon after a little rain, gave apparently large ionic densities, but this could not be asserted definitely because of comparatively large natural leaks.

§ 6. Ionic densities at Kusatsu and Kawara-yu Hot Springs.—Kusatsu hot springs lie in one of the shallow valleys radiating from Mount Kojirane, which is in the immediate neighborhood of the volcano Shirane-yama, at the height of 1340 meters above the sea. The plateau, corrugated with the shallow valleys, extending to the southeast of Kojirane, it may be noted, seems to form a connected whole with that (Rokuri-ga-hara) on the north side of Asamayama; through this great plateau the river Agatsuma has cut its way in the form of a deep valley by erosion. The upper end portion of the valley of Kusatsu is rather flat and is covered with wet greyish-white volcanic tuff, and all over this area of about 15 meters \( \times \) 300 meters there issues hot sulphureous water of 50°C or less, and there are found everywhere deposited yellow masses of sulphur, the air having the disagreeable odour of hydrogen sulphide. This place is called Sainokawara; the hot water issuing from these numerous sources form a stream and flows down the valley.

It may be remarked that at a spot between Sainokawara and Kusatsu, the valley is contracted and curved abruptly, so that these two places have rather the appearance of two separate localities connected only by a narrow neck.

The uppermost group of the hot springs of Kusatsu, consisting of Shirahata-no-yu, Netsu-no-yu and Matsu-no-yu, lies at a distance of about 200 meters from the contracted part of the valley. These springs are incessantly evolving gases from the bottom, thus making the appearance of boiling water. The temperature of the water was about 60°C at the surface exposed to air, without any sensible difference even on a snowy day, showing thereby the richness of the issue. All the springs, of which there are many more besides the above mentioned, give forth transparent acidic sulphureous water with acidic taste, and an odour of hydrogen sulphide, whose constituents are chiefly free sulphuric acid, free hydrochloric acid, sulphates and silicates of calcium, magnesium, aluminium, sodium, potassium and iron.

My observation was mainly carried out at several points in Saino-
kawara; the mean ionic densities observed in calm and fine days (Mar. 31, Apr. 1, 2, 3, '08,) were
\[ n_+ = 1260 \quad n_- = 896 \quad q' = 1.41. \]
They are greater than corresponding quantities at Isobe and Tôkyô or Itô and Atami, \( n_+ \) being the greater.

Towards the end of my stay in Kusatsu, we had a heavy snow; the observations made on that occasion will be mentioned under another subject.

On Apr. 9, I left Kusatsu by a snowy road, and after traveling 12 miles passed the night in Kawarayu, which is situated halfway up the mountain Kinko, at the height of 850m, and looks down upon the rapid stream of the Agutsuma river washing the foot of the steep slope of the mountain. The spring sends forth a salt mineral water of 30° (C.) (?) with a very slight odour of hydrogen sulphide and containing calcium sulphate, sodium chloride, etc.

A few experiments made a little before sunset in a room upstairs a lodging house, gave \( n_+^* = 396, \quad n_-^* = 642, \quad q' = 0.62. \)

§ 7. Ionic density at Nasu Hot Springs. In the northwestern part of the province Shimotsuke, there spreads the broad plane of Nasu-ga-hara, along the western boundary of which there lie Nasu and other thermal springs.

Of the so-called Nasu hot springs some are situated halfway up, and others at the foot of the active volcano Nasugadake. Among these the best known are Yumoto hot springs, which are situated at the south-eastern foot of the volcano, where there is a shallow valley running in the south-south-east direction. On the west slope of this valley, and halfway up, lie the Yumoto springs at the height of 900 meters above the sea. Yumoto, with hotels and inns, however, has no independent sources; it gets its hot water, by means of pipes, from a spot called Motoyu at a distance of about 300 meters up the valley. The water is acidic sulphureous water, containing mainly free sulphuric and hydrochloric acid, silicic acid, hydrogen sulphide, and sulphates of magnesium, aluminium, sodium, potassium and iron.

Beyond Motoyu, the valley is slightly broader; there it is filled up with greyish white tuff, and strewn with yellow masses of sulphur, and has a disagreeable odour like that of hydrogen sulphide. This place is called Sainokawara, and at its farther end, about 200 meters from Motoyu, there stands a stone called Sesshôseki of which it is said that every animal was killed on approaching it.
Observations were made near Sesshōseki, and also behind a bath basin which was nearest to the source at Motoyu. It was very cold and we had often severe wind and snow, which made outdoor work very inconvenient. By the way it may be remarked, that the snow fallen on the ground melted away instantly, probably because the ground was always warm. The most observations were thus made under abnormal conditions; they show that the numbers of positive and negative ions in free atmosphere, as well as their ratio, suffer considerable influence of atmospheric conditions. The few observations made under nearly normal conditions of the atmosphere gave for the mean densities the following values:

\[ n_+ = 1920 \quad n_- = 1840 \quad q' = 1.03. \]

The numbers obtained on other days will be mentioned under another subject.

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On the Correction for Open End of a Tube with Infinite Flange.

By K. Aichi.

[Read Sept. 26, 1906]

1. The correction for the open end is an important quantity in the theory of the open organ-pipes as well as in problems concerning electrical conductivity. There are two methods for its evaluation. Helmholtz's method\(^1\) consists of an exact solution of the problem for an approximate cylinder. Lord Rayleigh on the other hand takes a true cylinder, and finds that the correction must lie between 0.785 \(R\) and 0.82422 \(R\), \(R\) denoting the radius of the cylinder. This upper limit\(^2\) is obtained by calculating the energy of the motion on the supposition that the axial velocity is of the form

\[ 1 + \mu \frac{r^2}{R^4} + \mu' \frac{r^4}{R^8}, \]

\(r\) denoting the distance of the point considered from the centre of the mouth, determining \(\mu\) and \(\mu'\) so as to make the whole energy a mini-

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1) Ges. Abb. 1, p. 303, or Ostwald's Klassiker. No. 80.
2) Theory of Sound. 1. Append. A.