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 THE ABSORPTION OF CONDENSATION-PRODUCING ATMOSPHERIC DUST BY SOLID NUCLEI AND SURFACES, AND ON THE DIFFUSION VELOCITY OF SUPPOSEDLY NON-IONIZED DUST PARTICLES.**

LET r be the radius of a tube stretched along the axis X, and conveying dust-laden air at a velocity, v. Consider two sections at a distance dx apart; the dust entering per second at the near face is $\pi r^2 nv$; the dust leaving per second at the rear face is $\pi r^2(n + [dn/dx]dx)v$, if the air current is kept constant and n is the density of dust distribution, or is proportional to the number of particles per cubic centim. On the other hand, the absorption of dust particles by the walls of the section in question, is $k \cdot 2\pi r \cdot n \cdot dx$, where k is the absorption per square centim. per second, per unit of dust concentration, and the absorption, as a first hypothesis, is taken proportional to the density of distribution of particles in air.† Hence $-\pi r^2(dn/dx)dx \cdot v = k \cdot 2\pi r \cdot n \cdot dx$,

or
$$\frac{dn}{n} = -\frac{2k}{vr}dx. \qquad (1)$$

Let the density in case of air saturated

* Preliminary report of work made with a grant of the Smithsonian Institution, and published by permission of the Secretary.

† Briefly k is the diffusion velocity of the dust particle, *i. e.*, its normal velocity in air at rest. Equation (1) neglects the spontaneous dissipation of dust particles. This is permissible for the fast air currents v of Table I. The full equation is treated below.

with dust be taken as one. To determine the constant of integration it is to be observed that when $x = 0$, or $k = 0$, there is no absorption; but the current of air must nevertheless be kept up passing either through the absorption tube or not, to retain a colored field in the color tube. Now saturated dusty air would be objectionable seeing that an opaque field is produced unsuitable for measurement. Hence even when $x = 0$, or $k = 0$, the influx current is unsaturated, and we may suppose this minimum current to be obtained through a fixed initial length of tubing, x_0, of the same kind. Thus the tube virtually begins at $-x_0$, and equation (1) becomes on integration

$$n = e^{-\frac{2k(x+x_0)}{rv}}. \qquad (2)$$

If the observations be so made that the dust density issuing from the length x of tubing is constant, we have for a given color tube, $n = n'$ and

$$\frac{x + x_0}{v} = \frac{x' + x_0}{v'}. \qquad (3)$$

For different tubes under the same conditions,

$$k/k' = \frac{vr}{x + x_0} \Big/ \frac{v'r'}{x' + x_0}.$$

Hence, ignoring the undeterminable constant, one may write briefly

$$2k = vr/(x + x_0). \qquad (4)$$

With this preliminary theory as a point of departure, I have been making an extended series of observations on the condensation of supersaturated steam obtained from jets, and following the general method of color tubes described in my memoir* on the subject published by the U. S. Weather Bureau in 1895. By passing measured quantities of air (V litres per minute), saturated with the emanation of phosphorus, through different lengths of absorption tubing,* and regulating the air current by a graduated stop-cock till a definite color (full blue) appears in the field of the color tube, the condition $n =$ constant is fulfilled, on provision that no change has occurred in the action of the tube during the interval. As V is the influx of dusty air per minute, $1000v/60 = \pi r^2 \cdot v$, and as $2k = vr/(x + x_0)$,

$$k = \frac{2{\cdot}65}{r} \cdot \frac{V}{x + x_0},$$

where $V/(x + x_0)$ is given by the observations of volume in terms of length of absorption tube for a fixed blue in the field of the color tube. If V_0 be the minimum volume, *i. e.*, the influx volume of dusty air corresponding to $x = 0$, $k = 2.65/r \cdot V_0/x_0$; hence, finally,

$$k = \frac{2{\cdot}65}{r} \frac{V - V_0}{x}. \qquad (5)$$

Aside from the difficulty of observing subject to color criteria, equation (3) is well borne out by the data obtained, to the extent that V is a linear function of x. V_0, however, does not always coincide with observation, and a certain additional tube length must in certain cases be added to compensate for the dissipation (eddies?) encountered on entering the absorption tube. But this is non-essential.

A brief summary of the present results is given in the following table, which shows the material of the absorption tubes, their diameter, the variations of length (x) and volume (V) occurring in each series of experiments (usually 10 or 20 in number). The pressure under which steam issues from the jet is shown under p (centims. of mercury), and the temperature (°C.) of the air flowing into the color tube, under θ. Within reasonable limits, discussed elsewhere, the color tube is not sensitive to

*A Report on the Condensation of Atmospheric Moisture; Bulletin, No. 12, pp. 104, U. S. Weather Bureau, Washington, 1895.

*Ordinary tubing used for absorption purposes, *i. e.*, to catch the dust particles moving laterally out of the dust-laden air current.

either of these variations. The table also gives the ranges of the velocities of dust-laden air through the absorption tubes resulting from the differences of length, and the limit of values computed for k showing the errors of measurement. The final column contains the mean value of k obtained from the data as a whole.

to be seen whether greater refinements of method* will rather bring the k-values to coincide for all condensing surfaces or accentuate differences.

At all events, it is already clear that the velocity of the phosphoric dust particle is independent of its density of distribution.

In the Bulletin cited, the work of which was done in 1893, and elsewhere,† I denied that colored cloudy condensation was ever due to ions, a theory then rife and particularly discussed by the younger v. Helmholtz, Bidwell and others. None of these investigators have, to my thinking, made out a clear case. Since the advent of the X-rays and of the brilliant work done at the Cavendish Laboratory, however, the status of the question has changed materially. Nevertheless I am still loth to abandon my former conviction that condensation is always primarily due to nuclei; and that whether they are ionized or not (none were certainly known until recently), is a matter of secondary and perhaps negligible consequence. Thus for instance, concentrated sulphuric acid is a dust producer comparable to phosphorus; and yet this is the very reagent that has always been used in drying the chambers of apparatus when high insulation is specially wanted. Certainly one would be rash to thrust the wily ion in such a chamber. Indeed the interest which attaches to the above results is this,

TABLE.—ABSORPTION OF PHOSPHORIC DUST* IN TUBES.

Tube of	Diameter.	Range of Lengths, x	p	θ	Range of V†	Range of v‡	Range of k	Mean k
Gray rubber	.64cm.	0–455cm.	4cm.	26°	.7–7.0	40–360	.08–.12	.123
Pure rubber	.35 "	0–300 "	6 "	24°	.5–4.2	80–740	.12–.16	.137
Lead	.63 "	0–300 "	5 "	27°	.5–4.6	30–250	.15–.18	.162
Lead	.32 "	0–150 "	9 "	27°	.7–2.0	140–410	......	.160
Glass	.29 "	0–150 "	8 "	27°	.8–2.0	200–480	......	132

In view of the widely different values of the velocity with which the dust laden air traversed the absorption tubes, the high velocities employed and the marked difference of material which makes up the absorbing walls, the close proximity of the values of k is particularly noteworthy when the meaning of this constant is called to mind: k being the absorption per square centim. per second per unit density of distribution, is simply proportional to the velocity of diffusion of the phosphorus emanation, or in other words, to the velocity with which the particles ejected from phosphorus by an oxygen reaction travel normally through the surrounding air. In the cases of glass, of impure vulcanized gray rubber, of pure brown rubber, this velocity is so far as observation warrants, the same. In the case of lead tubes the velocity set forth by k is slightly larger, a circumstance which may have an electrical or a chemical bearing, or be referable to the greater density of these tubes. It is entirely premature to speculate upon it. It remains

*Similar results were obtained with dust particles ejected by concentrated sulphuric acid.

† Litres per minute.

‡ Centims. per second.

*The color estimates in the table were made by the eye. It will not be difficult to repeat them relative to some fixed standard blue.

† *Nature*, XLIX., p. 363, 1894.

that strong evidence is afforded in favor of a specific velocity of the particles of a supposedly non-ionized dust, so far as the phosphorous emanation has been known. Since they are always absorbed they must clearly soon vanish out of any vessel, usually within five minutes if considered in bulk. A large part of this dissipation is referable to the grosser dust particles in ordinary air.* Thus if phosphoric dust and a suitable small quantity of smoke of ammonium chloride (made in the usual way) be passed into the color tube, the field which is opaque with phosphoric dust alone, becomes cleared when the sal-ammonium smoke is added. The larger particles of the latter have therefore captured the finer particles of the former (phosphorus emanation); and as sal-ammonium smoke alone, if not itself opaque, is unable to produce colored cloudy condensation or opacity, the field clears at once. Now if sal-ammonium smoke can capture phosphoric dust then it is conceivable that agencies may exist which reverse the fortunes of war and liberate phosphoric dust. Heat is such an agency. If nearly effete dust be passed through a hot tube (say above 400°), experiment showed me that the condensation producing tendency is again restored, precisely as if the dust were dissociable. At a higher temperature still, though not necessarily above red heat, the tube itself becomes an energetic dust producer at its inner walls, even when of glass so that experiments of the present kind are delicate. Indeed long ago I asserted that the strong dust producing activity of flames was a conversion of coarsely disseminated into finely disseminated atmospheric dust, a conversion of the planets of this microcosm into nebulæ, as it were.

One may readily conceive the X-rays to be another such agency. After some trials I devised a form of apparatus appropriate for my purposes, by which the condensational tendency of air energized by X-rays,* shows almost as powerfully in the color tube as does the older dust laden air. So far as the effect of these different kinds of dust on the color field is concerned, one would be unable to distinguish any noteworthy difference of behavior. Both may be carried through tin tubes 2 inches in diameter and over 60 feet long, taking one or more minutes in the transfer, without encountering fatal diminution in the condensation producing power of either. Other and now well known experiments of an entirely different nature go to show that X-ray dust is ionized, or transferred in a region of ionized gas, whereas the ordinary dust, with which I have chiefly worked, is not; but I ask, if both classes of dust are under proper limitations, equally able to induce condensation in supersaturated aqueous vapor, how can one single out the exceptional quality of ionization as the cause of this tendency? It has been brilliantly proved by J. J. Thomson, Rutherford, Chattock, and indirectly by C. F. R. Wilson, that ionized dust has a definite velocity; but in as far as the above experiments have weight, so has the supposedly non-ionized dust.

* This secondary dissipation is neglected in the differential equation (1), being of much smaller order than the surface effect investigated. With the wide tubes (diameter 2 inches), presently to be mentioned, the differential equation replacing (1) above is

$$-\pi r^2 v\, dn/dx = kn2\pi r + k'n^2/v$$

where k' is the number vanishing per second per unit of concentration of dust in air. The last term decreases as v, the velocity of the air current increases. This equation is easily reduced as a case of Riccati's equation, and the integration may therefore be made without difficulty.

* Of course, the X-ray tube must be boxed up most carefully, the rays shining through an aluminum window, and the terminals imbedded in paraffine. Any highly potentialized conductor, like a hot body, is apt to dust the air.

One way of escaping between the horns of the dilemma is to suppose the ionization to exist even when not directly evidenced. Thus most of the dust with which I have worked is derived by oxidation, or by heat implying chemical action or dissociation, or from highly potentialized matter, etc. Phosphoric dust is quite inactive at low temperatures and in a current of air free coal gas. The same is true of molten sulphur. Concentrated sulphuric acid, however, shows increased activity when a current of coal gas is passed through it into the color tube; but the action here is probably a destruction of the coarse dust particles in air, the effect being similar to that referred to in the case of flames. Facing the question squarely it seems extremely difficult to account for a specific velocity in the non-ionized dust particle. Being already stupefied in observing that a much larger volume of air of initially constant dust content must be discharged through a wide tube than through a narrow tube of the same material, and within certain limits of diameter, instanced by the above table, one may well be daunted in confronting the case of a specific velocity in an inert dust particle.

The need of a direct decision is, therefore, urgent; is this phosphoric dust ionized or not; or better, is it generated in an ionized region? Using an electroscope, which in the dry room in which I worked retained its charge indefinitely, I aspirated a current of air across the charged terminal without appreciable result. I then blew air which was passed over phosphorus across the terminal, and found to my surprise that even with a small current the charge was dissipated more than one-half in the first minute. It made no difference whether a positive or a negative charge was on the electroscope. Hence, phosphorus, when emitting condensation-producing dust seems also to emit some form of obscure radiation; for the dust evolution* occurs in a strongly ionized region, or the dust is itself ionized. Relative to the experiments of the above table, therefore, fresh means are at hand for computing the velocity of the phosphoric dust particle, and the electricity carried per gram, in a way similar to the famous researches made at the Cavendish Laboratory, independently of the preceding results. This suggests one method of standardizing the colors of my color tube, absolutely in terms of the number of dust particles per cubic centim. producing the color effect.

With the question thus happily answered in the case of phosphorus, I next examined air passed over concentrated sulphuric acid, but found it without effect even on the electrometer. Though the acid is a weaker dust producer than phosphorus, the present electrical result seems out of proportion to the data of the color tube. The decision made is therefore partial, but I have not advanced beyond it. Other dust producers might be instanced in the same category, and it is for this reason that I have retained the antiquated designation 'dust' in this paper.

I may add that in the experiments which I have under way, I have been dealing somewhat extensively with questions of the above nature, using dust either ionized or not. My methods, however, are all restricted to an application of the steam jet,

* I shall show elsewhere, and have since verified experimentally, that if air energized by phosphoric dust be maintained between the plates of an air condenser, the difference of potential, ϕ, vanishes according to the equation

$$\phi = \phi_0 \varepsilon^{-nket}$$

in the lapse of time t, where e is the charge per particle. For different thicknesses, d, of air, the decay of energized dust particles in successive layers of air is very similar to the absorption of light in successive thicknesses of medium, viz., $n = n_0 10^{-ad}$. In my experiments I found $a = .25$, and thus the number of particles is reduced to 1/10 in a layer of air 4 centimeters thick.

since this is an instrument with which I am familiar, and since this mode of attack has not at all been cultivated by the recent investigators on allied questions. The steam jet method has undoubtedly many grave shortcomings; but it has one invaluable advantage of retaining a given color of field for an indefinite interval of time, so long as the conditions of action are left unchanged. My present work has shown me, moreover, that the complicated character of the evidence derived from the jet, is much less serious than I have hitherto supposed. Among the inquiries with which I have been much occupied, is a determination of the number of particles which give rise to a given colored condensation in the field of the color tube, contributing to an optic phenomenon of exceptional interest, the theory of which is as yet quite unknown. Should this phenomenon yield to treatment, there would be given, since there is no serious difficulty in finding the collective mass of the particles, an independent method, and one not depending on electrical agency, of ascertaining both the individual velocity and possibly the mass of these subtle and pervasive dust particles, absolutely. For let m_0 and m be the masses of dust absorbed per square centim. per second in the first and final sections of the absorption tube. Then $n = m / m_0$ and the velocity k in equation (2) is thus the only unknown quantity.

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RECENT OUTLOOKS UPON MUSIC.

The field of music is too vast to be seen from any single standpoint. The ignoring of this simple truth has led to countless misrepresentations of facts by writers, and misunderstandings of books by readers. For tacitly it is assumed by most of us that there is only one standpoint, indefinitely thought of as that of the modern musical performer or intelligent concert-goer; and if we do recall that some mathematicians praise another point of view, while Greek, Oriental and mediæval musicians apparently had others, we yet know they have been too rarely visited to have much influence on musical thinking.

But the discoveries of the last few years bearing on the questions of the basis of music and the historical development of scales have rendered it possible for the student of comparative music to occupy a point from which many long-known facts appear entirely changed, and older authorities, as Fétis, Helmholtz and Ambros, are seen to be inadequate, if not erroneous. In comparison with this standpoint, that of the modern musician appears to be a rapidly shifting one, like an observation car or the masthead of a ship.

It is the purpose of this paper to review from this new-found standpoint some parts of four rather recent books * of more than temporary interest and value, that deal with various parts of the field; and by their aid to define the musicians' standpoint, and indicate some of the problems now before the student of the history and basis of music.

I.

Klauser's book was the first in order of publication, yet is probably the least known of the four. From title page to conclusion it bristles with novel ideas, developed during, and verified, he asserts, by many years experience in teaching. The hearty pub-

* 'The Septonate and the Centralization of the Tonal System,' by Julius Klauser. Milwaukee, 1890, pp. vi + 274; 'The Art of Music,' by C. Hubert H. Parry. New York, 1893, pp. 374; (The new English edition has the title, The Evolution of the Art of Music); 'Primitive Music,' by Richard Wallaschek. London, 1893, pp. 326–9; 'A Study of Omaha Indian Music,' by Alice C. Fletcher; with a report on the 'Structural Peculiarities of the Music,' by John Comfort Fillmore, A.M. Peabody Museum, Cambridge, Mass., 1893, pp. vi + 152.