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LXXIV. On Prof. Lowell's method for evaluating the surface-temperatures of the planets; with an attempt to represent the effect of day and night on the temperature of the earth

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Summary of Results.

(1) Over the time of observation (205 days) radium is produced in actinium preparations at a constant rate.

(2) By suitable chemical treatment actinium preparations can be obtained which grow radium extremely slowly.

(3) The active deposit of actinium does not change directly into radium.

(4) The results indicate that in the ordinary actinium preparations there exists a new substance which is slowly transformed into radium. This direct parent of radium can be chemically separated both from actinium and radium.

(5) Observations have not extended over sufficient time to settle whether this direct parent of radium has any direct genetic connexion with actinium or not.

Experiments are in progress to devise more definite methods for separation and isolation of this new substance in order to examine its physical and chemical properties, and to determine its position in the long series of transformations of uranium.

Manchester, Sept. 20, 1907.

LXXIV. *On Prof. Lowell's Method for Evaluating the Surface-Temperatures of the Planets; with an Attempt to Represent the Effect of Day and Night on the Temperature of the Earth.* By J. H. POYNTING, *F.R.S.**

PROF. LOWELL'S paper in the July number of the Philosophical Magazine marks an important advance in the evaluation of planetary temperatures, inasmuch as he takes into account the effect of planetary atmospheres in a much more detailed way than any previous writer†. But he pays hardly any attention to the "blanketing effect," or, as I prefer to call it, the "greenhouse effect" of the atmosphere. He assumes in fact that the fourth power of the temperature is proportional to the fraction of solar radiation reaching the surface, and he neglects both the surface

* Communicated by the Author.

† In Phil. Trans. A. vol. ccii. p. 525 I attempted an evaluation, in which the atmosphere was taken into account as keeping the temperature at a given point practically the same day and night. I did not then know that Christiansen (*Beiblätter zu den Ann. der Physik und Chemie*, x. 1886, p. 532) had nearly twenty years earlier applied the fourth power law to calculate planetary temperatures. His work deserves recognition as the first in which this law was applied.

radiation reflected down again and the radiation downwards of the energy absorbed by the atmosphere.

This is brought out clearly in the footnote on p. 172, where he uses a formula of Arrhenius, to which I am unable to refer, but which I think he must misinterpret in making it give his result. The inadequacy of his method is well shown by its application to the cloud-covered half of the earth's surface. He finds that this half only receives 0·2 of the radiation which the clear sky half receives. The surface temperature under cloud should therefore be only $\sqrt[4]{0{\cdot}2}=0{\cdot}67$ of that under clear sky. If the latter is 300° A. the former is only about 200° A. Common observation contradicts this flatly, for the difference is at most but a few degrees.

On another point common observation appears, at any rate at first sight, to contradict Professor Lowell. He assumes that the loss in the visible spectrum radiation in its passage through the atmosphere is practically all due to reflexion, and he puts it down as about 0·7 of the whole in clear sky. If this were true the reflexion from the sky opposite to the sun would I think be vastly greater than it is. White card-board reflects diffusely about 0·7 of sunlight. But when a piece of white cardboard is exposed normally to the sun's rays it is several times brighter than the cloudless sky.

The "greenhouse effect" of the atmosphere may perhaps be understood more easily if we first consider the case of a greenhouse with horizontal roof of extent so large compared with its height above the ground that the effect of the edges may be neglected. Let us suppose that it is exposed to a vertical sun, and that the ground under the glass is "black" or a full absorber. We shall neglect the conduction and convection by the air in the greenhouse.

Let S be the stream of solar radiation incident per sq. cm. per sec. on the glass. Of this let rS be reflected, aS be absorbed, and tS be transmitted by the glass. Then $r+a+t=1$. Let the ground send out radiation R per sq. cm. per sec. and of this let r_1R be reflected, a_1R be absorbed, and t_1R be transmitted by the glass. Here also $r_1+a_1+t_1=1$. It is to be noted that since the edges are far distant R is incident on each sq. cm. of glass. The glass, then, absorbs $a\mathrm{S}+a_1\mathrm{R}$, and as it is thin it may be taken as having the same temperature on each side, so that it sends down to the ground $\frac{1}{2}(a\mathrm{S}+a_1\mathrm{R})$, the other half going upwards into space. Equating receipt and expenditure of radiation by the ground,

$$\mathrm{R}=t\mathrm{S}+r_1\mathrm{R}+\tfrac{1}{2}(a\mathrm{S}+a_1\mathrm{R}),$$

whence on putting $r_1 = 1 - a_1 - t_1$ we obtain

$$R = \frac{t + \frac{a}{2}}{t_1 + \frac{a_1}{2}} S.$$

The values of t and a depend upon the glass. By way of illustration let us take $t = 0{\cdot}6$, $a = 0{\cdot}3$. For radiation from a surface under 100° C. Melloni found that even thin glass is quite opaque. We have then $t_1 = 0$, and if we neglect reflexion, probably small, $a_1 = 1$.

Then $$R = \frac{75}{50} S = 1{\cdot}5\ S.$$

If the glass were removed we should have

$$R = S.$$

The temperature of the ground is therefore $\sqrt[4]{1{\cdot}5} = 1{\cdot}1$ times as high under the glass as it is in the open. If, for instance, it is 27° C. or 300° A. in the open, it is 330° A. or 57° C. under the glass.

If the glass reflects some of the radiation R then a_1 is less and the ground temperature is still higher.

If the ground, instead of being black, reflects a fraction ρ of the incident sunlight, or has total albedo ρ, the formula must be modified. If we take into account merely the first reflexion from the ground and assume that the glass has absorption a for it, then we easily find

$$R = S\ \frac{t + \frac{a}{2} + \left(\frac{a}{2} - \rho\right)t}{t_1 + \frac{a_1}{2}}.$$

If we take $\rho = 0{\cdot}1$ the numerator is $0{\cdot}78$ instead of $0{\cdot}75$, and if we assume the fourth power law for the low-temperature radiation emitted by the surface, the temperature is about 1 per cent. higher. But the ground will probably reflect a much smaller fraction of the whole spectrum, and the correction for total albedo becomes inconsiderable.

If we replace the sun by cloud the radiation is, on the average, of much lower temperature, and t and a are much nearer to t_1 and a_1. The value of R/S is then much nearer to 1, and the covered ground has a temperature much less raised above that of the open ground. This agrees of course with common experience.

A planetary atmosphere no doubt acts in some such way as the greenhouse glass. Let us, for the sake of comparison with Prof. Lowell's results, assume, as he has done, that we have a steady state, with the incident radiation normal to the surface. I do not see how to estimate the distribution of the radiation from the air between the upward stream into space and the downward stream to the surface. Since the lower layers of air are warmer than the upper probably more than half comes down, and the truth probably lies between the assumptions that the atmospheric radiation is $\frac{1}{2}(aS + a_1R)$ as it is with the greenhouse, and that it is $aS + a_1R$ when all the radiation would be downwards. Let us suppose that $\frac{1}{n}(aS + a_1R)$ comes downward.

The albedos of the surfaces of both the Earth and Mars average, according to Lowell, 0·1 for visible radiation. They must be much less for the whole spectrum. Where all the data are uncertain the effect of small albedo may be neglected, and indeed in our ignorance of the dependence of temperature on radiation with a partially reflecting surface, it is safer to neglect it. If θ_s is the actual surface temperature under a vertical sun, and θ is the temperature which the surface would have without atmosphere, it is easily found that

$$\theta_s = \sqrt[4]{\frac{t + a/n}{t_1 + (n-1)a_1/n}}\,\theta.$$

Earth.—If we use Lowell's figures for the Earth under a clear sky,

$$t = 0{\cdot}42,\ a = 0{\cdot}5 \times 0{\cdot}65 = 0{\cdot}325,$$

$t_1 = 0{\cdot}5$, since of the invisible radiation half is transmitted,
$a_1 = 0{\cdot}5$, ... very little is reflected,

We shall suppose in succession that
(*a*) half of the radiation is downwards or that $n = 2$.
(*b*) two-thirds .... $n = \frac{3}{2}$.
(*c*) all .... $n = 1$.

We then find

$$(a)\ \frac{\theta_s}{\theta} = 0{\cdot}94; \quad (b)\ \frac{\theta_s}{\theta} = 0{\cdot}99; \quad (c)\ \frac{\theta_s}{\theta} = 1{\cdot}12.$$

For the case of a cloud-covered earth the data are very uncertain. Lowell takes $t = 0{\cdot}2$ of $0{\cdot}42 = 0{\cdot}084$, assuming that the atmosphere has already reflected and absorbed 0·58 before the cloud is reached, surely an overestimate, since the cloud-surface is in the higher air. Let us guess that

$t=0{\cdot}1$. The absorption without cloud is according to Lowell about 0·3. With cloud much is reflected back without reaching the lower and more absorbing regions. Let us guess that $a=0{\cdot}2$. Of the radiation from the surface we may suppose perhaps that 0·2 passes through, that 0 7 is reflected, and that 0·1 is absorbed. Of the 0·2 passing we may suppose that 0·1 is absorbed and 0·1 goes into space. Then $t_1=0{\cdot}1$ and $a_1=0{\cdot}2$.

With these values we get for the different values of n

$$(a)\ \frac{\theta_s}{\theta}=1; \quad (b)\ \frac{\theta_s}{\theta}=1{\cdot}08; \quad (c)\ \frac{\theta_s}{\theta}=1{\cdot}31.$$

These guesses, then, make the temperature under a cloudy sky at least as great as under a clear sky. But this is certainly not true in common experience, where, however, we may have clouds accompanied by cold winds and no approach to the steady state here assumed. The results merely serve to show that with certain absorptions and transmissions clouds might actually raise the surface-temperature, and that for the present it is better to neglect them.

Mars.—If we apply Lowell's data for Mars we have

$$t=0{\cdot}64, \text{ and } a=0{\cdot}40\times0{\cdot}65=0{\cdot}26,$$

$$t_1=0{\cdot}6 \text{ and } a_1=0{\cdot}4, \text{ since R is dark radiation.}$$

With these values we get for the different values of n

$$(a)\ \frac{\theta_s}{\theta}=0{\cdot}99; \quad (b)\ \frac{\theta_s}{\theta}=1{\cdot}02; \quad (c)\ \frac{\theta_s}{\theta}=1{\cdot}10.$$

Comparison of the Earth and Mars.—Let us take the temperature of the Earth as 17° C. or 290° A. If it were removed to the distance of Mars its temperature would be inversely as the square root of the distance, which is 1·524 that of the Earth or 290/1·235=235°.

With the different values of n the temperature of Mars should be

$$(a)\ 235\times\frac{99}{94}=247^\circ \text{ A. or } -26^\circ \text{ C.},$$

$$(b)\ 235\times\frac{102}{99}=242^\circ \text{ A. or } -31^\circ \text{ C.},$$

$$(c)\ 235\times\frac{110}{112}=231^\circ \text{ A. or } -42^\circ \text{ C.}$$

Of course the data are very uncertain and the formula used is only an approximation. But with these data it is hard to see how the temperature of Mars can be raised to anything like the value obtained by Professor Lowell. Perhaps the data are quite wrong. It is conceivable that Mars has a quite peculiar atmosphere practically opaque to radiations from the cold surface. Those who believe that there is good evidence for the existence of intelligent beings on that planet, should find no difficulty in supposing that they have been sufficiently intelligent to cover the planet with a glass roof or its equivalent. Then we might easily have $t+\frac{a}{2}=0{\cdot}77$ and $t_1+\frac{a_1}{2}=0{\cdot}5$, and then the temperature might be raised to 281° A. or 8° C. Indeed, if the glass were of such kind as to transmit solar radiation, and if it were quite opaque to dark radiation while still reflecting a considerable proportion, the temperature might easily be raised far above this.

An Attempt to represent the Effect of Day and Night on the Temperature of the Earth.

The "greenhouse" formula, which has been used in the foregoing discussion, would hold only if all the conditions were steady. But in reality the alternations of day and night prevent a steady state, and we can only hope that the neglect of these alternations does not greatly affect the ratios of the temperatures found for different planets or for different elevations on the same planet.

I shall now attempt to represent the effect of the diurnal variation in the supply of solar heat to the Earth, or rather to an abstract Earth. For even if we could represent the actual conditions we should obtain differential equations so complicated that they would be useless for practical purposes.

To simplify matters, let us suppose that we are dealing with the equatorial region of the earth at the equinox, that the air is still, that the surface is solid and black, and that the sky is clear.

The temperature of the air except near the surface can change but little during 24 hours. For over each square centimetre at sea-level we have 1000 gms. of air with specific heat 0·2375, and therefore with heat capacity 237·5. Consider a band of the atmosphere 1 cm. wide round the equator. A stream of solar radiation of length equal to the diameter $2r$ of the earth enters a band of air of length equal to half the circumference. If the solar constant is 3 the average energy entering a sq. cm. column is $\frac{2rS}{\pi r}=\frac{2S}{\pi}=\frac{6}{\pi}$ cal./min. Then in 12 hours 1375 cal. enter on the average, and if this heat were all absorbed and retained it would raise the temperature on the average about $1375/237\cdot5=5^\circ\cdot8$ C.

As the absorption is only partial and as radiation takes place from the air, the rise cannot really average nearly as much as this.

Again, consider the radiation during the twelve hours of night. If the air were a black body and of temperature 300° A., and these are absurdly exaggerated estimates of its radiating power and of its average temperature, it would only radiate about 1·2 cal./min. per sq. cm. column from its two surfaces, or 864 calories in the twelve hours, and neglecting the radiation from the ground the temperature would only fall about $864/237\cdot5$ or $3^\circ\cdot6$ C. Obviously, then, the air as a whole cannot undergo much variation in temperature as day alternates with night. It is indeed a flywheel storing the energy of many diurnal revolutions. We may, then, in a rough estimate consider that its temperature and therefore its radiation remain constant during the 24 hours.

If the total radiation from a sq. cm. column per second is A, there will be a stream D downwards and U upwards where $D+U=A$. We can find an expression for A by equating it to the average absorption. Considering an equatorial band 1 cm. wide, the average energy entering it per sq. cm. in the 24 hours is $\frac{S}{\pi}$. Let the average amount absorbed be $\frac{\bar{a}S}{\pi}$. The value of $\bar{a}$ at sea-level varies for clear sky from perhaps 0·3 with the zenith sun to very nearly 1 with the setting sun. Let the average radiation from the surface during the 24 hours be $\overline{R}$, of which $a_1\overline{R}$ is absorbed by the atmosphere. Then neglecting conduction through the air, the constant temperature assumption gives us

$$A=\frac{\bar{a}S}{\pi}+a_1R.$$

If a fraction $\frac{1}{n}$ is radiated downwards

$$D=\frac{\bar{a}S}{n\pi}+\frac{a_1\overline{R}}{n}.$$

The actual surface temperature depends not only on radiation but also on conduction both by ground and air. But we shall neglect this conduction and shall suppose that the surface has reached an equilibrium between receipt and expenditure of radiation. This is a condition to which the surface tends at or soon after noon by day and before dawn at night. We shall suppose that the low temperature radiation from the surface is either transmitted or absorbed, so that, using the previous notation,

$$t_1+a_1=1 \quad \text{and} \quad r_1=0.$$

If R_d is the equilibrium surface radiation reached we suppose about noon

$$R_d=tS+\frac{\bar{a}S}{n\pi}+\frac{a_1\bar{R}}{n}.$$

If R_n is the equilibrium surface radiation in the later part of the night we have to omit tS and

$$R_n=\frac{\bar{a}S}{n\pi}+\frac{a_1\bar{R}}{n}.$$

To proceed further, we must express $\bar{R}$ in terms of S. We can only do this by some assumption. Probably it is not very far from the truth to assume that $\bar{R}=\frac{1}{2}(R_d+R_n)$, and we shall take this value. It gives us

$$\bar{R}=\frac{\frac{t}{2}+\frac{\bar{a}}{n\pi}}{1-\frac{a_1}{n}}S,$$

and substituting in the values of day and night radiations we get

$$R_d/S=t+\frac{\bar{a}}{n\pi}+\frac{a_1}{n}\cdot\frac{\frac{t}{2}+\frac{\bar{a}}{n\pi}}{1-\frac{a_1}{n}}$$

$$R_n/S=\frac{\bar{a}}{n\pi}+a_1\,\frac{\frac{t}{2}+\frac{\bar{a}}{n\pi}}{1-\frac{a_1}{n}}.$$

Though these formulæ are only obtained by making large assumptions, and by neglecting important considerations, they nevertheless show the tendency of the day and night effect, and it is worth while to apply them to the Earth, taking the best data at our command.

At the surface let us take $t=0{\cdot}42$ and $a_1=0{\cdot}5$ as before. For $\bar{a}$ we have no trustworthy observations, and I doubt whether a calculation from Langley's observations is of any more value than an estimate. Since a varies from perhaps about 0·3 to 1, let us take $\bar{a}=0{\cdot}628$ or $2\pi/10$, a value simplifying arithmetic.

At the level of Camp Whitney 3550 metres above sea-level, with barometer about 500 mm., and therefore with about $\frac{1}{3}$ of the atmosphere below it, we may take $t=0{\cdot}6$ and $a_1=0{\cdot}4$. For $\bar{a}$ we must take a value much smaller than that at sea-level. Since the most absorbing third of the atmosphere is below, I do not think it is far wrong to take $\bar{a}$ as having half the value at the lower level, and I therefore put $\bar{a}=0{\cdot}314$. But I have also examined the consequences of putting it equal to 0·419, *i. e.* $\frac{2}{3}$ of its value at the lower level, and the results are given below to show how much the figures are affected by the variation in the value taken.

We have no data for n. I have therefore calculated the values of R_d and R_n in terms of S for successive values of n equal to 1, $\frac{5}{4}$, $\frac{4}{3}$, $\frac{3}{2}$, 2; corresponding to D equal to A, $\frac{4}{5}$ A, $\frac{3}{4}$ A, $\frac{2}{3}$ A, and $\frac{1}{2}$ A respectively.

In the following tables the values of R_d/S and R_n/S are given, and also the mean $\bar{R}/S=\frac{1}{2}(R_d+R_n)S$. Then follow the ratios of the day and night temperatures, θ_d and θ_n, to the temperature θ of a black surface radiating S, and the mean value $\bar{\theta}/\theta$. The last column gives the range $\theta_d-\theta_n$ on the supposition that $\bar{\theta}=300°$ A.

TABLE I.

At sea-level. $t=0{\cdot}42$, $a_1=0{\cdot}5$, $\bar{a}=0{\cdot}628$.

n.	D/A.	R_d/S.	R_n/S.	$\bar{R}$.	θ_d/θ.	θ_n/θ.	$\bar{\theta}/\theta$.	Range about 300° A.
1	1	1·03	0·61	0·83	1·01	0·88	0·95	41°
5/4	4/5	0·83	0·41	0·62	0·95	0·80	0·88	51°
4/3	3/4	0·79	0·37	0 58	0·94	0·78	0 86	56°
3/2	2/3	0·72	0·30	0·51	0·92	0·74	0·83	65°
2	1/2	0 62	0·20	0·41	0·89	0·67	0·78	85°

TABLE II.

At 3550 m. above sea-level. Barometer 500 mm.
$t=0{\cdot}6$, $a_1=0{\cdot}4$, $\bar{a}=0{\cdot}314$.

n.	D/A.	R_d/S.	R_n/S.	$\bar{R}$.	θ_d/θ.	θ_n/θ.	$\bar{\theta}/\theta$.	Range about 300° A.
1	1	0·97	0·37	0·67	0·99	0·78	0·89	71°
5/4	4/5	0·86	0·26	0·56	0·96	0·71	0·84	89°
4/3	3/4	0·84	0·24	0·54	0·96	0·70	0·83	94°
3/2	2/3	0·80	0·20	0·50	0·95	0·67	0·81	100°
2	1/2	0·74	0·14	0·44	0·93	0·61	0·77	125°

TABLE III.

At the level of Table II. and with $t=0{\cdot}6$, $a_1=0{\cdot}4$,
but with $\bar{a}=0{\cdot}419=2/3$ of $0{\cdot}628$.

n.	D/A.	R_d/S.	R_n/S.	$\bar{R}$.	θ_d/θ.	θ_n/θ.	$\bar{\theta}/\theta$.	Range about 300° A.
1	1	1·02	0·42	0·72	1·01	0·81	0·91	66°
5/4	4/5	0·90	0·30	0·60	0·97	0·74	0·86	80°
4/3	3/4	0·87	0·27	0·57	0·97	0·72	0·85	88°
3/2	2/3	0·83	0·23	0·53	0·95	0·69	0·82	95°
2	1/2	0·76	0·16	0·46	0·93	0·63	0·75	120°

The third table is only given to show that the change in the value of $\bar{a}$ does not greatly affect the results. The value of $\bar{a}$ of Table II. is much more reasonable if that of Table I. is near the truth. We need, therefore, only compare the results given in the first two tables.

If we take the same values of n in each table the value of $\bar{R}$ is less at the higher level than at the lower in every case except that in which n has the extreme and probably inadmissible value of 2. The value of $\bar{\theta}$ is less at the higher level in every case. But it appears most probable that $1/n$ or D/A is greater at the lower level than at the higher. For consider a thin layer of air at sea-level. It is rediating equally up and down, but of the half going upwards a considerable fraction will be intercepted by the superincumbent and strongly absorbing layers. Now consider a thin layer close to the surface at the higher level. It, too, radiates half up and half down. But of the half going upwards a less fraction will be intercepted since the superincumbent layers are now less absorbing. Thus D/A will be greater at the lower than at the higher level*. We should, therefore, compare the results for any value of D/A in Table I. with the results in Table II. for a somewhat lower value.

We may exclude the extreme cases of $n=2$ and $n=1$, as the true value is certainly between these, and confine our examination to intermediate values.

Suppose, for example, that $D/A=4/5$ at the lower level, while it is $3/4$ at the upper level. Then $\bar{\theta}/\theta=0{\cdot}88$ from Table I. at the lower, while $\bar{\theta}/\theta=0{\cdot}83$ from Table II. at the upper level. Or if $D/A=\frac{3}{4}$ at the lower level, while it is $\frac{2}{3}$ at the upper level, $\bar{\theta}/\theta=0{\cdot}86$ below, while $\bar{\theta}/\theta=0{\cdot}81$ above. Or in each case the mean temperature is higher at sea-level by about 5 in 87 or by about 17° in 300°.

It is to be observed that the lower mean temperature at a higher level must hold good if the higher level is so much higher that there is practically no atmosphere above. For then $t=1$ and $a_1=0$, so that $R_d=S$ and $R_n=0$. Therefore $\bar{\theta}_d/\theta=1$ and $\theta_n/\theta=0$ and $\bar{\theta}/\theta=\frac{1}{2}$.

The lower mean temperature of elevated parts of the earth's surface is a well established fact. Perhaps if it were only observed in the case of mountain peaks it might be ascribed to the cold air blowing against them. The fall of temperature in free air as we go upwards tends towards that given by convective equilibrium, though recent observations show that it is not so great as that given by the adiabatic law. Thus for a rise of 3500 metres the adiabatic law would give a fall of about 32° C. if the sea-level temperature were 300° A.; whereas the observations of Teisserenc de Bort at Trappes show a mean annual fall of about 16° C. for this rise (*Encyc. Brit.* xxx. Meteorology, p. 695). A continual blast of air thus cooled might of course reduce the temperature on the mountain peaks, even if radiation did not tend to any such reduction. But we can hardly account in this way for the equally well established lower temperature of elevated continental plateaus. According to Abbe (*loc. cit.*

* Another consideration leading to the same conclusion is that the atmosphere acts like a plate with its lower surface much warmer than its upper. When we only have the part above an elevated region the difference of temperature between the surfaces is much less than for the whole air, and the radiations up and down are more nearly equal.

p. 694) 0°·5 C. must be subtracted from sea-level temperature for every 100 metres general elevation of the land surface or about 18° for an elevation of 3500 metres, and this fall may be ascribed to radiation in some such way as that here set forth.

If the atmosphere of Mars is comparable with our own atmosphere at high levels, and if the effect is of the same general character in the two cases, it appears probable that the surface temperature of Mars is actually lower by many degrees than that which the surface of the Earth would have at the same distance from the Sun.

LXXV. *On the Radioactivity of Lead and other Metals. By* J. C. McLennan, *Ph.D., Professor of Physics, University of Toronto**.

I. *The Relative Activities of Different Metals.*

In a paper in the Phil. Mag. of September 1906, Eve states that while investigating the natural ionization of air confined in vessels made of different metals, he found that 24 ions per c.c. were generated per sec. when the receivers were made of copper, zinc, iron, and tinned iron, while 96 ions per c.c. were regularly produced in air per second when the confining vessels were made of lead.

The high conductivity of air contained in lead vessels has been frequently noted by other observers; and from Eve's results it would appear that lead either contains some active impurity from which other metals are entirely free or else it possesses an intrinsic radiation very much stronger than that exhibited by other metals.

The view that lead contains an active impurity is supported by a description in the *Phys. Zeit.* of November 1906, of some experiments by Elster and Geitel, in which they succeeded in extracting from lead oxide small quantities of an active substance which from its characteristics they were inclined to think was Radium F. In this paper they state that they were unable to obtain any active emanation from the materials treated, and on this account they suggest that possibly the source of the Radium F can be traced to the presence of Radium D in the lead.

Since the decay period for Radium D is forty years it would follow, if the high activity of lead is due to the presence of this radium product, that very old lead should

* Communicated by Prof. J. J. Thomson, F.R.S.