TERRESTRIAL TEMPERATURE AND ATMOSPHERIC ABSORPTION

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The earth's temperature depends mainly on the balance of incoming solar energy and outgoing terrestrial energy of radiation. These two classes of rays lie chiefly in two far-separated regions of spectrum. Of solar rays, 98% lie between 0.3 and 3.0 microns (μ) of wave-length. Of terrestrial rays about the same proportion lie between 5 and 50 microns. According to Abbot and Fowle's researches, about 40% of the solar rays directed towards the earth are reflected to space. The earth must radiate to space $1.93 \times 0.60 \times 0.25$, or 0.29 calorie per cm^2 per minute on the average from its whole surface to keep a steady temperature in balance with the solar rays received over the area of its cross section. If the earth's surface was a perfect radiator and its radiation passed unhindered to space, it would emit according to Stefan's law $8 \times 10^{-11} \times (287)^4 = 0.55$ cal. per cm^2 per minute. How shall we explain the discrepancy between 0.29 and 0.55 calories?

1. Is the earth's surface a perfect radiator? Its surface is about three-fourths water. Of the remainder much is moist soil or moist vegetation. The radiative power of the earth must therefore be near that of water. My colleague, Mr. Aldrich, has lately studied the absorbing and reflecting powers of water for long-wave rays. He finds that of the rays emitted by lamp-black paint at 100°C. a layer of water 1 cm. thick transmits none and reflects as follows:

Incidence....................	0°	30°	55°	63°	70°	72°
Reflection...................	2%	3%	7%	10%	17%	22%

As the absorption is 1 − (Refl. + Trans.) he computes that of rays reaching a water surface from a hollow hemispherical enclosing lamp-black-painted surface at 100°, the absorption would be 90%. Experiments on lamp-black paint having shown nothing strongly selective about its radiation in this region of spectrum, we seem justified in concluding, in accord with Kirchoff's law, that water is a 90% perfect radiator in this region of spectrum. As is water, so is the earth's surface. Hence we conclude that the earth's surface sends out 0.50 calorie per cm^2 per minute on the average.

2. How much of this does the atmosphere transmit? My colleague Mr. Fowle has recently published[1] results of a long investigation of this subject in which he studied the spectrum up to a wave-length of 17μ by aid of a spectro-bolometer with rock salt prism. He employed a very long tube in which the beam traversed paths of air up to 250 meters in length containing quanti-

ties of water vapor up to the equivalent of 0.3 cm. of precipitable water. He also observed the solar spectrum to 17μ through paths of atmosphere containing water vapor up to the equivalent of 3.0 cm. of precipitable water. Since rock salt ceases to be sufficiently transparent beyond 17μ Fowle's spectrum work stopped there. But Aldrich, on Mount Wilson, by experiments not yet entirely finished, seems to have shown that neither incoming sun-rays nor outgoing earth-rays non-transmissible to rock-salt (that is over 17μ in wave-length) can traverse the atmosphere. Assuming that this result will be confirmed we have the following results from Fowle's and Aldrich's investigations representing the output and atmospheric transmission of rays from a perfect radiator at earth temperature.

Per cent of atmospheric transmission for stated cm. ppt. H_2O

WAVE-LENGTH	INTENSITY	CM. 0.003	CM. 0.03	CM. 0.3	CM. 3.0
μ μ					
4– 5	50	15	45	70	95
5– 6	142	16	43	66	95
6– 7	242	45	85	95	100
7– 8	315	13	42	85	100
8– 9	360	0	2	40	50
9–10	380	0	0	0	15
10–11	370	0	2	5	40
11–12	350	0	0	4	10
12–13	320	0	0	13	20
13–16	810	100	100	100	100
16–20	510	90	100	100	100
> 20	1,450	100	100	100	100
4–∞	5,300	49	57	66	75

From these results Fowle has computed that in clear weather, when precipitable water in the atmosphere is 1 cm., the atmosphere transmits 28% to space of the radiation emitted by the earth's surface. In the tropics where a load of atmospheric humidity equal to precipitable water of 3 cm. or more is common, the transmission would not exceed 20% on clear days. A. Ångström has shown[2] that on cloudy nights practically all radiation from the earth's surface to space is cut off. Hence (as it is cloudy half the time on the average of the earth's surface) out of 0.50 calories per square centimeter per minute emitted, the average escape to space, taking both clear weather and cloudy, is only 0.06 calories. As 0.29 calories per cm^2 per minute on the average must leave the planet earth, and as the earth's surface contributes, only 0.06 calories, it follows that the atmosphere is the main radiating source, furnishing three-fourths of the output of radiation of the earth as a planet.

Principal sources of the atmospheric radiation in order of their importance are: (1) The clouds; (2) water-vapor; (3) ozone; (4) carbon-dioxide. There is little difference between the importance of the ozone band at 10 μ and the carbon-dioxide band at 15 μ except that the former falls at a point in the spectrum where terrestrial radiation is most intense, and where water-vapor has almost no absorption, while the latter falls at a place where the radiation is not so intense and where water-vapor also absorbs powerfully.

No ozone band was found by Fowle in his work with the long tube, but in the solar spectrum it shows strongly. This accords with work of others who show that ozone is found only at high atmospheric levels. Apparently there is not enough ozone in the atmosphere to produce complete absorption in its band at 10 μ, and it may be that the earth's temperature would be profoundly altered if the ozone contents of the air could be changed. If it were possible, for instance, to charge the surface air above citrus fruit orchards strongly with ozone on a frosty night, perhaps hurtful frosts could thereby be warded off.

Carbon-dioxide exists in the atmosphere so plentifully that its full possible influence seems probably to be exerted. No increase of CO_2 would seem likely to produce a considerable effect on terrestrial temperature, and it is probable that the CO_2 content of the air could be reduced to less than a quarter of its present amount without notable temperature effects.

[1] *Smithsonian Misc. Coll., Washington,* **68,** No. 8.
[2] *Ibid.,* **65,** No. 3, p. 54.

MOBILITIES OF IONS IN VAPORS

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In a former paper on the Mobilities of Ions in Air, Hydrogen, and Nitrogen (these Proceedings, **4,** 1918, 91), the conclusion was reached that the so-called cluster hypothesis could no longer claim any reason for its existence and that the arguments for the small-ion theory should be considered conclusive.

It only remained for the small-ion theory to offer an adequate explanation for the difference between the positive and negative mobilities exhibited by all experimental results. This difference can easily be explained by the cluster hypothesis for if the ions were constituted by satellites of molecules surrounding single charges, the difference between the positive and negative mobilities could be ascribed to the difference between the number of constituent molecules in a positive and that in a negative ion. But with the small-ion theory such an explanation is not possible, since all ions are conceived of as single charged molecules.

In the aforementioned paper, an explanation for this experimental fact