From these latter a transmission of 65.4 per cent would be inferred for this amount of water.

From the combined work of Rubens and Aschkinass, Langley, Keeler and Very, and Nichols, we may then safely conclude that a tenth part of the average amount of water vapor in the vertical column of atmosphere above sea-level is enough to absorb more than half of the radiation of the earth to space, and it is highly probable that, considering the greater air mass attending the oblique passage of many of the rays to space, nine-tenths of the radiation of the solid and liquid surface of the earth is absorbed by the water vapor of the atmosphere even on clear days. On cloudy days none is transmitted, so that the average escape of radiation from the earth's surface to space probably does not exceed 5 per cent.

THE ABSORPTION OF CARBONIC-ACID GAS FOR TERRESTRIAL RADIATION.

Some writers have attributed a large share of the absorption of the atmosphere to the carbonic-acid gas which it contains, but though the experiments of Arrhenius [1] tended to show that carbonic-acid gas exercises a general absorption like water vapor, yet Ångström [2] and Koch [3] have shown that this is the case only when the carbonic acid is present in great density, and not, as in the atmosphere, when it is present in a long column of slight density. In atmospheric conditions the absorption of carbonic-acid gas in the spectrum of the earth appears to be confined to two bands extending from wave-length 3.6μ to 5.4μ, and from 13.0μ to 16.0μ, respectively.[4] In these bands its absorption is nearly total from 4.0μ to 4.8μ and from 14.0μ to 15.6μ, even when carbonic acid is present in much less quantities than the atmosphere contains. But the areas included by the energy curve of the "black body" at 287°.2 from 3.6μ to 5.4μ and from 13.0μ to 16.0μ are 0.5 per cent and 13.5 per cent of the total area of the curve, respectively; so that, as the earth has mainly a water surface which is doubtless practically "black," it appears that even in the absence of water vapor the total absorption possible by carbonic-acid gas would be 14 per cent. In all the lower regions of the atmosphere, however, water vapor is present in such quantities as almost completely to extinguish the radiation of the earth's surface in these two special regions, irrespective of the presence of carbonic-acid gas, and all the absorptive function of the latter worth considering, so far as the present evidence shows, must be exercised in the regions of the atmosphere higher than the altitudes to which water vapor extends in considerable quantities, or, in other words, above 5,000 [5] meters. Its effect there is merely to increase slightly the altitude of the layer which transmits radiation of two narrow spectral bands to space, and thus to decrease

[1] Annalen der Physik, vol. 4, p. 690, 1901.
[2] *Loc. cit.*, vol. 6, p. 172, 1901.
[3] Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar, Stockholm, vol. 58, p. 391, 1901.
[4] See fig. 2 of the article of Ångström, Annalen der Physik, vol. 3, p. 720, 1900.
[5] See Hann, Meteorologie, p. 223.

slightly the temperature at which these wave-lengths are finally emitted. It therefore does not appear possible that the presence or absence, or increase or decrease, of the carbonic-acid contents of the air are likely to appreciably influence the temperature of the earth's surface.

These conclusions are in accord with those expressed by Ångström on this subject.[1]

THE SURFACE WHICH EMITS RADIATION FROM THE EARTH TO SPACE.

It seems to be certain, in view of what has been said, that the earth's solid and liquid surface, and the lower parts of the atmosphere, contribute directly almost nothing to the amount of radiation which the earth as a planet sends to space. The earth's surface and the lower atmosphere of course exchange radiation together, and by this process, and by convection, the heat of these regions ascends toward space. But convection grows less and less as the air becomes rarer, and must at length cease to be an appreciable factor. It is the water vapor and carbonic-acid gas far above the earth's surface, where the absorption of the rays by the water vapor and carbonic-acid gas lying still higher becomes small, that form the true radiating surface of the earth considered as a planet.

TEMPERATURE OF THE EARTH'S RADIATING LAYER.

We have seen that less than a tenth, possibly less than a twentieth of the total amount of water vapor in the atmosphere would be sufficient to absorb half of the radiation of a "black body" at a temperature of 287°.2 absolute; and the absorption would be nearly the same for radiating bodies between this temperature and 260°. If the experimental evidence both as to the temperature of the atmosphere and as to the radiation and absorption of water vapor and carbonic-acid gas were complete, it would be easy to compute what each layer of the atmosphere contributes to the radiation of the earth as a planet, and from this could be found the average temperature and emissive power of its radiating surface. But even with the scanty material at hand, and in consideration of the distribution of water vapor in the free air,[2] it seems safe to put the effective position of the radiating surface at fully 4,000 meters above sea-level.

In accordance with the statements of Hann[3] there appears to be no very great difference, depending on the latitude, in the rate of decrease of temperature in the free air with increasing altitude; and it will be not far from the truth to assign an average rate of 0°.6 C. per 100 meters for heights not exceeding 4,000 meters. In these circumstances we may make a horizontal reduction of the zone temperatures used in computing the mean temperature of the earth, and thus we

[1] Annalen der Physik, vol. 6, p. 173, 1901.
[2] Hann, Meteorologie, pp. 223, 274, 275.
[3] Hann, Meteorologie, pp. 155–159.

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