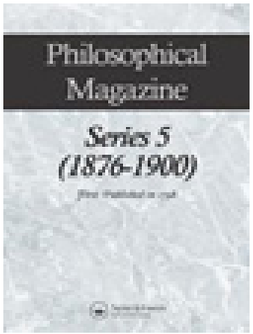

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XXVI. *On the Formation and Decomposition of Carbonic Acid.* *By* J. B. Lawes, *F.R.S.**

NO facts in science have been more clearly established than those which relate to the decomposition of carbonic acid by the green parts of plants (resulting in the fixation of the carbon and the return of the liberated oxygen to the atmosphere) and the part played by animal life and combustion in again uniting the carbon with the oxygen.

The vast quantity of carbon locked up in coal and other carbonaceous deposits leads to the conclusion that, at one period of the earth's existence, the amount of carbonic acid must have been larger than it is at the present time; but since the period when accurate determinations of carbonic acid were first made, no appreciable difference in the quantity has been shown to exist, although it would appear probable that the great increase of animal life, the destruction of forests, and the combustion of coal would tend to increase the amount.

The Rothamsted experiments which have been carried on for so long a period, while they clearly establish the fact that the atmosphere is the main, if not the exclusive, source of the carbon fixed by plants, at the same time point to conclusions which differ somewhat from those generally received, with regard to the action of man and animal life on one side, and that of plants on the other, in maintaining the equilibrium of the atmosphere.

I propose to take stock of the soil and atmosphere resting upon Great Britain, with the assumption (fortunately for us not a true one) that our atmosphere is as much a fixture as our soils, and is not constantly being exchanged with the atmosphere coming from other parts of the globe.

The sources of the carbon given off into the atmosphere as carbonic acid are three:—

(1) Those derived from the consumption of coal;
(2) From the imported products used as food or for combustion;
(3) From the products of our own soil.

The agricultural statistics make the area of Great Britain to consist of between 56 and 57 million acres. In order to reduce the amount of figures as much as possible, in adopting this estimate as my basis, I have given in the table below the figures which apply to each acre of the surface per annum.

The figures relating to the consumption of coal, which constitute far the largest item in the table, have been furnished

* Communicated by the Author.

me through the kindness of Mr. Robert Hunt, of the Museum of Practical Geology; and although they somewhat exceed two tons per acre per annum, I have based my calculation on that amount.

The figures relating to imports are based upon the larger articles of food (such as live animals, meat, sugar, potatoes) and combustible substances (as tallow, petroleum, &c.).

With regard to the carbon given off by the consumption of home produce, so far as relates to the $33\frac{3}{4}$ million acres which constitute the cultivated area, my estimates are formed upon what I believe to be the average yield of the land; upon the remaining area, consisting of mountains, heath, and waste, the only basis for calculation is to be derived from the rental value of such land, and the amount of stock which it will carry.

Without going into the detail of the figures, I have given in the following table a summary of the whole.

Carbon given off as Carbonic Acid per acre per annum in Great Britain.

	lbs.
By coal	3942
By imported products	300
By home-grown products...	1275
Total	5517

We find, according to the more recent estimates, that the amount of carbon, as carbonic acid, resting upon an acre of ground is equal to about 14,000 lbs. Now the amount given off by the sources which I have mentioned above would more than double the carbonic acid in our atmosphere in three years, provided that no compensation took place! I propose to examine into what is the probable extent of the compensation which may come in to limit this large increase.

With regard to coal and imported products, there is very little compensation possible; but with the products grown upon our own soils, there is a continuous exchange going on between the atmosphere and the plant; and the question is on which side the balance lies.

I am disposed to think that, upon arable land (when kept in a uniform state of fertility), the amount of carbonic acid, fixed and exhaled, would be nearly the same, but that, wherever the fertility of the soil was diminished, there the carbonic acid given off would be in excess of that fixed.

In the ordinary case of a farmer selling a certain amount of the products of his land and consuming the residue, the saleable products, consisting of corn and meat, are burnt into

carbonic acid, while the straw and other residue slowly assume the same form. But the food sold is derived from fertility stored up in the soil, accumulated by vegetation in ages long past, and thus goes also to swell the amount of carbonic acid contributed by the soil to the atmosphere.

This is made perfectly clear by long-continued experiments at Rothamsted, which show that crops raised on unmanured land, as also upon land receiving the mineral food of plants but no nitrogen, derive their nitrogen from the store in the soil; and as this nitrogen exists in combination with carbon, the latter is given off in the form of carbonic acid. Further, as agriculture is generally attended with more or less exhaustion of the soil, there is, in consequence, a slight increase in the carbonic acid added to the atmosphere by cultivation.

This is more clearly seen when we consider that most of the land which is now in cultivation was previously woodland or pasture. At Rothamsted we have found by analysis that the pasture contains more than twice as much organic carbon and nitrogen as the arable land—a result which may be attributed to the fact that on the latter these substances have been gradually destroyed or carried off by cultivation. On the other hand, in cases where arable land has been converted into permanent pasture, carbon again becomes fixed in the soil, both as roots in living vegetation and as organic carbon.

It is true that on land which receives a large dressing of dung annually we have found a very considerable increase of the carbon in the soil; in gardens also, in land laid down to pasture, and woodlands (especially newly planted woods) carbon would be abstracted from the air; but, generally speaking, I think that more carbon is given off from the products of the soil of Great Britain than is fixed by the living vegetation. If, in fact, we were entirely dependent on the atmosphere resting upon our country for existence we should very soon perish.

A process very similar to what I have described, though not to the same extent, is going on throughout the world: population and animals increase, fuel is burnt, forests are destroyed, and the stores of carbon and nitrogen accumulated in the soil by natural vegetation are slowly dissipated. We must look, therefore, to some other source, rather than to the land, for the restoration of the balance.

It is quite possible that this source is to be found in the ocean. According to analyses made by Dr. Frankland, the sea, even at a great depth, is very rich in organic carbon and nitrogen; it also contains large quantities of nitric acid; and these quantities are being increased from day to day by fresh

supplies carried in by all the rivers of the globe. The tendency of the operation going on upon the land is to reduce the stock of carbon and increase that of carbonic acid,

(1) by the combustion of coal and other substances used as fuel;
(2) by the destruction of carbon accumulated near the surface of the soil by natural vegetation;
(3) by the increase of man and animals.

On the other hand, there may be a corresponding increase of organic carbon in the ocean, and in this way the balance may be kept up. Dr. Frankland's various analyses of sea-water, extending to a depth of between 700 and 800 fathoms, show that even at this depth, which is less than half of the estimated average, the amount of carbon, as organic carbon, is about three times as much as the carbon, as carbonic acid, in the atmosphere resting upon an equal area of surface. When we consider the immensity of the ocean, it is evident that the operations of animal and vegetable life in it must have a vast influence upon our atmosphere, of the value of which we appear to be altogether ignorant.

XXVII. *On the Rate of the Decrease of the Light given off by a Phosphorescent Surface.* *By* Lieut. L. Darwin, R.E.*

I CARRIED out a series of experiments at Chatham with the view of determining the law of the rate of decrease of the light of a phosphorescent surface. The experiments were conducted by comparing the light given off by a surface covered with Balmain's luminous paint, with a sheet of tissue paper illuminated from the further side by a Sugg's burner regulated to give about the light of four standard candles. The surface coated with paint was one side of a thin metal vessel, which was filled with a mixture of ice and water; the object of this was to keep the temperature as uniform as possible, as any increase of temperature increases the light given off by the paint. A sheet of tissue paper, of about the same size as the painted surface, was arranged just above it so that the light of the burner illuminated the tissue paper from the further side to the observer. The whole was enclosed in a box with an opening at one side, through which the light of the burner reached the tissue paper only, and opposite to it a small hole through which the observations were made. In this way only the light from the two surfaces

* Communicated by the Physical Society. Read December 11th.