VII. *On a Method of Freezing at a distance.* *By* William Hyde Wollaston, *M. D. Sec. R. S.*

Read December 17, 1812.

THAT a fluid, from which a portion is evaporated, becomes colder in consequence of the heat absorbed by that part which assumes the gaseous state: that fluids rise in the state of vapour at a lower temperature when the pressure of the atmosphere is removed, and consequently may be cooled to a lower degree by evaporation *in vacuo* than in the open air, are facts too well known to need confirmation before the Members of this Society by any new experiments.

Nevertheless, a new mode of applying the most established principles may deserve to be recorded, if it assist the illustration of them, and be instructive from the novelty of the view in which it exhibits a certain class of phenomena; although no immediate use be at present proposed, to which it can be applied with advantage.

If an attempt were made to freeze water by evaporation, without other means than the vacuum of an air-pump, the pump must be of the best construction, and though the quantity of water be small, the receiver must be of large dimensions, otherwise its capacity would set too confined a limit to the quantity of vapour that will rise, and consequently to the degree of cold produced.

Supposing the commonly received estimates to be correct, as to the quantities of heat, that become latent in the conversion of ice into water, and of water into steam, being 140° and 960° respectively, we should find the following statement to be not far from the truth.

If 32 grains of water were taken at the temperature of 62°, and if one grain of this were converted into vapour by absorbing 960°, then the whole quantity would lose $\frac{960°}{32} = 30°$, and thus be reduced to the temperature of 32°.

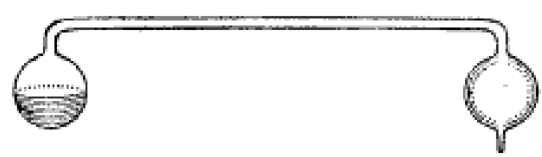
If from the 31 grains, which still remain in the state of water, 4 grains more were converted into vapour by absorbing 960°; then the remaining 27 grains must have lost $\frac{4}{27}$ of $960° = 142°$, which is rather more than sufficient to convert the whole into ice. In an experiment, conducted upon a small scale, the porportional quantity evaporated did not much differ from this estimate.

If it be also true, that water in assuming the gaseous state, even at a low temperature, expands to 1800 times its former bulk; then in attempting to freeze the small quantity of water abovementioned, it would be requisite to have a dry vacuum with the capacity of 5×1800, or equal to that of 9000 grains of water.

As a means of avoiding the necessity of so large a vacuum, Mr. LESLIE had recourse to the ingenious expedient of employing an extensive surface of sulphuric acid, for the purpose of absorbing the vapour generated in the course of the experiment, and by that means contrived to freeze much larger quantities of water, than could otherwise have been done, and by a far less laborious process.

But even in this method the labour is not inconsiderable, and the apparatus, though admirably adapted to the purpose for which it is designed, is large and costly. I have therefore thought the little instrument I am about to describe may possess some interest, as affording a readier and more simple mode of exhibiting so amusing and instructive an experiment.

Let a glass tube be taken, having its internal diameter about $\frac{1}{8}$ of an inch, with a ball at each extremity of about one inch diameter; and let the



tube be bent to a right angle at the distance of half an inch from each ball. One of these balls should contain a little* water, and the remaining cavity should be as perfect a vacuum as can readily be obtained. The mode of effecting this is well known to those who are accustomed to blow glass. One of the balls is made to terminate in a capillary tube, and when water admitted into the other has been boiled over a lamp for a considerable time, till all the air is expelled, the capillary extremity, through which the steam is still issuing with violence, is held in the flame of the lamp till the force of the vapour is so far reduced, that the heat of the flame has power to seal it hermetically.

When an instrument of this description has been successfully exhausted, if the ball that is empty be immersed in a freezing mixture of salt and snow, the water in the other ball, though at the distance of two or three feet, will be frozen solid in the course of a very few minutes. The vapour contained in the empty ball is condensed by the common opera-

* If the ball be more than half full, it will be liable to burst by the expansion of water in freezing.

tion of cold, and the vacuum produced by this condensation gives opportunity for a fresh quantity to arise from the opposite ball, with proportional reduction of its temperature.

According to a theory that does not admit of positive cold, we should represent the heat of the warmer ball to be the agent in this experiment, generating steam as long as there remains any excess of heat to be conveyed. But if we would express the cause of its abstraction, we must say that the cold mixture is the agent, and may observe, in this instance, that its power of freezing is transferred to a distance, by what may be called the negative operation of steam.

The instrument, by which this is effected, may aptly be called a Cryophorus, which correctly expresses its office of frost-bearer.