

XXVI. *An Account of some new Experiments on the Production of artificial Cold. In a Letter from Thomas Beddoes, M. D. to Sir Joseph Banks, Bart. P. R. S.*

Read May 10, 1787.

DEAR SIR,

Oxford, May 2, 1787.

MR. WALKER, Apothecary to the Radcliffe Infirmary here, has been engaged upwards of a year in a series of experiments on the means of producing artificial cold, several of which seem to me to be very remarkable, and such as, considering their novelty, and the attention which has lately been paid to this subject, I flatter myself, will be found to deserve a place among the Transactions of the Society over which you preside.

Mr. WALKER, in his first experiments, found, as BOERHAAVE had done before him, that sal ammoniac, as well as nitre, well dried in a crucible, and reduced to a fine powder, will produce a greater degree of cold than if they had not received this treatment. But BOERHAAVE, by sal ammoniac, lowered the temperature of water only by 28° ; whereas Mr. WALKER observed his thermometer to fall 32° , and when he used nitre 19° . It occurred to him, that the combination of these substances would produce a greater effect than either separately: and he found that this was really the case. A proposal for freezing water in summer, mentioned by Dr. WATSON (Essays, III. 139.) determined him to attempt the same thing

thing in this way. Accordingly, April 28, 1786, the thermometer standing at 47° , he made a solution of a powder, consisting of equal parts of sal ammoniac and nitre, in a basin, by means of which he cooled some water, contained in a glass tumbler, to 22° . To this he added some of the same powder, and immersed two very small phials in it; one containing boiled, the other unboiled water; when he soon found the water in the phials to be frozen, the unboiled freezing first.

Having observed that GLAUBER'S salt, when it retains its water of crystallization, produces cold during its solution, he thought of adding this to his other powers, and July 18, 1786, reduced the thermometer 46 degrees. In this experiment the following proportions were used: the temperature of the air being 65° , to water four ounces, at 63° , were added,

Of sal ammoniac	℥ xi	thermometer sunk to	32° , that is,	31°
Of nitre	℥ x	-	24° , that is,	8°
Of GLAUBER'S salts	℥ ij	-	17° , that is,	7°
				46°

In this way he froze water on a day so hot that the thermometer in the shade stood at 70° . By first cooling the salts and water in one mixture, and then making another of these cooled materials, he sunk the thermometer 64 degrees.

August 28. The temperature of the air being 65° , half an ounce of rectified spirit of wine was diluted with three ounces and an half of water, and immersed in the same frigorific mixture. When cooled to 24° , it began to freeze. A quantity of the neutral salts, likewise cooled in the mixture, were put into the diluted spirit, when the thermometer fell to -4° , so that the liquor was cooled 69 degrees.

Spirit of nitre, diluted in the manner described by Mr. CAVENDISH (Phil. Transf. vol. LXXVI. part I.), having reduced the thermometer to -3° , sal ammoniac was added, upon which it fell to -15° .

Nitrated volatile alkali, during its solution in water, reduced the thermometer 35 degrees (from 50° to 15°); but the cold was not increased by sal ammoniac or nitre.

Mr. WALKER's most remarkable experiment was made on the 21st of March, 1787, when he found that nitrous acid, when poured upon GLAUBER's salt, produced effects nearly the same as when it is poured on pounded ice; and that the cold, thus produced, is rendered still more intense by the addition of sal ammoniac in powder.

Mr. WALKER, by many trials, discovered that the best proportion of these ingredients is the following: of concentrated nitrous acid, 2 parts by weight, of water 1 part; of this mixture cooled to the temperature of the atmosphere eighteen ounces, of GLAUBER's salt a pound and an half (avoir-du-pois), and of sal ammoniac twelve ounces. On adding the GLAUBER's salt to the nitrous acid, thus diluted, the thermometer fell from $+51^{\circ}$ to -1° , or 52 degrees; and on adding the sal ammoniac it fell to -9° , that is full 60 degrees. Nitrated volatile alkali, employed instead of sal ammoniac, produced a cold rather more intense.

By means of this mixture, in a very few minutes, in the laboratory before the class, I froze some spirits above proof, diluted with an equal bulk of water; and another gentleman this day sunk the thermometer 68 degrees.

On April 20, 1787, Mr. WALKER effected the congelation of quicksilver by a combination of these mixtures, without a particle of snow or ice. When he began his experiment the temperature

temperature of the mercury was 45° , so that, the freezing point of that metal being -39° , there were produced 84 degrees of cold.

This experiment was performed as follows. Four pans, of sizes progressively diminishing, so that one might be placed within the other, were procured. The largest of these pans was placed in another vessel still larger, in which the materials for the second frigorific mixture were thinly spread, in order to be cooled. The second pan, containing the liquor (*viz.* vitriolic acid, properly diluted) was placed in the largest pan. The third pan, containing the salts for the third mixture, was immersed in the liquor of the second pan; and the liquor for the third mixture was put into wide-mouthed phials, which were immersed in the second pan likewise, and floated round the third pan. The fourth pan, which was the smallest of all, containing its cooling materials, was placed in the midst of the salts of the third pan.

Of the materials for the mixtures to be made in these four pans, the first and second consisted of diluted vitriolic acid and GLAUBER'S salt, the third and fourth of diluted nitrous acid, GLAUBER'S salt and sal ammoniac, in the proportions assigned.

The pans being adjusted in the manner above described, the materials of the first and largest pan were mixed: this mixture reduced the thermometer to $+10$, and cooled the liquor in the second pan to $+20$; and the salts for the second mixture, which were placed underneath in the large vessel, nearly as much. The second mixture was then made with the materials thus cooled, and it reduced the thermometer to 3° . The ingredients of the third mixture, by immersion in this, were cooled to $+10^{\circ}$, and when mixed reduced the thermometer to -15° . The materials for the fourth mixture were cooled by immersion in this third mixture to about -12° . On mixing they made the mercury in the thermometer sink rapidly, and as it

appeared to Mr. WALKER, below -40° . Its thread seemed to be divided below that point; but the froth occasioned by the ebullition of the materials prevented his making so accurate an observation as he could have wished.

The reason why this last mixture reduced the thermometer more than the third, though both were of the same materials, and the last at a lower temperature, Mr. WALKER imagines to have been partly because the fourth pan had not another immersed in it to give it heat, and partly because the materials were reduced to a finer powder.

I should imagine, that mercury reduced to its freezing point will freeze more quickly than water reduced to its freezing point, because it appears, from experiments on their capacity for heat, that the latter of these bodies has so much more latent heat in its liquid state; which greater quantity of latent heat must, as it becomes sensible, more retard the congelation.

I forbear to enumerate many variations of these experiments which Mr. WALKER has among his notes; but there is one mixture which, though its power is not equal to that which I have last described, may prove very serviceable in experiments of this nature, on account of its cheapness. It consists of oil of vitriol diluted with an equal weight of water: added to GLAUBER'S salt, it produces about 46 degrees of cold. The addition of sal ammoniac renders it more intense by a few degrees. One remarkable circumstance occurred to Mr. WALKER, as he was endeavouring to ascertain the best strength of the vitriolic acid: he happened to be trying a mixture of two parts of oil of vitriol and one of water, when he observed, that, at the temperature of 35° , the mixture coagulated as if frozen, and the thermometer became stationary; but, on adding more GLAUBER'S salt, it fell again, after some little time, but so great a

cold was not produced as when this circumstance did not occur, and when the acid was weaker. The same appearance of congelation took place with other proportions of acid and water, at other temperatures.

Mineral alkali, when it retained its water of crystallization, added to some of these mixtures heightened their effects. But when it had lost this water, it rather produced heat than cold; and the same thing is also true of GLAUBER'S salt. This circumstance leads us, in some measure, to the theory of these phenomena. Water undoubtedly exists in a solid state in crystals; it must therefore, as in other cases, absorb a determinate quantity of fire, before it can return to its liquid state. On this depends the difference between GLAUBER'S salt and fossil alkali in their different states of crystallization and efflorescence. The same circumstance too enables us to understand the great effect of GLAUBER'S salt, which, as far as I recollect, has the greatest quantity of water of crystallization.

Those, therefore, who shall choose to pursue the path which Mr. WALKER has opened to them, would do well to try combinations of salts containing much water of crystallization; but they must take care lest the effect should be diminished or destroyed by the formation of compounds that fix a smaller quantity of fire. It is, however, but justice to Mr. WALKER to observe, that he has carried his experiments in this way very far, and with great ingenuity.

I have the honour to be, &c.

THOMAS BEDDOES.

