XXVI. *An Account of a moſt extraordinary Degree of Cold at* Glaſgow *in* January *laſt; together with ſome new Experiments and Obſervations on the comparative Temperature of Hoar-froſt and the Air near to it, made at the* Macfarlane *Obſervatory belonging to the College. In a Letter from* Patrick Wilſon, *M. A. to the Rev.* Nevil Maſkelyne, *D. D. F. R. S. and Aſtronomer Royal.*

Read April 20, 1780.

SIR,

Glaſgow College, Feb. 27, 1780.

THE obſervations and experiments related in the ſequel were made here during the great froſt in the courſe of laſt month. I ſhall be extremely happy if they contribute any thing to your entertainment, being induced to ſend you the account in conſequence of your having on a former occaſion ſo politely invited me to a further correſpondence. If the paper ſhall appear to

you deſerving the notice of the Royal Society, you will pleaſe to conſider it as entirely at your own diſpoſal.

Moſt part of the time my father was confined to his room with bad health, and could not therefore gratify his curioſity by taking a part in the obſervations. I have now the pleaſure of acquainting you, that he is quite well again, and on this occaſion he begs to be remembered to you with beſt compliments.

On Tueſday, Jan. 11th, there was a ſlight froſt, and on the evening of that day we had a fall of ſnow to the depth of twelve inches. Next day the cold continued to increaſe, but ſo gradually, that at ſun-ſet FAHRENHEIT'S thermometer pointed only to 22°. Upon returning home to the College from a viſit about midnight, I hung out a very accurate thermometer at a high North window, where it ſoon after pointed to 6°. At this time the air was very ſtill and ſerene, and the barometer ſtood at 30 inches.

Thurſday

Thurſday morning, Jan. 13, 1 o'clock, thermometer pointed to	gr. +6
$1\frac{3}{4}$	+6
$2\frac{1}{2}$	+4
3	+6
4	+3
$4\frac{1}{2}$	+2
5	+2
$5\frac{1}{2}$	0

At 6 o'clock this morning I carried the thermometer over to the Obſervatory Park, and when it was there laid down upon the ſnow the mercury ſunk to gr. 13 below 0. Your friend Profeſſor ANDERSON ſoon after arriving, we repeated the obſervation with an excellent thermometer made by Mr. RAMSDEN, and it agreed exactly with the other.

At this time we thought it unneceſſary to ſtay abroad ſo long in the cold as to try the temperature of the air by hanging up the thermometers, eſpecially as we imagined that this had been done more readily, and as truly, by taking the degree from the ſurface of the ſnow which had been

expoſed to the open air during the night; but upon reflecting afterwards on the ſnow at the Obſervatory being ſo much below 0, the greateſt cold of the air at the College, and having on other occaſions found a difference of only 4° at moſt in air at theſe two ſtations, I was led into a ſuſpicion that the ſnow might perhaps have been ſo far cooled down by an evaporation at the ſurface. With a view to this opinion I projected the experiment with the bellows deſcribed below, by which I was not without expectations of producing a ſtill more remarkable fall of the thermometer when lying on the ſnow. Before dinner this day I met with Dr. IRVINE, to whom I communicated the above obſervations, and the intention of trying the evaporation; for that ſnow and ice did actually evaporate in ſome circumſtances ſeemed ſufficiently proved by an experiment made here by my father in 1768, which is related in the Philoſophical Tranſactions, vol. LXI. p. 326. Dr. IRVINE approved much of the propoſal, and moſt obligingly agreed to ſpend the night at the Obſervatory, that we might, by a regular courſe of obſervations, aſcertain the difference of temperature, and try whether evaporation was really the cauſe of it.

All the afternoon the cold was very intenſe, and at ſeven o'clock at night the thermometer at the high North window pointed to gr. o. At eight Dr. IRVINE and I repaired to the Obſervatory, and made choice of a ſtation at a ſufficient diſtance from the houſe, and to the windward, as a light air was felt coming from the Eaſt. Here we laid down two thermometers on the ſnow with their balls half immerſed, and hung up other two freely expoſed to the air at two feet and a half from the ſurface.

In the following obſervations the interruption of the ſeries from $2\frac{1}{2}$ to $6\frac{1}{2}$ o'clock was owing to an accident having befallen one of the thermometers whilſt the other was employed in the trials, of which an account is ſubjoined.

Thurſday,

Thurſday evening, Jan. 13.

Below 0.

$8\frac{1}{2}$ o'clock,	therm. on the ſnow pointed to	gr. −12	Therm. in air to gr. 0
9		−14	− 2
10		−14	− 4
11		−17	− 6
$11\frac{1}{2}$		−18	− 6
$\frac{1}{2}$ o'clock Friday morning		−20	− 8
1		−23	− 7
$1\frac{1}{2}$		−22	− 8
2		−22	− 9
$2\frac{1}{2}$		−21	− 8
3			− 9
$3\frac{1}{2}$			−10
4			−12
$4\frac{1}{2}$			−12
5			−12
$5\frac{1}{2}$			−12
6			−14
$6\frac{1}{2}$		−22	−13
7		−22	−13
$7\frac{1}{2}$		−22	−13
8		−19	−10

EX-

EXPERIMENT I.

At half paſt one o'clock, when the thermometer pointed to − 22°, the ſnow contiguous to the ball was blown upon for two minutes by a pair of hand-bellows, held with the pipe nearly horizontal, and half a foot above the ſurface of the ſnow. The bellows had been lying out on the ſnow to cool from the time we firſt came over; and, in order to promote their cooling, they were now and then wrought in the open air. Care was alſo taken to ſtand to leeward of the thermometer, and to extend the bellows as far as poſſible from the body in the time of blowing. We were ſurpriſed to find, however, notwithſtanding all our precautions, that the thermometer at the end of the experiment had got up no leſs than 10°, for it now pointed only to − 12°. In this experiment the noſle of the bellows was held about ſix inches from the thermometer, but the blaſt, though moderate, frequently drifted away the ſnow from the ball.

EXPERIMENT II.

At half paſt two o'clock, a bread-baſket was filled with ſnow, taken up near the ground at + 14°. The contents being relatively ſo warm, the baſket was placed

to leeward of the common ſtation, and the thermometer laid on the ſurface of this ſnow.

At 3 o'clock in the morning, thermometer on the baſket pointed to . . .	−10°
$3\frac{1}{2}$	−15
4	$-16\frac{1}{2}$
$4\frac{1}{2}$	−18
5	−18
$5\frac{1}{2}$	−18
6	−18

EXPERIMENT III.

At four o'clock in the morning, when the thermometer in the baſket had got down to − 16°, a piece of thin fir plank about a foot ſquare was laid on the ſnow, upon which was placed a ſmall plate of tin which accidentally lay at hand. Upon this was laid one of the thermometers which had been hanging in the air.

At 5 o'clock, therm. on the plate pointed to	−16
$5\frac{1}{2}$	−16
6	−18

At ſeven this morning Profeſſor ANDERSON made us a viſit, and had the ſatisfaction of ſeeing the thermometers whilſt they indicated ſuch an extraordinary degree of cold.

cold. During the whole time not a cloud was perceivable, but there was a faint haze in the air when viewed towards the horizon. There was little or no tremor in the atmoſphere, which made the ſtars to ſhine with a full and ſteady light like that of the planets. Many of the citizens, who had thermometers hung out at their windows in different places of the town, found them pointing ſeveral degrees below o at nine o'clock in the morning. On the afternoon of this day, being Friday, Jan. 14th, the air became much warmer, and the barometer had now fallen four-tenths. Next day a thaw came on, and continued for ſome time.

As the above experiment with the bellows favoured ſo little the opinion, that the difference of temperature was cauſed by evaporation, I began to think, that it might be owing to a continued deſcent of cold air ſomewhere in the neighbourhood, which cooled the ſnow by ſweeping along its ſurface in ſo thin a ſheet as not to affect the air a little higher up. But as this ſolution of the phenomenon was ſo arbitrary, and unſupported by any facts, I wiſhed for another opportunity of making further experiments, and of enquiring into circumſtances ſtill more attentively. A good occaſion offered on Saturday, Jan. 22. The froſt, which before this time had again returned, became on this night very keen;

and a good deal of the former ſnow yet remaining on the ground, the following obſervations and experiments were made whilſt I was favoured with the company and aſſiſtance of Dr. ADAIR CRAWFORD, who paſſed the whole of this night at the Obſervatory.

On Sunday morning, Jan 23,

$\frac{1}{2}$ o'clock, therm. on the ſnow pointed to			+4	Therm. in air	+14
$\frac{3}{4}$	.	.	+5	.	+14
$1\frac{1}{4}$	.	.	+4	.	+11
$1\frac{3}{4}$	.	.	+3	.	+11
$2\frac{1}{4}$	.	.	+3	.	+11
$2\frac{3}{4}$	.	.	+3	.	+11
$3\frac{1}{2}$	.	.	+1	.	+ 8
4	.	.	+1	.	+ 6
$4\frac{1}{2}$	.	.	0	.	+ 6
5	.	.	−1	.	+ 5
$5\frac{1}{2}$	.	.	−1	.	+ 6
$6\frac{1}{4}$	.	.	−1	.	+ 6
7	.	.	0	.	+ 6
$7\frac{1}{2}$	.	.	−3	.	+ 5
$7\frac{3}{4}$	.	.	−2	.	+ 5
$8\frac{1}{2}$	.	.	+1	.	+ 7

EXPERIMENT IV.

This night, inſtead of blowing on the ſnow, we fanned it by means of a ſheet of brown paper fitted to the end of a long ſlender ſtick. This apparatus was previouſly cooled by lying on the ſnow, and in fanning we took care to ſtand to leeward of the thermometer. The effect was, that the mercury roſe nearly to the ſame degree given by the thermometer in air at the ſame time.

EXPERIMENT V.

At three quarters paſt one o'clock, when the thermometer on the ſnow pointed to + 3°, it was ſcreened by two ſheets of brown paper ſet up on their edges, and ſo inclined againſt one another as to ſtand. The paper had been previouſly cooled by lying on the ſnow. At a quarter paſt two o'clock the thermometer thus ſheltered pointed to +9°. This experiment was afterwards repeated with the ſame event.

EXPERIMENT VI.

We next went up to the leads of the Eaſt wing of the Obſervatory. Here we hung a thermometer to the hook of a long pole, and raiſed it in the air about twenty-four feet from the ground, and at the ſame time inclined the pole over the balluſtrade, ſo as to put the inſtrument fully to windward of the houſe.

Upon ſuddenly lowering the pole, after half an hour, and examining the thermometer, the air at that elevation was found to be pretty conſtantly 4° warmer than at the ſtation below.

EXPERIMENT VII.

The reſult of this trial appeared more remarkable than any thing which had hitherto occurred. We lowered the pole till the thermometer was brought down within half a foot of the balluſtrade, but keeping it ſtill a few inches to windward of the building, and by this means it was found that the air here was never colder than +10°. Upon the balluſtrade there happened to be

ſeveral detached bodies which had attracted a very thick hoar-froſt. When the thermometer was taken off the hook of the pole, and laid on this hoar-froſt, there was always a remarkable fall of the mercury, not leſs than 6°. Both Dr. CRAWFORD and I were much ſtruck with this fact, and attended to it very carefully.

In tranſlating the inſtrument from the pole to the balluſtrade, it was commonly laid on ſome hoar-froſt three quarters of an inch deep, which had ſettled on a piece of thin board which had been for years expoſed to the weather. Some fragments of the hoar-froſt were alſo made to touch the upper part of the ball; which was done by puſhing them on with a long frozen ſtraw.

EXPERIMENT VIII.

When the thermometer taken from the pole as in laſt experiment was laid on pieces of ſtone, from which the hoar-froſt had been bruſhed away for ſome time before, the mercury ſunk but very little by ſuch a change of ſituation.

Next night, being that of Sunday Jan. 23. the thermometers were placed in their former ſtation below, when at

9 o'clock

9 o'clock at night, therm. on ſnow pointed on			+5	Therm. in air to	+9
9½	.	.	+5	.	+ 8
10	.	.	+6	.	+ 8
10½	.	.	+6	.	+10
11	.	.	+6	.	+ 9
11½	.	.	+5	.	+ 8
12	.	.	+5	.	+ 8
12½	.	.	+4	.	+ 7
1 o'clock Monday morning			+4	.	+ 8
1½	.	.	+4	.	+ 8

From theſe obſervations it appears, that the cold now was very moderate when compared to that of the 14th, and ſomewhat more moderate than that of the preceding night. Experiment 7th was again repeated with a ſimilar reſult, though the difference of temperature was not now ſo great.

This night I made another experiment with a view to the evaporation, not ſo liable to objections as thoſe of the bellows and the fan. This ſhall now be deſcribed.

EXPERIMENT IX.

When the thermometer in air at the lower ſtation had contracted a conſiderable film of frozen matter all over

over the ball, it was ſwung round at the end of a packthread, about a yard and a half long. Upon ſtopping the motion at the expiration of two minutes, and making the ſervant who waited approach quickly with a lighted candle, I found the mercury had got up 2°. In this experiment, which was repeated four times with the ſame reſult, care was always taken to keep the inſtrument to windward of our bodies, and of the lighted candle.

This night the thermometer, when put under the ſnow cloſe to the ground, pointed to +18°. Both now and on the preceding night there were no clouds, though the air, as on the 14th, was a little thick towards the horizon, and there was always a very perceptible and conſtant motion of it from Eaſt to Weſt. On this and the preceding night the Moon, a little paſt the full, ſhone very bright, and the mercury was ſtationary at 30 inches.

On Sunday, Feb. 13. we had a ſlight froſt accompanied with a thick fog. This occaſioned a vaſt ſettling of hoar-froſt upon the ſmall branches and twigs of trees, and upon all thin and detached bodies expoſed to the open air. The weather continued much in this ſtate on Monday, when, at ten o'clock forenoon, I repeated the ſeventh experiment on the balluſtrade, but now found no difference whatever in the temperature of the hoar-froſt and the air in its neighbourhood. The thermome-

ter in both caſes pointed to +22°. About 11 o'clock the ſun-ſhine broke through the fog, when the temperature of the hoar-froſt was as quickly affected as that of the air. The air on this day was quite ſtill, and equally cold both at the upper and under ſtations. It may alſo be here obſerved, that no ſnow lay on the ground. The ninth experiment was alſo repeated, but the thermometer was not now in the leaſt affected by ſwinging it round. Neither on this occaſion, nor when the experiment was firſt made, did any of the frozen matter appear to have parted from the ball.

If we conſider the exceſs of cold in the ſnow which Dr. IRVINE and I firſt obſerved as a phenomenon of the ſame kind with that deſcribed in the ſeventh experiment, and proceeding from the ſame cauſe, it is manifeſt that neither the one nor the other can be accounted for by any previous cold ſtate of the air, according to an hypotheſis alluded to in the beginning of this letter: for in the ſeventh experiment the air at the balluſtrade was never colder than +10°, and yet the hoar-froſt there was at the ſame time found in ſeveral inſtances as cold as +2°. That both theſe phenomena are of the ſame kind appears extremely probable from this conſideration, namely, that when the ſnow upon the fields was attentively examined, the ſurface was found quite covered

over

ever with the ſame ſort of hoar-froſt which was attached to other bodies which had been long expoſed.

The two following experiments afford ſome grounds for believing that no kind of evaporation was going on at the time the remarkable exceſs of cold in the ſnow and hoar-froſt was obſerved.

EXPERIMENT X.

On Sunday morning, Jan. 23. before one o'clock, Dr. CRAWFORD and I repeated the experiment with the metal ſpeculum which was tried here in 1768. A large ſpare metal of a two-foot teleſcope was laid out to cool, after which a film of ice was imparted to its poliſhed ſurface by breathing on it four or five times. It was then expoſed as before, and in half an hour the whole film diſappeared in the way of evaporation. But when the experiment was again repeated, and a thicker film imparted, ſome of this, towards the middle of the ſpeculum, remained fixed, and would not go off after long expoſure. The ſpeculum was next warmed, and its poliſhed ſurface made quite clean, and then laid out for two hours and a half. Before the expiration of this time it began to draw frozen matter from the air, which ſettled all over the poliſhed ſurface in long parallel lines which

gradually multiplied, till at length it was moſtly covered with a thin film reſembling a ſpider's web.

The evaporation ſhewn in the firſt part of this experiment was probably owing to the ſpeculum not having been ſufficiently cooled when the film was firſt communicated to it from the lungs, and to its being further heated by that very operation. In the ſecond part of the experiment the evaporation ſeems to have ſtopped when the heat in the metal which favoured the proceſs was exhauſted; that is, when the ſpeculum had arrived at the temperature of the ambient air, for after that no heat could paſs from the metal in order to contribute to the evaporation. But from the laſt part of the experiment, the true diſpoſition of the air at that time, relative to bodies as cold or colder than itſelf, ſeems to be determined, namely, that of giving out or depoſiting hoar-froſt.

EXPERIMENT XI.

On Sunday night, January 23, ſeveral things were laid out at the Obſervatory, ſuch as ſheets of brown paper, pieces of boards, plates of metal, glaſſes of ſeveral kinds, &c. which all began to contract hoar-froſt ſeemingly as ſoon as each body had time to cool

down to the temperature of the air. The ſheets of brown paper being ſo thin acquired it ſooneſt, and when beheld in candle-light they became beautifully ſpangled over by innumerable reflections from the ſmall cryſtals of hoar-froſt which had parted from the air.

Evident ſymptoms of the ſame tendency of the air to depoſit occurred on all the former nights of obſerving, by which the tubes of the thermometers were ſo much ſtained, that it required ſome attention to keep that part which correſponded to the ſcale quite clear.

Theſe experiments indeed rather favour the opinion of the exceſs of cold at preſent treated of depending upon a principle the very reverſe of evaporation. But till opportunities offer in this or in a colder climate of making more experiments, it will be too early to ſay any thing deciſive concerning the nature or extent of a COOLING PROCESS which has ſo recently come under obſervation. All that can at preſent be affirmed is, that in certain circumſtances ſuch a proceſs goes on, and that it depends probably upon principles different from evaporation or chymical ſolution. At the ſame time ſome of the experiments ſhew that a free communication betwixt the hoar-froſt and external air, perhaps whilſt in motion, is neceſſary; but in what manner this promotes the REFRIGERATION doth not as yet appear.

Thoſe gentlemen whoſe opportunities have led them to know how far the philoſophy of heat hath, of late times, been extended by the great diſcoveries of Dr. BLACK, Dr. IRVINE, and Dr. CRAWFORD, will be moſt intereſted in the views which offer from the foregoing experiments. If at firſt ſight there appears any thing adverſe to certain general principles already eſtabliſhed, yet we may reſt ſatisfied that this is but in appearance only; as the perfect method of induction, purſued by theſe philoſophers, leaves no room to apprehend that any future diſcovery will militate againſt their concluſions. In the further proſecution of this ſubject, and in whatever way it may be cleared up, it is probable, that we ſhall meet with a fine inſtance of the congruity of nature in all her operations, and of the ſtability of thoſe general laws, which have been derived from a cautious obſervance of the rules of the experimental philoſophy.

I am, &c.

The following obſervations which relate to the diſpoſition of the air in giving out hoar-froſt may be here ſubjoined.

It would be going too far were we to conclude from the experiments related above, "that very cold air is

"never

" never diſpoſed to depoſit its contents except upon bo-
" dies as cold or colder than itſelf." And yet that this is frequently the caſe ſeems probable from a number of common appearances. We often find, after a night of froſt, the ſlates and other thinner parts about a houſe whitened with hoar-froſt, when the walls and more ſolid parts of the building remain quite free. In like manner the ſmaller branches and twigs of trees often acquire this frozen ornament, when the main branches and trunk remain naked for a long time; and, in general, any thin or detached body, capable of being eaſily cooled, attach hoar-froſt the ſooneſt.

In favour of this general poſition, the following remarkable caſe lately occurred, which at the time I ſhewed to Dr. REID, in conſequence of whoſe approbation I am induced at preſent to bring it into view.

Between the public library and the buildings of the new court there is a long rail compoſed of bars of caſt iron, but divided into two parts by two maſſy ſtone pillars which ſupport the iron gate-way that leads into the garden. The bars are about ſix feet high and an inch ſquare, and faſtened with lead into a ſtone parapet below in the uſual way. A few bars much larger are ſet in among the reſt at regular diſtances, in order to give the rail more ſtability. On Sunday morning, Feb. 13, when

we

we had the ſlight froſt accompanied with a fog, it was entertaining to obſerve how the hoar-froſt had ſettled during the night upon theſe bars. Very little was to be ſeen upon the flat ſides, but a great deal upon the angles, by which means from the top downward every bar was garniſhed with four fringes, which made the whole rail look very gay and ornamental. Running the eye along the foot of the bars near to the parapet it was obſerved, that the fringe of hoar-froſt upon the corners ſtopped ſhort about twelve inches from the bottom, and that ſo much of every bar was entirely free. Two bars next the houſe and two next the library were likewiſe perfectly clear of it from top to bottom. One bar next the pillar of the gate was quite free, and the ſecond had contracted but little. The ſame thing preciſely may be ſaid of the two bars contiguous to the other pillar. And it was alſo obſerved, that the few thicker and ſtronger bars were leſs fringed at the corners, and were quite free much farther above the parapet than the others.

It is manifeſt, that during the night the air ſurrounding the bars muſt have been conſtantly endeavouring to make them as cold as itſelf, whilſt they, on the other hand, reſiſted this change by drawing heat from every neighbouring ſource which offered it, namely, from the parapet, from the pillars in the middle, and from the pillars

at

at both ends immediately adjoining to the library, and to the houſe in the new court: for theſe bodies from their great bulk muſt have been but very little cooled in the courſe of the night. Wherever the air ſeems to have got the better in this ſtruggle, as at the angles of the bars, which evidently muſt be the parts the ſooneſt cooled, there we find that the hoar-froſt was depoſited, but no where elſe.

Several other inſtances were found quite of the ſame kind with that of the rail. Among the reſt, a figure of an unicorn in ſtone, which ſtands within the college, had reſiſted the attacks of the air all to the tip of his horn, which accordingly was the only part diſtinguiſhed by a patch of hoar-froſt. Beſides this kind of hoar-froſt which joined itſelf to bodies by a regular arrangement, there was ſome of a different ſort found upon the uppermoſt ſurface of ſuch bodies as were fully expoſed to the open air. But this always lay ſcattered like very thin flakes of meal, or hair-powder, and was found to proceed from minute parts, moſtly columnar, previouſly formed in the air, falling down by their own gravity.