STANLEY, J. T. (P)

AN

ACCOUNT

OF THE

HOT SPRINGS

IN

ICELAND;

WITH AN

Analysis

OF

THEIR WATERS.

[1791]

AN

ACCOUNT,

&c.

An Account *of the* Hot Springs, *near Rykum, in Iceland: In a Letter to Dr.* Black, *from* John Thomas Stanley, *Esq.* F.R.S. F.S.A.A. Lond. *and* F.R.S. Edin.

[*Read, Nov.* 7. 1791.]

Dear Sir,

Alderley, August 15, 1791.

I HAVE been prevented hitherto, by various occupations, from acquitting myself of a promise you received from me, (I am ashamed to think how long a time since), that I would send you an account of the Hot Springs in Iceland, from whence the water was brought which you have lately analyfed. I have trufted you would excufe a delay not altogether voluntary. It will be now my endeavour to gratify your curiofity as far as I am able; and to acquaint you with every particular, as well concerning the fprings, as the country near them, which I think you may find in the leaft interefting.

We faw many fprings in the courfe of our journey befides thofe I am going to defcribe; nor indeed are they confined to the part of the ifland we vifited, but break out in every divifion of it. For a general account of the moft remarkable, I refer you to a letter, written by Dr. VAN TROIL, (the prefent Archbifhop of Upfal), to Profeffor BERGMAN, publifhed with fome others concerning Iceland, in the year 1777.

The defcriptions given by this author are fo accurate, that it will not be in my power to give you much new information. I muft, in a great meafure, repeat what he has faid. It may be fatisfactory, however, to you to have his relations corroborated; and fome further details, with an account of the changes which, in a few inftances, have taken place fince he vifited thefe particular fprings in 1772, may contribute to explain their hiftory, and the caufe of their very fingular appearances.

You received two kinds of water, one from a fpring near a farm called Rykum, and the other from the fountain known by the name of the Geyzer, the moft remarkable in the ifland. It rifes near the farm of Haukadal, about forty miles from Rykum. They are both fituated in the S. W. divifion of the ifland.

I fhall begin with a defcription of the country, and the fprings near Rykum, and of the firft view we had of them in our way from Rykavick to Mount Hecla. Rykum is fituated in a valley, which, on account of its fertility, and the ftrong contraft it made with the dreary fcenes we had paffed fince our laft ftation, appeared to us with great advantage while we approached it. We had traverfed a country, feven or eight miles in breadth, entirely overfpread with lava, and other volcanic matter. It was furrounded with hills, not fufficiently high to be majeftic, and too rugged and too barren to be pleafing. We were told by our guides, that on a clear day, the fummits of Hecla might be ſeen above thoſe which were immediately before us; but heavy and lowering clouds, which threatened us inceſſantly with a ſtorm, concealed every diſtant object from our ſight.

We ſaw many diſtricts in Iceland covered with lava; but I do not recollect one ſo uncouth and deſolate as this. No vegetation was to be ſeen, but that of a few ſtunted buſhes of willow and birch, growing between the crevices and hollows of the lava, into which the wind had drifted ſufficient ſoil for them to take root. We could diſcover no mouth or crater from whence we could conjecture, with any degree of probability, the lava to have iſſued. It extended round us like a ſea; and it had burſt perhaps from ſome part of the country it now covered, while the fire to which it owed its origin, had eſcaped with its ſhowers of cinders and aſhes, from ſome other orifice, and had formed one of the numberleſs cones we could diſcover amidſt the neighbouring hills.

The unpleaſantneſs of our ride over this country was increaſed by the continual danger to which we were expoſed of our horſes falling. The road was no other than what the few travellers of the country, as they paſſed from their farms to Rykavick, had tracked over the lava, where it was leaſt rough; but even this was interrupted by many breaks and crevices, formed by the cooling of the matter, and the contraction of its parts.

To this uncomfortable ſcene ſucceeded the view of a rich valley, opening into an extenſive green plain, bounded by the ſea. A river was ſeen winding between ſeveral fertile meadows; and beyond theſe, the valley was terminated by a range of high and bold rocks. But our attention was chiefly attracted by the clouds of ſteam, which aſcended in various parts of the valley from the hot ſprings, and by jets of water which, from ſome of them, were inceſſantly darted into the air.

We deſcended into the valley by a road winding over the lava, which in one place had flowed from the upper plain into the country below. On each ſide it had ſtopped abruptly, and had thus formed a perpendicular wall, at leaſt ſixty feet high.

We pitched our tents in a pleaſant field, on the ſide of the river, oppoſite to the farm, and not far from it; and at the foot of the hills which bounded the valley. Several fragments of rocks, which had fallen from thefe, lay fcattered round our ftation. Thefe were entirely volcanic; fome of dark blue lava, not unlike bafalte; others of a yellow fubftance; and again others of a grey lava, mixed with a great quantity of white glafs: but the moft curious confifted of an heterogeneous mixture of various fubftances, cemented indifcriminately together by fome operation, fubfequent to their original formation, and fo ftrongly, that the rock was broken with difficulty by our hammers. It confifted of pieces of black glafs, (a lava in all probability much vitrified), and large pieces of a clofe, grey lava, the cavities and pores of which were filled with zeolites finely radiated. Some pieces of black lava, in parts compact, and in other parts fo porous as to approach nearly to a pumice ftone, were mixed with the reft of the mafs. A mixture of thefe fame fubftances, (the lavas, the glafs, and the zeolites), pounded in fmall grains, filled the fpaces between the larger pieces, and connected the whole into a folid rock. The heat (if heat it was) which had cemented thefe materials, had not been ftrong enough to reduce any one to a ftate of fufion; for the angles of the fragments were as ſharply defined as if newly ſeparated from their reſpective original beds.

The rocks from whence theſe different maſſes have been detached, lay heaped together in ſo disjointed and irregular a manner, that ſome violent convulſion has evidently taken place among them ſince their firſt formation; but ſimilar appearances of diſorder are to be ſeen in every range of hills in the country. Regular ſtrata are no where to be met with. It appears as if all this part of the iſland, at different periods, had been thrown up from its foundations.

The valley is, in this place, fertile; and nearly half a mile in breadth. It becomes more narrow towards the north; and it is there rendered barren by heaps of crumbled lava, or other rubbiſh, brought down from the hills by the waters. Theſe have the appearance of artificial mounds, and a great number of ſprings are continually boiling through them. Below the ſurface, a general decompoſition ſeems taking place: for almoſt wherever the ground is turned up, a ſtrong heat is felt, and the looſe earth and ſtones are changing gradually into a clay, or bole of various colours, and beautifully veined, reſembling a variegated jaſper. The heat may poſſibly proceed from a fermentation of the materials compoſing theſe mounds; but more probably (I ſhould conjecture) from the ſprings and ſteam forced up through them. The ſprings muſt have acquired their heat at ſome greater depth, from ſome conſtant, ſteady cauſe, (however difficult to explain), adequate to the length of time they have been known to exiſt, with the ſame unvaried force and temperature.

Springs do not boil on or near theſe banks only. They riſe in every part of the valley, and within the circumference of a mile and an half, more than an hundred might eaſily be counted. Moſt of them are very ſmall, and may be juſt perceived ſimmering in the hole from whence the ſteam is iſſuing. This, trailing on the ground, depoſits, in ſome places, a thin coat of ſulphur. The proportion varies; for near ſome of theſe ſmall ſprings, ſcarce any is perceptible, whilſt the channels by which the water eſcapes from others, are entirely lined with it for ſeveral yards. Neither the water, nor the ſteam from the larger ſprings, ever appear to depoſit the ſmalleſt proportion of ſulphur; nor can the ſulphureous vapour they contain be diſcovered, otherwiſe than by the taſte of what has been boiled in them for a long time.

Many ſprings boil in great caldrons or baſons, of two, three, or four feet diameter. The water in theſe is agitated with a violent ebullition, and vaſt clouds of ſteam fly off from its ſurface. Several little ſtreams are formed by the water which eſcapes from the baſons; and as theſe retain their heat for a conſiderable way, no little caution is required to walk among them with ſafety.

The thermometer conſtantly roſe in theſe ſprings, to the 212th degree; and in one ſmall opening, from whence a quantity of ſteam iſſued with great impetuoſity, Dr. WRIGHT obſerved the mercury riſe, in two ſucceſſive trials, to the 213th degree.

I have already ſaid, that the ground, through which many of the ſprings were boiling, was reduced to a clay of various colours. In ſome, the water is quite turbid; and, according to the colour of the clay through which it has paſſed, is red, yellow, or grey.

The ſprings, however, from whence the water overflows in any great quantity, are, to appearance, perfectly pure. The moſt remarkable of theſe was about fifty or ſixty yards from our ſtation, and was diſtinguiſhed by the people of the neighbourhood, by the name of the Little Geyzer. The water of it boiled with a loud and rumbling noiſe in a well of an irregular form, of about ſix feet in its greateſt diameter; from thence it burſt forth into the air, and ſubſided again nearly every minute. The jets were daſhed into ſpray as they roſe, and were from twenty to thirty feet high. Volumes of ſteam or vapour aſcended with them, and produced a moſt magnificent effect, particularly if the dark hills, which almoſt hung over the fountain, formed a back ground to the picture. The jets are forced, in riſing, to take an oblique direction, by two or three large ſtones, which lay on the edge of the baſon. Between theſe and the hill, the ground (to a diſtance of eight or nine feet) is remarkably hot, and entirely bare of vegetation. If the earth is ſtirred, a ſteam inſtantly riſes, and in ſome places it was covered with a thin coat of ſulphur, or rather, I ſhould ſay, ſome looſe ſtones only were covered with flakes of it. In one place, there was a ſlight efflorеſcence on the ſurface of the ſoil, which, by the taſte, ſeemed to be alum.

The ſpray fell towards the valley, and in that direction covered the ground with a thick incruſtation of matter which it depofited. Clofe to this, and in one fpot, very near the well itfelf, the grafs grows with great luxuriance.

Where the foil was heated, it was gradually (as on the mounds) changing into a clay. But it was here more beautiful than in any other place. The colours were more varied and bright, and the veins were marked with more delicacy. The tranfition likewife from one fubftance into the other was more evident and fatisfactory.

To the depth of a few inches, the ground confifted of loofe lavas, broken and pounded together, of blue, red, and yellow colours. The blue lava was hardeft; and feveral pieces of it remained firm and unaltered, while the reft were reduced to a duft. The colours became brighter, as the decompofition of the fubftances advanced, and they were changed at the depth of nine or ten inches into a clay; excepting, however, the pieces of dark blue lava, which ftill retained fufficient hardnefs to refift the preffure of the finger. Round thefe, (which appeared infulated in the midft of the red and yellow clay), feveral veins or circles were formed of various fhades and colours. A few inches deeper, theſe alſo became part of the clay, but ſtill appearing diſtinct, by their circles, from the ſurrounding maſs. The whole of this variegated ſubſtance reſted on a thick bed of dark blue clay, which had evidently been formed in the ſame manner from ſome large fragment of blue lava, or ſtratum of it, broken into pieces.

The reſemblance of theſe clays to jaſper is ſo ſtriking to the eye, that I cannot forbear believing their origin to be ſimilar, at leaſt, that ſome circumſtances in the formation of each are the ſame. You will ſay, with reaſon, that the difference, notwithſtanding the apparent ſimilitude, is in reality very wide; that theſe clays, before they can be converted into jaſpers, require to be conſolidated, and impregnated with a conſiderable proportion of ſiliceous earth. It is ſomething, however, to have detected nature in the act of forming, in any ſubſtance, the veins and figures common to marbles and jaſpers. What ſtill remains of the proceſs, after thus much of it has been traced, may not long continue unknown; and in Iceland, probably ſooner than elſewhere, will be diſcovered beds of clay, like this, hardening into ſtone, either by the effect of ſubterraneous heat, or preſſure promoting an adheſion of the particles, or by ſome inſinuation of matter (perhaps ſiliceous) into the pores of the maſs.

There is another fountain in the valley, not much inferior in beauty to that which I have deſcribed. It breaks out from under one of the mounds, cloſe to the river. Its eruptions are, I think, in ſome reſpects, more beautiful than thoſe of the former. They riſe nearly to the ſame height, and the quantity of water thrown up at one time is greater, and not ſo much ſcattered into ſpray. The jets continue ſeldom longer than a minute, and the intervals between them are from five to ſix minutes. They are forced to bend forwards from the well, by the ſhelving of the bank, or probably their height would be very conſiderable; for they appear to be thrown up with great force. We never dared approach near enough to look deep into the well; but we could perceive the water boiling near its ſurface, from time to time, with much violence. The ground in front of it, was covered with a white incruſtation, of a more beautiful appearance than the depoſition near any other ſpring in this place. By a trial of it with acids, it ſeemed almoſt entirely calcareous.

I have now defcribed to you the two moft remarkable fountains in the valley of Rykum, the only two which throw up water to a confiderable height with any regularity. There are fome from whence, in the courfe of every hour, or half hour, beautiful jets burft out unexpectedly; but their eruptions continue only a few feconds, and between them the water boils in the fame manner as in the other bafons.

Towards the upper end of the valley, there was a very curious hole, which attracted much of our attention. It feemed to have ferved at fome former period as the well of a fountain. It was of an irregular form, and from four to five feet in diameter. It was divided into different hollows or cavities at the depth of a few feet, into which we could not fee a great way, on account of their direction. A quantity of fteam iffued from thefe receffes, which prevented us from examining them very clofely. We were ftunned while ftanding near this cavern, and in fome meafure alarmed, by an amazing loud and continued noife which came from the bottom. It was as loud as the blaft of air forced into the furnace from the four great cylinders at the Carron iron-works.

We could difcover no water in any of the cavities; but we found near the place many beautiful petrifactions of leaves and moffes. They were formed with extreme delicacy, but were brittle, and would not bear much handling; their fubftance feemed chiefly argillaceous.

We perceived fmoke iffuing from the ground in many places in the higher parts of the valley, much further than we extended our walks. I am forry to fay we left many things in this wonderful country unexamined; but we were checked in our journey by many circumftances, which allowed us neither the leifure nor the opportunity for exploring every part of it as we could have wifhed. The fubftances depofited near the different fprings feemed to me, in general, a mixture of calcareous and argillaceous earths; but near one fpring, not far from our tents, there feemed to be a flight depofition of filiceous matter. To the eye it refembled calcedony; but with its tranfparency, it had not the fame hardnefs, and, if preffed, would break to pieces. The water you have analyfed came from this fpring, and we were obliged to take fome care in filling the bottles; for though gradually heated, they would break when the water was poured into them, if it had not been previouſly expoſed to the air for ſome minutes in an open veſſel.

The water of this ſpring boiled, as in moſt of the others, in a cauldron four or five feet broad. I do not recollect to have ſeen any of it ever thrown up above a foot, and ſome meat we dreſſed in it taſted very ſtrongly of ſulphur.

Mr. BAINE, by a meaſurement of the depth, the breadth, and the velocity of the ſtream flowing from the Little Geyzer, found the quantity of water thrown up every minute by it to be 59,064 wine gallons, or 78.96 cubic feet. Mr. WRIGHT and myſelf followed the ſtream, to obſerve how far any matter continued to be depoſited by the water. We found ſome little ſtill depoſited where it joined the river, a quarter of a mile at leaſt from its ſource. At that place, it retained the heat of 83 degrees by Fahrenheit's thermometer.

The vegetation on the banks of the ſtream, and in the pleaſant meadows through which it flows, is exceedingly luxuriant. The farmer and his people were at this time employed in cutting the hay in them, which, though not high, was thick, and remarkably ſweet. The plants which Mr. Wright found in the greateſt perfection, were the ſedum acre,* the veronica becabunga,† the polygonum viviparum,‡ and the comarum paluſtre.§

A little above, where the current from the Little Geyzer falls into the river, part of the lava, which has deſcended from the upper into the lower plain, has aſſumed cloſe to its banks, for the ſpace of ſome yards, a regular columnar ſhape. The pillars are ſhort, and have five or ſix ſides. I cannot be very exact in my account of them, as they were on the oppoſite ſide of the river. I ſhould ſuppoſe they were nearly a foot and an half in diameter. Some were horizontal, and others vertical. We obſerved the ſame appearance in many of the tracts of lava we traverſed on our journey, and, in one or two inſtances, in thoſe which had flowed from the ſides of Mount Hecla, though the pillars there were leſs perfectly defined.

* Pepper ſtone crop.

† Brook lime.

‡ Snake weed.

§ Purple marſh ariquefoil.

So many ſtreams of hot water fall into the river, that it receives from thence a very perceptible degree of heat. The thermometer, immerſed in it above where it is joined by the waters of the Little Geyzer, roſe to 67 degrees, while in the open air it ſtood at 60. The breadth of the river in the ſame place is forty feet; its mean depth two feet and an half, and its courſe is rather rapid. Several kinds of fiſh are found in it; in particular, numbers of very fine ſalmon.

The village of Rykum or Ryka, called either indiſcriminately, from *Ryk*, an Icelandic word, ſignifying ſmoke, is ſituated in the middle of the valley, and, by an obſervation made by Mr. BAINE, is in latitude 64° 4′ 38″ N. about twenty miles from Rykiavick, and eight or ten from Oreback, a ſmall harbour on the ſouthern coaſt of the iſland. The village conſiſts of the farmer's houſe, and the houſes of his ſervants or dependants, and a ſmall church. All the adjacent lands belong to him, and he keeps a conſiderable number of ſheep and cattle, and ſome few horſes. Theſe conſtitute his riches; and he purchaſes at Rykiavick, with ſkins, wool, and butter, whatever he requires, of which the chief article is fiſh, for his winter's proviſion.

I have now related to you every circumſtance that has occurred to me worth mentioning concerning this intereſting valley. I have regretted much, however, my inability to give you a more accurate account of ſome parts of it; in particular, of the many ſprings which break out near the hills to the north, and of the rocks above the field where we placed our tents, which deſerved more attention than I gave to them. But we remained in this valley a ſhort time only, and the weather, during our continuance there, was very unfavourable. I ſhall here cloſe this letter, and reſerve for another (which you may very ſoon expect) the account I have yet to ſend you of the Great Geyzer, and the ſprings near Haukadal.

I am, Dear Sir, with great eſteem, your moſt obedient ſervant,

JOHN THO. STANLEY.

An ACCOUNT *of the* HOT SPRINGS *near Haukadal, in Iceland: in a ſecond Letter to Dr.* BLACK, *from* JOHN THOMAS STANLEY, *Eſq.* F.R.S. F.S.A *Lond. and* F.R.S. *Edin.*

[*Read April* 30, 1792.]

Groſvenor Place, March 30, 1792.

DEAR SIR,

PART of my promiſe has been accompliſhed in a former letter, in which I gave you the fulleſt account I could of the ſprings of boiling water that riſe in the valley of Rykum. It now remains for me to ſend you a deſcription of thoſe we viſited in the neighbourhood of Haukadal.

Theſe laſt are the moſt remarkable in the iſland, and the eruptions of water from ſome of them ſo aſtoniſhing, that I doubt whether any adequate idea of their effect can be given by deſcription. Abler pens than mine might fail probably in attempting to do juſtice to ſuch wonderful phenomena. The objects, however, are ſo highly intereſting in themſelves, that even the ſimpleſt narrative that can be given of them will be read with more than ordinary attention.

They are ſituated about ſix and thirty miles from Mount Hecla, and about twelve miles, in a north-eaſt direction, from the village of Skalholt.* The road from thence to the ſprings is over a flat country, which, although marſhy in ſeveral places, is not unpleaſant to the eye, and abounds in excellent paſturage.

The ſteam aſcending from the principal ſprings during their eruptions may be ſeen from a conſiderable diſtance. When the air is ſtill, it riſes perpendicu-

* Skalholt conſiſts of the Cathedral, a large building of wood, and of a very few houſes belonging to the Biſhop and his dependants. The Biſhops of the ſouthern diviſion of Iceland have always reſided there; but in future their reſidence will be at Rykiavick, a town now building on the ſouth-weſt coaſt of the iſland. The preſent Biſhop, however, the worthy and learned Mr. Finson, has obtained the permiſſion of continuing his reſidence at Skalholt during the remainder of his life.

larly, like a column, to a great height; then ſpreads itſelf into clouds, which roll in ſucceſſive maſſes over each other, until they are loſt in the atmoſphere. We perceived one of theſe columns, when diſtant ſixteen miles at leaſt, in a direct line from Haukadal.

The ſprings moſtly riſe in a plain, between a river that winds through it, and the baſe of a range of low hills. Many, however, break out from the ſides of the hills, and ſome very near their ſummits. They are all contained, to the number of one hundred or more, within a circle of two miles.

The moſt remarkable ſpring riſes nearly in the midſt of the other ſprings, cloſe to the hills. It is called Geyzer;* the name probably in the old Scandinavian language for a fountain, from the verb *geyſa*, ſignifying *to guſh*, or *to ruſh forth*. The next moſt remarkable ſpring riſes at a diſtance of one hundred and forty yards from it, on the ſame line, at the foot of the hills. We called it the New Geyzer, on account of its having but lately played ſo violently as at preſent.

* Three or four only of the principal ſprings in Iceland are diſtinguiſhed by the name of Geyzer, and of all the ſprings near Haukadal the greateſt is alone called Geyzer, or Great Geyzer.

There are others of confequence in the place, but none that approach to thefe in magnificence, or that when compared with them, deferve much defcription. The generality of the fprings are in every refpect fimilar to thofe near Rykum; boiling in caldrons of three or four feet diameter, and fome of them throwing their water from time to time, by fudden jets, into the air. Many fprings in this place, as in the other, boil through ftrata of coloured clay, by which they are rendered turbid. Here, however, the red clays were brighter, and in a greater proportion to the clays of other colours. Here alfo, as in the valley of Rykum, are many fmall fprings, which throw out fulphureous vapour, and near which the ground, and the channel of the water, are covered and lined with a thin coat of fulphur.

The farm of Haukadal, and the church of the parifh, ftand near to each other about three quarters of a mile beyond the great fpring. The houfe is one of the beft built in Iceland. It occupies a large fpace of ground, and confifts of feveral divifions, to each of which there is an entrance from without. Some of thefe are ufed as barns and ftables for the cattle, and others as work-ſhops.* The dwelling part of this houſe was ſmall but comfortable. There was a parlour with glaſs windows, a kitchen, and ſeparate bedchambers for the family. The building was partly of ſtone, partly of wood, and covered with ſods, under which the bark of birch trees on boards was placed, as a greater ſecurity againſt rain.

We were obliged to the miſtreſs of this farm, who was a rich widow, for a very hoſpitable reception, altho' at firſt ſhe ſeemed to conſider us as rather unwelcome viſitors, and left us, though we had requeſted admittance into her houſe, (as we were drenched with rain, and our tents and baggage not yet arrived) to take up our lodging in the church. We had not been long there, however, before ſhe invited us to her houſe, and by her kindneſs made ample amends for her former inattention. She put us in poſſeſſion of her beſt room, and ſet before us plenty of good cream, ſome wheat

* As the diviſion of labour is yet very imperfect in Iceland, the farmer is under the neceſſity either of exerciſing himſelf the ſeveral trades required in the formation of the inſtruments of agriculture, or of maintaining ſuch ſervants as are capable to ſupply them.

cakes, fugar, and a kind of tea made of the leaves of the *dryas octopetala*.*

I mention thefe circumftances of our reception at Haukadal, as characteriftic of the manners of the Icelanders. Several times during my ftay in the country, I experienced this fucceffion of civility to coldnefs. The Icelanders are naturally good, but not eafily roufed to feeling. When once their conftitutional indifference was overcome, we ufually found them defirous of pleafing, and zealous to do us fervice.

As the houfe was not fufficiently large to contain the whole of our party, we were under the neceffity of returning again to the church, as foon as our baggage arrived. Here we paffed the firft and fecond nights of our ftay, in the neighbourhood of the fprings. On the third day we left Haukadal, to fix ourfelves in fome ftation nearer to them, from which we could watch their eruptions with more convenience.

* Called in Englifh the Mountain Avens. We found this plant growing very luxuriantly, and in great abundance, in every part of Iceland that we vifited.

The view from near the church was very beautiful. It extended toward the ſouth along the plain into an open country. On the other ſide, it was bounded by hills, which had not the barren and rugged appearance that deform almoſt every ſcene in this diviſion of the iſland. It was, however, ſtill finer from ſome of the eminences near the ſprings. The plain and the ſurrounding mountains, ſeen from a height, appeared to more advantage; and the eruptions from the great wells breaking from time to time, the general ſtillneſs that prevailed, were much more diſtinct. The courſe of the river winding under the eye, could be traced with greater accuracy. It flows through the plain into an open country, where, being increaſed by the waters of numerous ſtreams and rivulets, it bends to the weſtward, and near Skalholt falls into a conſiderable river, the Huit-aa.

The pleaſant and fertile paſtures near its banks were enlivened by numerous herds of cattle and ſheep, the united riches of three or four farmers in the neighbourhood of Haukadal. The mowers alſo at work in the different fields ſurrounding each houſe, gave, at this ſeaſon, additional beauty to the proſpect. High hills to the weſtward were ſeparated from the eminencies immediately above the ſprings, by a narrow valley. They were partly clothed with buſhes of birch, which although in no place above five feet high, were gratifying to the ſight, which ſo ſeldom in Iceland can reſt on any appearance even of underwood. Above theſe, ſome vegetation ſtill continued to cover the ſides of the hills, and Mr. WRIGHT found a variety of plants* near their ſummits, which were certainly, in ſome places, not leſs than 1600 feet above the plain.

To the eaſtward, the plain, ſeveral miles in breadth, was bounded by a long range of blue mountains, extending conſiderably to the ſouth. Beyond theſe, the triple ſummit of Hecla may be ſeen from the weſtern hills; but I could not diſtinguiſh it from the plain, or even from the heights whence the view of the ſurrounding country was taken, which I am now deſcribing.

To the north behind Haukadal, there were many high mountains, but at a great diſtance, and of which

* Amongſt others, he found the *ſalix herbacea* (teſt willow), the *ceraſtium tomentoſum* (woolly mouſe ear chickweed), the *rumex digynus* (round leaved mountain ſorrel), and the *koenigia*, (a plant peculiar to Iceland), growing in great abundance, though generally in low and marſhy grounds.

the moſt diſtant were covered with ſnow. They formed part of a dreary aſſemblage of *Jokuls* or ice-mountains, which occupy a conſiderable extent of the interior country. Their forms were moſtly conical; and from their general reſemblance to other mountains in the iſland, from which ſtreams of lava have been emitted, I think it probable they were once volcanos. They are not ſo connected as to form a continued range or chain of hills. Each ſtands inſulated; and therefore the ſnows which have for ages reſted on their ſides, are no where accumulated in valleys, and converted into lakes of ice and glaciers, as amidſt the Alps of Switzerland and Savoy.

A view ſo different from the general features of the country, impreſſed us with the moſt agreeable ſenſations. Hitherto we could but compare one ſcene of drearineſs with another; and although the view before us was deſtitute of trees, yet the verdure, and pleaſant diſtribution of hills and plain, in ſome meaſure compenſated for this deficiency.

I now return to the account of the ſprings, which I have already obſerved break out in different places from the ſides of a hill, and the ſpace incloſed between its baſe and the windings of a river. The ſoil through which they riſe is a mixture of crumbled materials, waſhed by degrees from the higher parts of the hill. In ſome places, theſe have been reduced into a clay or earth; in others, they ſtill remain looſe and broken fragments of the rocks from whence they have fallen, or a duſt produced by their friction againſt each other. Wherever the ground is penetrated by the ſteam of the ſprings, theſe fragments are ſoon decompoſed, or changed into coloured clays. In other places, the ſurface of the ground is covered with incruſtations depoſited by the ſprings, or with a luxuriant vegetation of graſs or dwarf buſhes of willow and birch, and the *empetrum nigrum*,* the berries of which were at this time ripe and in great abundance.

Above the great ſpring, the hill terminates in a double pointed rock, which Mr. BAINE found by meaſurement to be 310 feet higher than the courſe of the river. The rock is ſplit very ſtrangely into lamina, and at firſt ſight has much the appearance of a ſchiſtus, or

* The crow berry. This is almoſt the only fruit we met with in Iceland. Mr. WRIGHT found a few ſtrawberries. Neither gooſeberries nor currants will come to perfection by any management whatever.

bed of thick ſlate. It conſiſts, however, of a grey coloured ſtone of a very cloſe grain, the ſeparate pieces of which, although divided as they lay, do not break in the hand in any particular direction. I ſhould ſuppoſe the ſubſtance of this rock to be chiefly argillaceous, and that, like every other ſtone in the iſland, it has ſuffered ſome change by the action of fire. I do not mean to call it lava, as it bears no mark of having been once in a melted ſtate, whatever baking or induration it may have ſuſtained in the neighbourhood of ſubterraneous heat. It contains no heterogeneous matter, or cavities, in which agates, or zeolites, or vitrified ſubſtances of any kind, could have been formed.

All theſe rocks that have been either altered or created by fire, ſeem much more liable to decay and decompoſition than any others I have ever ſeen.—Mounds, ſimilar to thoſe in the valley of Rykum, have been formed by the ruins of the hill half way up its aſcent, between the Geyzer and the pointed rock. Springs boil in many places through theſe mounds, and near to one of them, I obſerved that the coloured clay felt much more ſoapy than any I had tried before.—This quality probably was owing to a greater proportion of the earth of magnefia in its compofition, as in other refpects it agreed perfectly with the reft.

My attention, during the four days I remained in this place, was fo much engaged by the beauties and remarkable circumftances of the two principal fprings, that I cannot (were I fo inclined) give you a minute account of thofe which, next to them, were deferving of notice. The fprings in general refemble thofe at Rykum; but there are five or fix which have their peculiarities, and throw up their waters with violence to a confiderable height. Their bafons are of irregular forms, four, five, or fix feet in diameter, and from fome of them the water rufhes out in all directions, from others obliquely. The eruptions are never of long duration, and the intervals are from 15 to 30 minutes. The periods of both were exceedingly variable. One of the moft remarkable of thefe fprings threw out a great quantity of water, and from its continual noife we named it the Roaring Geyzer. The eruptions of this fountain were inceffant. The water darted out with fury every four or five minutes, and covered a great fpace of ground with the matter it depofited. The jets were from thirty to forty feet in height. They were fhivered into the fineft particles of fpray, and furrounded by great clouds of ſteam. The ſituation of this ſpring was eighty yards diſtant from the Geyzer, on the riſe of the hill.

I ſhall now, Sir, attempt ſome deſcription of this celebrated fountain, diſtinguiſhed by the appellation of Geyzer alone, from the pre-eminence it holds over all the natural phenomena of this kind in Iceland.

By a gradual depoſition of the ſubſtances diſſolved in its water for a long ſucceſſion of years, perhaps for ages, a mound about thirty feet high has been formed, from the centre of which the Geyzer iſſues. It riſes through a perpendicular and cylindrical pipe, or ſhaft, ſixty-one feet in depth, and eight feet and a half in diameter, which opens into a baſon or funnel, meaſuring fifty-nine feet from one edge of it to the other.— The baſon is circular, and the ſides of it, as well as thoſe of the pipe, are poliſhed ſmooth by the continual friction of the water, and they are both formed with ſuch mathematical truth, as to appear conſtructed by art. The declivity of the mound begins immediately from the borders of the baſon. The incruſtations are in ſome places worn ſmooth by the overflowing of the water; in moſt, however, they riſe in numberleſs little tufts, which bear a refemblance to the heads of cauliflowers, except that they are rather more prominent, and are covered, by the falling of the finer particles of fpray, with a cryftalline efflorefcence fo delicate as fcarcely to bear the flighteft touch. Unmolefted, the efflorefcence gradually hardens, and although it lofes its firft delicacy, it ftill remains exceedingly beautiful.

These incruftations are of a light brown colour, and extend a great way, in various directions, from the borders of the bafon. To the northward they reach to a diftance of 82 feet; to the eaft, of 86; to the fouth, of 118; and of 124 to the weft. They are very hard, and do not appear, in any part, decaying, or mouldering into foil.*

* The fubftance of thefe incruftations has been analyfed by Profeffor BERGMAN, and he gives a long and particular account of it in a letter to the Archbifhop of Upfal, publifhed with the Archbifhop's Letters on Iceland. He fays, "The ftrongeft acids, the fluor acid "not excepted, are not fufficient, with a boiling heat, to diffolve "this fubftance. It diffolves very little (if at all) by the blow pipe, "with the fufible falt of urine, a little more with borax, and makes "a ftrong effervefcence with fal fodæ. Thefe effects are peculiar "only to a filiceous earth or flint. There cannot remain therefore "a doubt concerning the nature of this cruftated ftone."

When our guides firſt led us to the Geyzer, the baſon was filled to within a few feet of its edge. The water was tranſparent as cryſtal; a ſlight ſteam only aroſe from it, and the ſurface was ruffied but by a few bubbles, which now and then came from the bottom of the pipe. We waited with anxiety for ſeveral minutes, expecting at every inſtant ſome interruption to this tranquillity. On a ſudden, another ſpring, immediately in front of the place on which we were ſtanding, darted its waters above an hundred feet into the air with the velocity of an arrow, and the jets ſucceeding this firſt eruption were ſtill higher. This was the ſpring already mentioned under the name of the New Geyzer.

While gazing in ſilence and wonder at this unexpected and beautiful diſplay, we were alarmed by a ſudden ſhock of the ground under our feet, accompanied with a hollow noiſe, not unlike the diſtant firing of cannon. Another ſhock ſoon followed, and we obſerved the water in the baſon to be much agitated. The Icelanders haſtily laid hold of us, and forced us to retreat ſome yards. The water in the mean time boiled violently, and heaved as if ſome expanſive power were labouring beneath its weight, and ſome of it was thrown up a few feet above the bafon. Again there were two or three fhocks of the ground, and a repetition of the fame noife. In an inftant the furrounding atmofphere was filled with volumes of fteam rolling over each other as they afcended, in a manner inexpreffibly beautiful, and through which, columns of water, fhivering into foam, darted in rapid fucceffion to heights which, at the time, we were little qualified to eftimate. Indeed, the novelty and fplendour of fuch a fcene had affected our imaginations fo forcibly, that we believed the extreme height of the jet to be much greater than it was afterwards determined to be. In a fubfequent eruption, Mr. Baine afcertained, by means of a quadrant, the greateft elevation to which the jets of water were thrown, to be 96 feet.

Much of the water began to defcend again at different heights, and was again projected by other columns, which met it as they rofe. At laft, having filled the bafon, it rolled in great waves over its edge, and forming numberlefs rills, made its way down the fides of the mound. Much was loft in vapour alfo, and ftill more fell to the ground in heavy fhowers of fpray. The intervals at which the feveral jets fucceeded each other, were too fhort for them to be diftinguifhed by the eye

As they rofe out of the bafon, they reflected, by their denfity, the pureft and moft brilliant blue. In certain fhades, the colour was green, like that of the fea; but in their further afcent, all diftinction of colour was loft, and the jets, broken into a thoufand parts, appeared white as fnow. Several of them were forced upwards perpendicularly; but many, receiving a flight inclination as they burft from the bafon, were projected in beautiful curves, and the fpray which fell from them, caught by a fucceeding jet, was hurried away ftill higher than it had been perhaps before.

The jets were made with inconceivable velocity, and thofe which efcaped uninterrupted terminated in fharp points, and loft themfelves in the air. The eruption, changing its form at every inftant, and blending varioufly with the clouds of fteam that furrounded it, continued for ten or twelve minutes; the water then fubfided through the pipe, and difappeared.

The eruptions of the Geyzer fucceeded each other with fome degree of regularity, but they were not equally violent, or of equal duration. Some lafted fcarcely eight or ten, while others continued, with unabated violence, fifteen or eighteen minutes. Between the great eruptions, while the pipe and bafon were filling, the water burft feveral times into the air to a confiderable height. Thefe partial jets, however, feldom exceeded a minute, and fometimes not a few feconds, in duration.

After the eruption of it had been violent, the water funk into fubterraneous caverns, and left the pipe empty. If the eruption had been moderate, the fubfidence of the water was proportionably lefs. The firft time the pipe was perfectly emptied, we founded its depth, and found the bottom very rough and irregular. The pipe remained but a fhort time empty. After a few feconds, the water rufhed into it again with a bubbling noife, and during the time that it was rifing in the pipe, it frequently darted fuddenly into the air to different heights, fometimes to two or three, fometimes fixty feet above the fides of the bafon. By a furprife of this kind, while we were engaged meafuring the diameter of the well, we had nearly been fcalded; and although we were able to withdraw ourfelves from the great body of water as it afcended, yet we remained expofed to the falling fpray, which fortunately was fo much cooled in the air as to do us no mifchief.

Of theſe jets we counted twenty in an hour and an half, during which the waters had filled the pipe, and in part the baſon. It then ſeemed oftentimes agitated, and boiled with great violence. The jets were more beautiful, and continued longer, as the quantity of water in the baſon increaſed. The reſiſtance being greater, their force was in ſome degree broken, and their form, more divided, produced a greater diſplay of foam and vapour.

While the pipe was filling, we threw into it ſeveral ſtones of conſiderable weight, which, whenever the water burſt forth with any violence, were projected much higher than itſelf. Theſe ſtones in falling were met by other columns of water, and amidſt theſe they roſe and fell repeatedly. They were eaſily diſtinguiſhed amidſt the white foam, and contributed much to the novelty and beauty of this extraordinary phenomenon.

When the baſon was nearly full, theſe occaſional eruptions were generally announced by ſhocks of the ground, ſimilar to thoſe preceding the great eruptions. Immediately after the ſhocks, the whole body of water in the baſon heaved exceedingly; a violent ebullition then took place, and large waves ſpread themſelves in circles from the centre, through which the column forced its way.

When the water had been quiet in the bafon for fome time, the thermometer placed in it ftood at 180° only, but immediately after an eruption it rofe to 200°. We boiled a piece of falmon in it, which tafted exceedingly well, not being in the leaft tainted with fulphur. Our cookery at Rykum had not been quite fo fuccefsful.

The water thrown out from the Geyzer is joined at the bottom of the mound by that which flows from the fpring called the Roaring Geyzer, formerly defcribed. The ftream produced by their united waters flows three or four hundred paces before it falls into the river, where its temperature is reduced to 72°. Even at this place is depofited much of the fubftances it contained; but during the whole of its courfe, the plants growing on its banks were covered with beautiful incruftations. Some of thefe we wifhed to preferve, but from their extreme delicacy they fell into pieces on every attempt to remove them.

The ſituation of the New Geyzer* is in the ſame line from the foot of the hill with the Great Geyzer. Its pipe is formed with equal regularity, and is ſix feet in diameter, and forty-ſix feet ten inches in depth. It does not open into a baſon, but it is nearly ſurrounded by a rim or wall two feet high. After each eruption, the pipe is emptied, and the water returns gradually into it, as into that of the Old Geyzer. During three hours nearly that the pipe is filling, the partial eruptions happen ſeldom, and do not riſe very high; but the water boils the whole time, and often with great violence. The temperature of the waters after one of theſe eruptions, was conſtantly found to be 212°. Few

* Before the month of June, 1789, the year I viſited Iceland, this ſpring had not played with any great degree of violence, at leaſt for a conſiderable time. (Indeed the formation of the pipe will not allow us to ſuppoſe, that its eruptions had at no former period been violent). But in the month of June, this quarter of Iceland had ſuffered ſome very ſevere ſhocks of an earthquake; and it is not unlikely, that many of the cavities communicating with the bottom of the pipe had been then enlarged, and new ſources of water opened into them. The difference between the eruptions of this fountain, and thoſe of the Great Geyzer, may be accounted for from the circumſtance of there being no baſon over the pipe of the firſt, in which any water can be contained to interrupt the column as it riſes. I ſhould here ſtate, that we could not diſcover any correſpondence between the eruptions of the different ſprings.

incruſtations are formed round this ſpring, excepting in the channel where the water flows from it.

The great eruption is not preceded by any noiſe, like that of the Great Geyzer. The water boils ſuddenly, or is heaved over the ſides of the pipe; then ſubſiding a little, it burſts into the air with inconceivable violence. The column of water remains entire, until it reaches its extreme height, where it is ſhivered into the fineſt particles. Its direction was perpendicular, and greateſt elevation 132 feet. Like the eruption of the Old Geyzer, this conſiſted of ſeveral jets, ſucceeding each other with great rapidity. Whatever we threw into the well was hurled into the air with ſuch ſwiftneſs that the eye could ſcarcely diſcern it,* and the diviſion of the water at the extremity of the column was ſo minute, that the ſhowers of ſpray which fell were cold. Towards the end of an eruption, when more ſteam than water ruſhed from the pipe, I ventured to hold my hand near the edge of the column, in the way of ſome of the divided particles of water, and found them tepid only.

* Mr. BAINE meaſured the height to which a ſtone was thrown by one of theſe jets, and found it 129 feet. Some others roſe conſiderably higher.

You may probably think this a raſh experiment, and certainly it was ſo. But we had made our obſervations on the uniform direction of the column, and confided our ſafety in it. Once or twice, however, we had reaſon to think ourſelves more fortunate in eſcaping, than prudent in avoiding, the danger which attended a too near approach to theſe eruptions of boiling water. During ten or fifteen minutes, the water continued to be thrown upwards with undiminiſhed impetuoſity. At the end of that period the quantity became leſs, and at length, ceaſing entirely, ſteam alone aſcended. In one inſtance the eruption continued thirty minutes. It ſeldom, however, exceeded twenty, and ſometimes was completed in fifteen minutes. The force with which the ſteam riſes abates as the water ſinks in the pipe, and when this is exhauſted, that ſoon diſappears.

I have now, Sir, given you ſuch a deſcription of theſe celebrated fountains as was in my power. I hope that it will afford you ſome ſatisfaction, and I could wiſh that it might ſerve as an inducement to ſome curious inquirer into the hiſtory of nature to viſit them, who ſhall have all the knowledge requiſite for making ſuch obſervations as are yet to be deſired concerning them. I cannot flatter myſelf, that the deſcription I have attempted of their eruptions will impreſs you with a juſt idea of their beauty. Sources of compariſon are wanting, by which the portraiture of ſuch extraordinary ſcenes can be aſſiſted. Nature no where offers objects bearing a reſemblance to them; and art, even in conſtructing the water-works of Verſailles, has produced nothing that can at all illuſtrate the magnificent appearances of the Geyzer. All then that I hope for is, to have ſaid ſo much as may enable you to complete in your imagination, the picture which I have only ſketched. Imagination alone can ſupply the noiſe and motion which accompany ſuch large bodies of water burſting from their confinement; and muſt be left to paint, what I have not been able to deſcribe, the brilliancy of colouring, the purity of the ſpray, the quick change of effect, and the thouſand varieties of form into which the clouds of ſteam, filling the atmoſphere on every ſide, are rolled inceſſantly.

I have avoided entering into any theory of the cauſe of theſe phenomena, that you may not ſuppoſe the account I give you has been biaſſed by a favourite hypothesis. I have given you an accurate state of facts, and I leave to you the explanation of them. There cannot, however, be two opinions concerning the immediate cause which forces the water upwards. It is obviously the elasticity of steam endeavouring to free itself. In addition to this, the form of the cylinder through which the water rises, gives it that projectile force which carries it so high. Beyond this, it would not become me to hazard any opinion.

Of the antiquity of these springs I can say nothing, further than that they are mentioned as throwing up their waters to a great height by SAXO GRAMMATICUS, in the Preface to his History of Denmark, which was written in the twelfth century; but from the general features of the country, it is likely, that they have existed a great length of time. The operations of subterraneous heat seem indeed to be of great antiquity in Iceland, and the whole country probably owes its existence to the fires which burn beneath its surface. Every hill proves, at least, with what violence these fires have acted for ages; and the terrible eruptions of lava, which burst from the mountains of Skaptefield, in 1783, ſhow that they are as yet far from being extinguiſhed.

I am,

Dear Sir,

With great regard and eſteem,

Your very obedient ſervant,

JOHN THO. STANLEY.

AN

ANALYSIS

OF THE

Waters

OF SOME

HOT SPRINGS

IN

ICELAND.

By JOSEPH BLACK, M. D. &c. &c.

An ANALYSIS *of the* WATERS *of some* HOT SPRINGS *in* ICELAND. *By* JOSEPH BLACK, M. D. *Professor of Medicine and Chemistry in the University of Edinburgh; First Physician to his Majesty for Scotland, Fellow of the Royal College of Physicians, and of the Royal Society of Edinburgh; Member of the Academy of Sciences, and of the Society of Medicine of Paris, of the Imperial Academy of Petersburgh,* &c. &c.

[*Read July* 4, 1791.]

SIR JOSEPH BANKS, to whose indefatigable ardour for the advancement of natural history, the philosophical world is so much indebted, made a voyage to Iceland in the year 1772, to inquire into the productions of that remote part of the world, and particularly into those of its famous volcano. When he returned, he brought from thence, among many other natural productions, ſome petrified vegetables, and incruſtations, formed by the waters of the boiling ſprings; and he was ſo good as to preſent a part of them to his friends here, who were ſurpriſed to find them compoſed of ſiliceous earth. As this was the firſt example obſerved of water containing this earth in ſuch quantity as to form ſiliceous petrifactions, it raiſed a ſtrong deſire to have an opportunity of examining the water, and of learning by what means this ſiliceous matter was diſſolved in it; and this opportunity was at laſt given us by JOHN THOMAS STANLEY, Eſq. who, excited by motives ſimilar to thoſe of Sir JOSEPH BANKS, equipped likewiſe a veſſel, and made a voyage to Iceland, during the ſummer 1789. He brought from thence, and from the Faro Iſlands, a number of fine ſpecimens of volcanic and other foſſil productions, and along with them, a quantity of the water of the two moſt remarkable boiling and exploding ſprings of Iceland, called by the natives *Geyzer* and *Rykum*; and having favoured me with a portion of theſe waters, and expreſſed his deſire that I would examine them, I have accordingly made a number of experiments with them, an account of which I ſhall now ſubmit to the Society. If the detail of it ſhould appear tedious; if I ſhall be thought to have given much attention to very ſmall matters, it muſt be conſidered, that the nature of the ſubject requires exactneſs. The quantities of the materials which are to be examined in ſuch experiments, are but ſmall, though it often happens, that theſe ſmall quantities of matter, acting in nature for a great length of time, produce accumulations, and other effects, that appear very ſurpriſing and worthy of attention. I muſt alſo confeſs, that I took pleaſure in promoting, as far as I could, the information concerning Iceland, which the philoſophical zeal and ſpirit of the Gentlemen I mentioned, have procured for us.

Both theſe waters had a weak ſmell of the Hepatic Gas, or a ſmall degree of the odour, which is well known in Harrowgate, and other ſulphureous waters. The quantity, however, of this ſulphureous matter in them was ſo very ſmall, that I was not able, by any experiments, to obtain it in a ſeparate ſtate, or bring it into view in any form whatever. I therefore could not make any attempt to eſtimate the quantity of it.

Thoſe who are acquainted with ſulphureous waters, know that an incredibly ſmall quantity of their volatile ſulphureous matter is ſufficient to give a perceptible odour; and it is ſo liable to be decompounded and changed, while we attempt to ſeparate it from water, that ſuch an attempt never ſucceeds when the quantity of it is ſmall. There was alſo reaſon to believe, that ſome part of it had already been loſt or changed during the voyage, this matter being one of thoſe volatile ingredients of mineral waters, which are the moſt liable to be evaporated or changed by the action of the air, and other cauſes. I therefore think it ſufficient to mention, that theſe waters contained a ſmall quantity of this ſubſtance.

I began by making a few preliminary trials, to acquire ſome notion of the nature of theſe waters.

1. An equal quantity of lime-water being added to the Iceland waters, there was a little diminution of tranſparency, but only in the ſmalleſt degree, and no ſediment was formed.

2. Mild volatile alkali produced no effect whatever.

3. Paper ſtained blue with the March violet, being dipped into the water and dried, had its colour changed alittle towards a green.

4. Cambric ſtained to a blueiſh purple, with infuſion of litmus, aſſumed a more perfect blue colour, when dipped into the water and dried.

5. Acid of ſugar did not produce a perceptible muddineſs or precipitation.

6. Nor did the ſolution of corroſive ſublimate.

7. The ſolution of ſal ſaturni (plumbum acetatum) made the water very muddy, and white, but a ſmall quantity of diſtilled vinegar re-diſſolved nearly the whole of the precipitate, and made the water almoſt perfectly clear again.

8. The ſolution of barytes in muriatic acid made the water become muddy, and depoſit a ſediment, which was not re-diſſolved by adding purified nitric acid.

9. The ſolution of ſilver produced a ſtrong muddineſs, and conſiderable precipitation, which was not re-diſſolved by adding purified nitric acid.

The laſt trial ſhewed the preſence of the muriatic acid, and the one preceding it, that of the vitriolic acid in the compoſition of theſe waters; but by the 3d, 4th, and 7th, I alſo learned, that there was more than enough of alkaline matter to ſaturate both of them. The 5th trial ſhewed that the alkaline matter was not calcareous earth, but alkaline ſalt; and the 6th, that this alkaline ſalt was not the volatile, but one of the fixed alkalis. The 1ſt trial ſhewed, that this unſaturated fixed alkali was not combined with air, or that if any was combined with it, the quantity was ſo ſmall as to be ſcarcely perceptible.

None of theſe trials gave any indication of the earthy matter contained in theſe waters; and as my principal object was to inveſtigate the nature of their petrifying power, I now began with the following experiment:

Evaporation of the Water.

I evaporated 10,000 grains weight of each of theſe waters to dryneſs with a gentle heat, in ſeparate glaſſes. The dry extract of the water of Rykum weighed gr. 8.25, and that of Geyzer, gr. 10.

The evaporation was performed in cylindrical glafs veffels, about 3 inches wide and $7\frac{1}{2}$ deep, which received heat from the fteam of boiling water, not directly, but through the intervention of white-iron cafes, which fitted the glaffes, and in which they hung. I have often ufed this apparatus in examining and comparing different waters; and the advantages of it are, that the greater part of the fixed matter is collected on a fmall furface; that the glaffes are fo moderately heated, that they bear water to be added, during the evaporation, without danger of breaking; and laftly, when the whole water is evaporated, the fixed matter, while it is thoroughly dried, by leaving it expofed fome hours to the heat, never becomes fo hot as to fuffer the lofs of any part of the acid of the faline compounds which it may contain, and when it is dry, the quantity of it is accurately determined, by weighing it in the glafs, the weight of which can be afcertained, both before the water is put into it, and after the extract is taken out.

In the end of thefe evaporations of the Iceland waters, they emitted an odour fimilar to that of alkaline leys, which contain an alkali not very pure or well calcined, and afterwards, when the evaporation was nearly completed, the refiduum affumed the form of a tranſparent jelly, which had nearly the thickneſs of half a crown. This jelly afterwards became divided by fiſſures, into a great number of ſmall portions, which, in drying, contracted their ſize, and greatly widened the fiſſures, forming at laſt a number of ſmall fragments of white cruſt, unconnected with one another, and not adhering to the bottom of the glaſs. A ſmall quantity only of this matter attached itſelf to the ſides of the glaſs during the evaporation, and formed there circles of an exceeding thin incruſtation, which adhered ſtrongly, and required much patience to ſcrape it off with a knife.

Theſe phenomena are exactly ſimilar to thoſe which appear in evaporating water which contains ſiliceous earth, diſſolved in it artificially by means of an alkaline ſalt. The colour of the dry matter obtained from Rykum water was almoſt a pure white; that of the water of Geyzer was a yellowiſh white.

While theſe dry extracts were kept for ſome time in the glaſſes, placed in a cold room, in the winter ſeaſon, they attracted humidity, and the extract of Geyzer attracted the moſt. Eight grains of the extract of Rykum attracted in one week four grains of humidity; the fame quantity of the extract of Geyzer attracted in the fame time ten grains of humidity. My attention, however, was turned for fome time from thefe experiments; but refuming them again after fome months, I found that thefe extracts remaining in the fame glaffes, and in the fame room, had again become dry, and had loft the greater part of the weight which they had acquired at firft by attracting humidity. This I imputed partly to the ftate of the atmofphere, and partly to their having attracted fixed air, by their union with which they had loft their ftrong attraction for water.

The conftituent parts of thefe extracts were next to be inveftigated. I foon perceived that they contained a portion of alkaline falt not faturated with acid, which became evident when a fmall quantity of them was wetted and applied to paper ftained with the juice of violets, or the colouring matter of the common purple radifh; the colour in either cafe was changed to a green. I further collected and fcraped thefe extracts out of the glaffes, and placing each in a fmall filtre, I dropped diftilled water on them repeatedly, until the water came away from them infipid. The waters which had been thus filtrated through them were put into china cups, and the greater part evaporated with a gentle heat, the reft was allowed to evaporate fpontaneoufly in a dry room. Thus, a number of fmall faline cryftals were formed, which were partly regular cryftals of common falt, and partly cryftals of an oblong and flatted form, larger than thofe of the common falt. Thefe larger cryftals were diftinguifhable, not only by their form, but by fome of their properties. They became white, opaque, and mealy in dry air, and being taken out, and tafted and tried in different ways, were found to contain fome of the foffil alkali in a cryftallized ftate.

The undiffolved matter which had remained on the filtrating paper, appeared by its properties to be totally or principally made up of filiceous earth. It was white and exceedingly fpungy and light. A fmall portion of it was triturated, and made into a pafte with water; which pafte being laid on a piece of charcoal and dried, was heated intenfely with the blowpipe. No part of it was melted; it was only contracted in its dimenfions, and acquired a weak degree of cohefion. Another fmall portion was triturated dry, with an equal weight of aërated and exficcated foffil alkali; and being put into a fmall platina fpoon, againft the bottom of which the flame of the blowpipe was ftrongly directed, the mixture was foon melted into a tranfparent colourlefs glafs, which afterwards, by being digefted, with a fmall quantity of diftilled water, was completely diffolved, and formed a liquor which had all the qualities of the *liquor filicum*.

I need not take notice here of the quantity of the earth, and faline matter which were in fome meafure feparated from one another in this experiment. I had reafon to fufpect, that neither of them were obtained in this way without fome lofs. The odour emitted by the water in the end of evaporation, gave reafon to fufpect the lofs of fome part of the falts; and it was probable that a part of the earth would remain combined with the alkali, in a foluble ftate, in the dry extract, and would pafs through the filtre, when I diffolved and wafhed away the faline matter.

I therefore planned a fet of experiments, by which the quantity of each ingredient in thefe waters might be more certainly known: and began with the following

Experiments to investigate the Quantity of the un-neutralized alkaline Salt.

In making the experiments to decide this queſtion, I made uſe of an acid, which I had often employed before in experiments, to learn the quantity of pure or cauſtic alkali, contained in aërated alkalis, and in various barillas, kelps, and other ſuch heterogeneous maſſes. This acid was a quantity of the vitriolic, the power of which, in ſaturating pure alkalis, I had carefully examined, and I was accuſtomed to add it very gradually to filtrated ſolutions of the above ſubſtances, until they were exactly ſaturated; and then, from the quantity of acid required to produce this effect, I learned the quantity of un-neutralized alkali which theſe ſubſtances contained. The ſpecific gravity of this vitriolic acid, compared with that of water, was as 1798 to 1000, in a temperature of heat equal to 60° of FAHRENHEIT. When I had uſed it on former occaſions, I diluted ſome of it, with four times its weight of diſtilled water, and uſed this mixture in place of the pure acid, that I might the more readily portion it into ſmall doſes; but on this occaſion, I made a mixture of it, with about 100 times its weight of diſtilled water;

and eſſaying this mixture afterwards, with great attention, I found that 112 grains of it ſaturated one grain of the pure alkaline part of the alkali of tartar, and 171.55 grains were required for the ſaturation of one grain of the pure, or cauſtic part of the foſſil alkali.

With this largely-diluted acid, the ſtrength of which was thus aſcertained, I began to inveſtigate the quantity of alkali in the Iceland waters. I gave a pale purple, or blue colour to a portion of the Rykum water, by adding a few drops of an infuſion of litmus, the bluiſh purple of which became more blue when mixed with this alkaline water, and I began to add, very gradually, ſome of the largely-diluted vitriolic acid, expecting to ſee the colour change to a reddiſh purple, when the alkali became completely ſaturated. This method, however, did not ſucceed ſo well as I had ſuppoſed; for although I changed the colour to a reddiſh purple, or even to a pure red, by adding an exceeding ſmall quantity of the diluted acid, the red thus produced was not permanent. Next day, I found it returned again to the blue, and requiring a new addition of acid; and this happened ſo often, after repeated additions of acid, that this proceſs appeared very tedious, and ſcarcely capable of being brought to a precise limit; for in proportion as I continued the process the longer time, or had made the more numerous additions of acid, the time neceſſary for the return of the colour from red to blue was always the longer, and at laſt was no leſs than ſeveral weeks.

Theſe phenomena appear to me to have proceeded from the very weak and ſlow action of the acid and alkali on one another, in conſequence of the exceſſively-diluted ſtate in which they were mixed together, the alkali at the ſame time not being pure, but combined with the ſiliceous earth, a ſubſtance for which it has a conſiderable attraction. I therefore ſuppoſed, that when I added the ſmall doſes of diluted acid, the acid particles remained for ſome time diſperſed through the liquor, without joining the alkali, and the water contained, at the ſame time, a ſilicated alkali, if I may ſo call it, and an unſaturated acid; but the colour of litmus being much more diſpoſed to be affected and changed by acids than alkalis, it became red, and retained this colour as long as any particles of the acid remained unſaturated. Theſe, however, after ſome time, being all attracted and ſaturated by the alkali, the colour was again changed by the remaining unſaturated alkali.

It may, perhaps, be fufpected, that a fmall quantity of fixed air, detached from the alkali, might be the caufe of this temporary red colour, and that the colour returned again to blue, when the fixed air evaporated from the water; and I know, that a very fmall quantity of fixed air contained in water, is fufficient to change the colour of litmus, and that a confiderable time is required for its evaporation from the water; fo that the litmus may recover its natural tint: but it is equally true, that the fixed air never requires fo long a time for its evaporation as feveral weeks, and that it has not the power to redden litmus, when an alkali is prefent, except when the quantity of the alkali is exceedingly fmall, and that of the fixed air incomparably more than fufficient for faturating the alkali. In the prefent cafe, the laft of thefe conditions never could take place, the quantity of acid added at once being far too fmall to detach enough of air, even although the alkali had been originally faturated with air, which it certainly was not; it appeared rather to be in a cauftic ftate, or very nearly cauftic. This reafoning fuggefted to me another mode of making the experiment, which fucceeded perfectly in a moderate time.

The foregoing experiments, and others which I made with ſmall quantities of the water, enabled me to form ſome judgment of the proportion of acid neceſſary to ſaturate the alkali which this water contained. I therefore added to 10,000 grains of the Rykum water, 200 grains, accurately weighed, of the largely-diluted vitriolic acid; which quantity I judged to be conſiderably more than ſufficient for ſaturating the alkali of this water; and after the acid was poured in, the ſmall and light glaſs in which it was weighed was rinſed ſeveral times with diſtilled water, which was added to the Rykum water. I alſo gave it a pale tincture with ſome drops of the infuſion of litmus, and then boiled the water gently in a thin-bottomed glaſs, until it was reduced to one fourth of its firſt quantity. It ſtill continued of a red colour, without the leaſt tendency to a purpliſh hue, and ſhewed that the acid was more than enough to ſaturate the alkali.

It was neceſſary, in the next place, to learn with certainty, how much of the acid had been ſuperfluous. With this intention, I added a largely-diluted ſolution of alkali of tartar in diſtilled water. In this ſolution, the pure alkali, conſidered as diſtinct from the air which was joined to it, conſtituted one fortieth part of the weight of the fluid. I weighed 38.6 grains of this ſolution; which quantity I knew, by the previous experiments, was exactly, or nearly sufficient for saturating the superfluous acid. I poured it at once into the hot water, and rinsing the small and light glass in which it was weighed two or three times with distilled water, I poured in this also. A little effervescence appeared in the hot water; I therefore set it again on the furnace to boil, that the fixed air might be expelled, and I added now and then a little distilled water, to prevent it from boiling down too much. In less than half an hour's boiling, the fixed air being all expelled, the colour changed from red to purple, with a very small tendency towards the red. This shewed that the quantity of salt of tartar, which had been added, was exactly sufficient for saturating the superfluous acid. Had the saturation not been sufficiently exact, I could have added a little more of the alkali, or a little more of the acid, as I had done in the smaller essays which were preparatory to this; but the tint of colour which I had here produced, was that which I had found to be the most discernible and satisfactory sign of exact saturation, in former experiments; and it is proper to mention, that one grain more of the largely-diluted vitriolic acid changed this purple, very remarkably, to a more decided red, and that with one grain less, the hue of the purple, by being inclined to blue, would have been equally diſtinguiſhable; of which I ſatisfied myſelf, by adding as much of the ſolution of ſalt of tartar as ſaturated one grain weight of the largely-diluted acid.

The quantity of the diluted acid added at firſt was 200 grains. From this was to be ſubſtracted 108.32 grains, the quantity ſaturated by the 38.6 grains of the ſolution of ſalt of tartar; the remainder is gr. 91.68. From this quantity, however, we muſt make another deduction; for, as Profeſſor BERGMAN juſtly obſerved, the infuſion of litmus contains ſomething which is of an alkaline nature, or is capable of ſaturating a certain quantity of acid. To learn how much was to be deducted on this account, I tinged a ſmall quantity of diſtilled water, with the ſame number of drops of the infuſion of litmus that I had uſed in tinging the Iceland water, and then making the diſtilled water boiling hot, I began to add ſome of the largely-diluted vitriolic acid, and kept the water boiling all the time. The firſt additions of acid, as I expected, did not produce a change of colour, or, if any change was produced, it ſoon diſappeared again, while the water was boiling; but as ſoon as I had added gr. 3.5, a permanent change was produced to a reddiſh purple. This quantity therefore muſt, in the next place, be deducted from the gr. 91.68, and thus we have gr. 88.18, as the quantity of the diluted vitriolic acid which was employed ſolely in ſaturating the alkali of the water. But from the eſſays I had made of the power of this diluted acid in ſaturating alkalis, it is evident that this quantity of it was ſufficient for ſaturating gr. 0.514 of the pure, or cauſtic foſſil alkali, or gr. 0.857 of that which is ſaturated with air, and evaporated to dryneſs, or about gr. 2.38 of that which is ſaturated with air, and in form of tranſparent cryſtals.

The next ſtep was to make a ſimilar experiment to determine the proportion of alkali in the Geyzer water; but here I found it neceſſary to change a little the mode of aſcertaining the point of ſaturation.

The water of Geyzer, by means of the ſulphureous gas, which it contained in greater quantity than the other, and perhaps alſo by means of ſome of the other ingredients which it contained, and which gave it a light yellowiſh colour, produced ſuch a change in the colour of litmus, that it could not be employed, as in the laſt experiment, by mixing it with the acidulated water, and boiling them together; the purple of the litmus was changed to an orange, which could not be made to return to blue or purple, although I added a quantity of alkali, which rendered the liquor very evidently alkaline, when it was examined by other trials. I therefore had recourſe to the common method, which I had formerly practiſed in many other experiments of a ſimilar nature, I mean the uſe of linen rags, or bits of cambric, which had been tinged with an infuſion of litmus. A little bit of theſe, when touched with a liquor that is in the ſmalleſt degree acid or alkaline, has its colour changed from the purple to red or blue. This method is, next after the one employed in the laſt experiment, the moſt nice that I know; provided that, in having recourſe to it, we remember what was remarked in the former experiment, that the litmus colour is affected by acids in general much more eaſily than by alkalis; and that, though a liquor contain a ſmall quantity of alkali, if this be ſaturated and ſuperſaturated with fixed air, the firſt effect of ſuch liquor upon the ſtained paper, will be to change it towards a red. This tint of colour, however, being produced by the ſuperfluous aërial acid, is made to diſappear, by drying the bit of cambric. The colour of it, while drying, will quickly change from the red to purple, and from that to blue, in conſequence of the evaporation of the ſuperſaturating air. Being appriſed of this particular, I firſt made ſome preparatory experiments, with gr. 1000, and alſo with gr. 10,000 of the Geyzer water, and afterwards a more ſatisfactory one with gr. 10,000 of the ſame, in the following manner:

To gr. 10,000 of the Geyzer water, I added gr. 400, accurately weighed, of the largely-diluted vitriolic acid, and began ſoon after to evaporate the water, by boiling it gently in a thin-bottomed glaſs. The above quantity of acid I knew to be conſiderably more than what was ſufficient for ſaturating the alkali.

The water was boiled until it was reduced to a quantity little exceeding gr. 3000. I then added gr. 84.5 of the dilute ſolution of ſalt of tartar, and boiled the water again gently until it was reduced to gr. 2000. In weighing ſuch ſmall quantities of acid, or alkaline liquors, as were added to the water in theſe experiments, it is eaſy to adjuſt the weight with the greateſt preciſion, by dipping the end of a ſlender glaſs rod, or of a pointed ſlip of paper, into the fluid. By theſe means, we can take up a quantity of it, as ſmall as we pleaſe; and this method I likewiſe uſed, when I meant to add these fluids gradually, and by very small quantities at a time, to any mixture. The end of a slender glass rod was dipped into them, and afterwards transferred into the mixture.

When I now examined the above boiled water, by means of the tinctured paper, or linen rag, I found it reduced to the exact degree of saturation which I desired; that is to say, it scarcely produced a change in the litmus colour, or if any change was produced, it was only a vergency towards the red, which was scarcely perceptible; and when the state of saturation was varied from this point, by an addition of 3 grains of the largely-diluted vitriolic acid, or by an equivalent quantity of the alkaline solution, the tint of the colour was remarkably changed towards the red or towards the blue. Supposing therefore the above state of saturation exact, and I believe it to be the most exact that could be depended on, the quantity of largely-diluted vitriolic acid, employed in saturating the fossil alkali of the water, was gr. 163.4; for the whole quantity added was gr. 400, and the salt of tartar of the gr. 84.5, of the dilute solution had required gr. 236.6 for its saturation. It follows, therefore, from the essays I had made, of the power of this diluted acid, in saturating the pure or cauſtic foſſil alkali, that the unſaturated quantity of this alkali, contained in the gr. 10,000 of the water, was gr. 0.952, which is equal to gr. 1.587 of the ſame alkali combined with air and evaporated to dryneſs, or gr. 4.409 of the ſame in a cryſtallized ſtate.

The reaſon for boiling theſe waters, with the quantities of acid which I had added to them, in theſe laſt experiments, is ſufficiently obvious. The abundance of acid was meant to inſure the complete ſaturation of the whole of the alkali, and ſeparation of it from the ſiliceous earth; and the boiling promoted the ſame purpoſe, both by means of the heat which was applied, and alſo by bringing the acid and alkaline particles the nearer to one another, while the water evaporated.

A doubt may, however, poſſibly ariſe in the minds of ſome of my readers, whether this boiling of the water might not be attended with the diſſipation of ſome part of the ſuperfluous acid, which was not neutralized by the alkali of the water; and if any part of the acid was diſſipated, the concluſions concerning the quantity of the alkali would be neceſſarily erroneous.

To remove this ſcruple, I took gr. 10,000 of diſtilled water, and added gr. 112 of the diluted acid. This mixture was then boiled down, in the ſame manner as the Iceland water; that is to ſay, in a glaſs which had an oval, or nearly globular body, about five inches deep, with a neck as long, and half an inch wide. This glaſs was placed in a ſhallow ſand-heat, the bottom of which was a flat iron plate. The boiling was continued until three fourths of the water were evaporated, and then, removing it from the fire, I added gr. 40 of the dilute ſolution of ſalt of tartar. This neutralized it exactly, and ſhewed that no part of the acid had been diſſipated in boiling; and it continued to ſhew the ſigns of ſufficiently exact ſaturation, after I had evaporated it further to the weight of one ounce, in which ſtate any ſuperfluous alkali, by being leſs diluted, would have been more eaſily diſcernible.

Experiments to determine the Nature and Quantity of the earthy Matter.

Having thus determined the quantity of unſaturated alkali in theſe Iceland waters, my attention was next turned to the earthy matter. A ſmall part of this earthy matter came into view in the boiled and neutralized portions of thefe waters with which I had made the above-defcribed experiments. The neutralized liquors were a little muddy, and depofited flowly a fmall quantity of fediment, which collected itfelf clofely to the bottom of the glafs, and adhered to it flightly. This fediment in the *Rykum* water was deeply tinged with the colouring matter of the litmus; in the *Geyzer* water, it had a brown tinge, and there was a little more of it than in the other. I collected thefe fediments, by firft decanting the greater part of the liquor from them, and afterwards filtrating the reft in a fmall filtre, in which the fediment was wafhed, by paffing diftilled water through it feveral times. Being then dried on the filtrating paper, it contracted greatly, and was divided by fiffures into a great number of fmall parts, as would have happened to fine clay, had the fame quantity of it been dried on paper in a fimilar manner; and when it was feparated from the paper, and further examined, it fhewed the qualities of an argillaceous earth, combined with a fmall quantity of colouring matter. This appeared by the following experiments:

1. I put ſome of it, which I had procured in different experiments, into a platina ſpoon, and made it red hot. While heating, it firſt became black, then underwent a ſlight inflammation, and afterwards became white, without changing its external form, being only a little contracted in its ſize, and diminiſhed in its weight.

2. To another ſmall maſs of it, laid on a plate of glaſs, I added a drop of aquafortis, which neither effervesced with it, nor diſſolved it, but only changed the colour to a paler red.

3. Another ſmall portion, which had been gently calcined, was well mixed with an equal weight of the aërated foſſil alkali, and then expoſed to a ſtrong heat in the platina ſpoon. The alkali was quickly melted, and became cauſtic; but I could not by its means bring the earth into fuſion, or if any was diſſolved by the melted alkali, it was only a very ſmall portion, not perceptible by the appearances.

4. Nor did I ſucceed much better, when I tried to melt or diſſolve it, by means of borax, heated on charcoal, with the blow-pipe. A little maſs of this earth continued undiſſolved in the melted borax, and without

any appearance of effervefcing with it, until I was tired of the experiment.

This earth therefore cannot be any other than the argillaceous. Had it been the filiceous, it would have been melted with the alkali into a tranfparent glafs, which happened eafily with different fpecimens of pure filiceous earth, fubjected to the fame trial; and had it been any of the alkaline earths, the borax would have diffolved it quickly with effervefcence. The quantity of this earthy fediment, from either of thefe neutralized waters, was very fmall. From gr. 10,000 of *Rykum* water, I could only collect a quantity, which, after receiving an obfcure red heat, weighed the twentieth part of a grain; from the fame quantity of the *Geyzer* water, I got about 38 or 39 hundredths of a grain.

In one of my experiments with *Rykum* water, I got this argillaceous earth from it by another procefs. I had a dry extract, obtaining by evaporating gr. 20,000 of this water, and which weighed gr. 16½. Thirty grains of aquafortis were added to it. This aquafortis was made up of equal parts of the ftrongeft nitrous acid and water. The extract was digefted with it fix or eight hours, and then diftilled water being added, the mixture was filtrated in a ſmall filtre, to ſeparate the clear acid liquor from the undiſſolved matter. The filtrated acid liquor was then ſaturated, and a little more than ſaturated with a pure aërated alkaline ſalt, and the ſaturated mixture was heated to a boiling heat. It became muddy, and depoſited a ſmall quantity of ſediment like mucilage, which being collected by filtration, and dried, and heated to an obſcure red heat, weighed juſt one tenth part of a grain, and had the qualities above enumerated, which ſhewed that it was an argillaceous earth. In another experiment, I digeſted an extract of *Geyzer* water with ſtrong vitriolic acid, and thus got from it a ſimilar earth; but the quantity of it was very little greater than that which I had got by ſubſidence from the neutralized and boiled part of the ſame water, in the experiments above deſcribed.

The greater part, however, of the earthy matter had not yet made its appearance; I mean the ſiliceous earth. It ſtill remained in a ſtate of perfect diſſolution in the neutralized and boiled mixtures above deſcribed, ſome part of which had actually paſſed through filtrating paper; and I learned by other trials, that the whole of theſe neutralized mixtures might have been filtrated, without danger of ſeparating any part of the ſiliceous earth from the water, by that operation. This is a conſequence of the ſingular nature of the ſiliceous earth, ſeveral properties of which, hitherto unnoticed, or not exactly deſcribed, I became acquainted with in the courſe of theſe experiments.

We have no experience of the poſſibility of diſſolving this earth in its concrete ſtate by water alone; but if it be diſſolved in water, by means of an alkaline ſalt, although we afterwards completely ſaturate the alkali with an acid, the earth thus ſeparated, provided there is enough of water, will not ſubſide; it will remain diſſolved; the mixture will appear perfectly tranſparent, and will paſs through the filtre without the ſmalleſt difficulty. To gr. 1000 of the *Geyzer* water, I added more than enough of acid to ſaturate the alkali. I then boiled the mixture a little while, until a ſmall part of it only was evaporated, and I ſet it aſide in a quiet place. I know it contains a little more than half a grain of ſiliceous earth; but after ſtanding twelve months, there is not the ſmalleſt appearance of ſeparation, the mixture is ſtill perfectly tranſparent and fluid in every part of it, though it be decidedly acid; and I know, that had it been boiled down to a proper degree, a ſeparation of the ſiliceous earth would have happened in a ſhort time. I learned this by another experiment with *Rykum* water. To gr. 1000 of this water, I added a quantity of acid more than ſufficient for ſaturating the alkali. The water was then boiled till it weighed only 138 grains, and it was ſet up in my cloſet to remain undiſturbed. In about eight days, the tranſparency of it was a little diminiſhed, and afterwards there was a very ſlow ſubſidence of the matter which had produced this effect. It formed gradually, at the bottom, a ſtratum of ſome thickneſs, which was a little leſs tranſparent than the clear water above, and was thereby diſtinguiſhable from it. After a week or two more, I poured off the clear water entirely, without diſturbing the ſediment, which was in fact a tender jelly, adhering to the bottom of the glaſs, and the upper ſurface of which was level and ſmooth. I knew the quantity of ſiliceous earth contained in it; and comparing this with the weight of the water when reduced by boiling to gr. 138, I found the proportion of the earth to that quantity of water to be as 2.68 to 1000; and having weighed the jelly by itſelf, the proportion of ſiliceous earth to the water in it, ſuppoſing that it contained the whole of the earth, was 10.88 to 1000. In another experiment, in which a ſimilar mixture had been leſs boiled, and in which the ſiliceous earth bore to the water the proportion of 2.1 or 2.2 to 1000, I found a soft jelly formed at the end of 40 days. And in another, in which the boiling and evaporation was continued until the jelly began to be formed in the upper part of the liquor while it was boiling, I found the proportion of the siliceous earth to the remaining water to be nearly as 3 75 to 1000.

After this jelly is once formed, I never could bring it again into a state of dissolution by water alone, whatever quantity of this last was added.

It appears therefore by these experiments, that when siliceous earth, united with an alkali, is dissolved in 1000 times, or in more than 500 times its weight of water, it will not separate or subside from that quantity of water, although we separate or disengage the alkali from it. The particles of it, placed at that distance, do not act on one another by their attraction of cohesion or concretion. It is necessary, in order to enable them to attract one another, that they be brought nearer, by diminishing the quantity of the water, until it be less than 500 times the weight of the earth. When this is done, they will enter into a state of cohesion, sooner or later, according as the water has been more or lefs diminifhed. But this ftate of cohefion into which they firft enter is alfo remarkable. The force of it is exceedingly weak, and it takes place while the particles of the earth are ftill at a confiderable diftance from one another. They therefore retain and entangle among them a large quantity of water, amounting to about 100 times their own weight, and perhaps more than 200 times their bulk, with which they form a confiftent jelly, almoft perfectly tranfparent.

It may be afked here, what prevents the particles of this earth from approaching one another more nearly, and entering into a ftate of ftronger cohefion? We may, if we pleafe, imagine that they retain round each of them, by chemical attraction, a quantity of water, which forms a little fphere, or polyhædron, with the particle of earth in its centre. Thus, each particle is prevented from coming within a fmaller diftance of the other particles around it, than the diameter of that fphere; but let the water of thefe fpherules be diminifhed in quantity by evaporation, in confequence of heat, or the attraction of the air, the particles of the earth will immediately enter into a ftate of clofer connection and ftronger cohefion, of which we have examples in the exceffive contraction of the jelly, while it is dried up into crufts, and in thofe circles of thin incruftation which were formed on the fides of the glafs veffels, while the waters were evaporated to drynefs in the firft experiment, the particles of which were fo ftrongly united to one another, and to the furface of the glafs, that they coft me much trouble and time to fcrape them off with a knife.

When fuch a concretion is once formed of this earth, and afterwards receives frequent additions of the fame matter, which infinuating itfelf into the pores of the concretion, is fixed there, and increafes its denfity and folidity, the mafs may in time acquire a furprifing degree of hardnefs. The petrifactions of *Geyzer* are undoubtedly formed in this manner, and fome of them are fo denfe and hard, that they are fcarcely diftinguifhable from agate or calcedony.

After making thefe obfervations on the nature of the filiceous earth, the proper method for extracting it from the above boiled and neutralized portions of thefe waters, was fufficiently obvious. I feparately evaporated them to drynefs with a gentle heat in two china cups, carefully wafhing every drop of them from the glaffes into the cups with diftilled water, and then taking the dry extracts out of the cups, I put them ſeparately into ſmall filtrating papers, and paſſed diſtilled water through them repeatedly, until all the ſaline matter was waſhed away. The papers being then carefully dried, I found the earth in them exceedingly ſpungy, fine, and tender. The quantity of it obtained in this ſtate from the gr. 10,000 of *Rykum* water, was gr. 3.8, which were reduced by the action of an obſcure red heat to gr. 3.73 nearly. From the ſame quantity of the *Geyzer* water, I got gr. 6.8 of the dried earth, which, by a ſimilar heat, were reduced to gr. 5.4, and theſe gr. 5.4, being digeſted with aqua-fortis, and again waſhed with diſtilled water, to extract any argillaceous earth that might remain in them, I obtained only gr. 0.1 of this earth, which, added to the quantity obtained before, makes up gr. 0.48 of the argillaceous earth, from the gr. 10,000 of *Geyzer* water, the remaining gr. 5.3 being pure ſiliceous earth. Some of it was melted into a perfect glaſs in the platina ſpoon, with one half of its weight of aërated foſſil alkali evaporated to dryneſs. The diminution of the weight of the dried earth, from gr. 6.8 to gr. 5.4, which happened when it was gently calcined, proceeded from ſome inflammable matter, which adhered to it at firſt, and gave it a yellowiſh colour. This colour changed firſt to black, and afterwards to a pure white, during the calcination. The inflammable colouring matter might have been received in part from the veſſels in which the water was brought, ſome of which were tainted with the odour of ſpirituous liquors, or the water might have got a part of it from ſubterranean ſtrata of clay, or other earths containing inflammable matter.

Experiments to learn the Quantity of the Neutral Salts.

The only ingredients of theſe waters, the quantity of which had not yet been examined, were the neutral ſalts. The preliminary experiments, and the appearances obſerved in the watery ſolutions of the extracts of theſe waters, gave me reaſon to be ſatisfied, that theſe neutral ſalts were partly common ſalt and partly Glauber's ſalt. To aſcertain the quantities of them, I made the following experiments: I had ſome common ſalt, which had been refined by a ſecond cryſtallization, and was in ſolid dry and large cryſtals. Of this I weighed ten grains exactly, which were diſſolved in about half a pound of diſtilled water. I then added a ſolution of ſilver, which contained a little ſuperfluous acid. The silver was precipitated in the form of luna cornea, or argentum muriatum; and I took care to add rather more than the quantity which the ten grains of common salt could precipitate. The luna cornea, after complete subsidence, and decantation of the saline water from it, was carefully collected on a small filtre, and well washed with distilled water, and thoroughly dried and weighed. I thus learned, that 100 parts of common salt are sufficient to give 235 of luna cornea. This enabled me to learn, by similar experiments, how much common salt is contained in the Iceland waters, and I found that the quantity contained in 10,000 grains of *Rykum* water was gr. 2.90, and in the same quantity of the *Geyzer* water, I found there was gr. 2.46 of common salt. Some of my readers may, perhaps, be inclined to suspect, that the Glauber's salt contained in the Iceland waters might, by means of its vitriolic acid, contribute to the precipitation of a part of the silver; but experiments have satisfied me, that a small quantity of vitriolic acid, or of any vitriolic salt, dissolved in a large quantity of water, does not precipitate silver;* and to prevent any part of the silver being precipitated by the

* See the Appendix to this paper.

alkali of the water, I added of purified aquafortis, more than enough to ſaturate the alkali, before I added the ſolution of ſilver.

Another ſet of experiments, on the ſame plan, but made with Glauber's ſalt and the ſolution of barytes, in place of common ſalt and ſolution of ſilver, enabled me to aſcertain with equal exactneſs the quantity of Glauber's ſalt contained in theſe waters. I firſt learned, that if pure Glauber's ſalt be perfectly exſiccated, by evaporating the water that is in its cryſtals, ten parts of this exſiccated ſalt are ſufficient to precipitate as much barytes, from its ſolution in muriatic acid, as will form 17 of barytes vitriolica. This fact being aſcertained, I added ſome of the diſſolved barytes to ſeparate portions of the Iceland waters, ſo long as any muddineſs and precipitation was produced; and I carefully collected, waſhed, dried, and weighed the precipitates.* I thus learned, that the water of Rykum contains in gr. 10,000 of it, as much Glauber's ſalt as

* The method by which theſe ſmall quantities of ſediments and precipitates were collected and weighed, is explained in the Appendix to this paper.

would give gr. 1.28 of exſiccated Glauber's ſalt, and the water of Geyzer as much as would give gr. 1.46.

In making theſe laſt experiments alſo, I added ſome purified nitric acid to the Iceland waters, to prevent any precipitation of the barytes which might have been occaſioned by the alkali of the water.

In reviewing the experiments I have now deſcribed, if we neglect the ſmall quantity of ſulphureous gas, the contents of theſe waters will appear as follows:

In gr. 10,000 of *Rykum* water there are,

Of cauſtic foſſil alkali	- - -	gr. 0.51
Argillaceous earth	- - - -	0.05
Siliceous earth	- - - -	3.73
Common ſalt	- - - -	2.90
Glauber's ſalt when exſiccated	-	1.28
Total	-	8.47

In gr. 10,000 of *Geyzer* water,

Cauſtic foſſil alkali - - -	gr. 0.95
Argillaceous earth - - - -	0.48
Siliceous earth - - - -	5.40
Common ſalt - - - -	2.46
Glauber's ſalt exſiccated - - -	1.46
Total -	10.75

Theſe quantities of the ingredients, as determined by the above experiments, exceed the quantities of dry extract which I obtained by evaporation. Gr. 10,000 of the *Rykum* water gave, by evaporation, gr. 8.25 of dry extract, and the ſame quantity of *Geyzer* gave gr. 10 only. This difference, however, can eaſily be accounted for. It is well known, that common ſalt, and other ſalts, ſuffer ſome loſs by evaporation, when watery ſolutions of them are evaporated to dryneſs; and the odour which was perceived in the end of the evaporation of theſe waters, made me ſuſpect that a little of the ſalt might have been loſt. There was therefore no reafon to expect, that the refult of the analytical experiments would tally exactly with the extract by evaporation. I was rather furprifed and pleafed to find that they came fo near, and I am perfectly fatisfied that this analyfis is as complete and exact as it was in my power to make it, with that quantity of water which I got for this purpofe.

The proportions of the above enumerated ingredients to the water in which they are contained, fhew the quantities of them contained in an Englifh gallon of 231 cubical inches, or 58,484 grains, which are as follows:

In an Englifh gallon of *Rykum* water.

Cauftic foffil alkali - - -	gr. 3.
Argillaceous earth - - - -	0.29
Siliceous earth - - - -	21.83
Common falt - - - -	16.96
Glauber's falt exficcated - - -	7.53

In an English gallon of *Geyzer* water,

Caustic fossil alkali	- - -	gr. 5.56
Argillaceous earth	- - -	2.80
Siliceous earth	- - - -	31.38
Common salt	- - - -	14.42
Glauber's salt exsiccated	- -	8.57

Having now stated the several ingredients of these hot springs, and their proportions, the principal questions which remain to be considered, are, how is the siliceous earth dissolved in them, or combined with the water? Has hot water alone a power to dissolve this earth, or was it dissolved by the medium of the alkali only? And how came the salts which we find in these waters, and the sulphureous gas to be combined with them? As all attempts to answer these questions must be conjectural, different opinions will be formed concerning them; and I may offer what I have imagined, without its being thought necessary to make an apology. Professor BERGMAN considered the siliceous earth in these waters as dissolved by the power of the hot water alone; and supposed, that water, aided by excessive heat, became a solvent of this ſpecies of earth. He formed this opinion, however, under diſadvantageous circumſtances, and from a partial view of the ſubject. He only knew that this earth is actually diſſolved in theſe waters, and depoſited by them; and that they ſpring out of the ground of a full boiling heat, with appearances of their having been hotter below. He did not know what other ingredients they contained along with the earth. As we now know they contain an alkali, which is a powerful medium for combining this earth with water, I do not think that the power of water alone to diſſolve it can be admitted, until it is proved by direct experiments; and I am not of opinion that theſe will ſucceed. I am perſuaded, that both the ſiliceous and the argillaceous earth have been diſſolved by the medium of the alkali, but, at the ſame time, that the violent and long-continued heat contributed greatly, and was even neceſſary to this diſſolution. The proportion of the cauſtic alkali to the earthy matter in one of theſe waters, is as $13\frac{1}{2}$ to 100; in the other it is 16 to 100. When we form artificial compounds of ſiliceous earth and alkali in theſe proportions, we find that cold water has no power to diſſolve them, though boiling water, by length of time would certainly act on them. Even cold water, or the humidity of the earth, is well known to penetrate the hardeſt glaſs that is expoſed to it for years or for ages; and I have had the experience of the power of hot water to act on glaſs, when I have diſtilled water in the ſame glaſs retorts a great number of times, or evaporated water often in other glaſs veſſels. Their internal ſurface was evidently affected by the continued action of the hot water. Its firſt effect is to ſoften thin laminæ at the ſurface of the glaſs, and to make them ſeparate from that ſurface, in conſequence probably of their being ſwelled and extended by the water penetrating into them; and by a longer action of the water, there is no doubt that they, or ſome part of them, are completely diſſolved.

Thoſe who may have objections againſt admitting, that a boiling heat, and great length of time, are ſufficient aids to enable water to diſſolve a compound of the ſiliceous earth with ſuch a ſmall proportion of alkali, may imagine this earth to have been at firſt combined with a larger proportion of alkali, than that we now find combined with it, and that after it was diſſolved in the water, a part of this alkali was neutralized by acid vapours, or acid ſubſtances, which the water found in its way towards the ſurface.

On the whole, however, the ſuppoſition which appears to me the moſt probable is, that common ſalt and Glauber's ſalt, conveyed by ſea-water, or contained in foſſils formed from ſea-plants, have been applied, under the influence of a violent heat, to ſome of the numerous earthy and ſtony ſtrata which contain mixtures of ſiliceous and argillaceous earth; that thoſe ſalts have been in part decompounded, by the attraction of theſe earths for the alkali of the neutral ſalt, part of the acid has been diſſipated, or changed into ſulphur, and ſulphureous gas, by the action on it at the ſame time of inflammable matter, which we know to be preſent in many of the ſtrata; and that the compound of alkali and earthy matter has afterwards been long expoſed, and continues expoſed, to the action of the hot water. By ſuch a ſuppoſition, we can imagine how the ſeveral ingredients of theſe hot ſprings became diſſolved in them; and this ſuppoſition appears the more probable, when we attend to the accurate obſervations of Mr. STANLEY, on the nature of the country, and ſtate of the ſoil, in which theſe two hot ſprings are found. The rocks and mountains, which are at a ſmall diſtance, or in the immediate vicinity of each of them, are formed chiefly of different kinds of lava. The lower country and ſoil at the foot of theſe, and in which the ſprings riſe, is compoſed of fragments of theſe lavas; but in digging into this ſoil or rubbiſh, to a ſmall depth only, theſe fragments are every where found reſolving, or reſolved, into a matter, like clay. At a certain depth, the fragments of ſome ſpecies of lava remain entire and hard, while the reſt are changed. At a greater depth, even theſe more durable kinds are found to have undergone the ſame change with the reſt. As this change is produced by the conſtant action of the hot water, it probably depends on a gradual diſſolution and extraction from theſe lavas of ſome of their ingredients, which are diſſolvable in water; and thoſe which we have actually found in the water may have been ſome of theſe. But I offer all this as a conjecture only, which every perſon who does not like it, is at liberty to reject.

I ſhall venture further to offer another conjecture, which ſome particulars I learned by Mr. STANLEY's voyage to Iceland have ſuggeſted to my mind. It is concerning the origin of the pure ſulphur, which is found at the ſurface of the earth, in the neighbourhood of many volcanos in different parts of the world. In Iceland, there are places in which ſulphur is thus found in very great quantity, covering the ſurface of the ground, and that of the ſtones and rocks, in form of a thick cruſt, and conſtituting what are called ſulphur banks. This was ſeen in Iceland in particular ſpots, in which there were very ſtrong ſulphureous hot ſprings, which emitted ſuch a quantity of ſulphureous or hepatic gas, that the air all around was infected with it to the higheſt degree, and the water itſelf was muddy and black, and conſtantly boiling. Now, as we know that vital air has the power to decompound this gas, and to make it depoſit the ſulphur which it contains, I am of opinion, that the ſulphur which appeared in ſuch quantity in the vicinity of theſe ſprings, had been depoſited and accumulated in this manner from the hepatic gas, which theſe ſtrongly-ſulphureous ſprings have emitted during a great length of time.

APPENDIX.

IN order to ſhew, that ſuch a ſmall proportion of a vitriolic ſalt as is contained in the Iceland waters, has not the power to precipitate ſilver, I diſſolved gr. 0.3 of exſiccated Glauber's ſalt, in gr. 2000 of diſtilled water, which thus contained a proportion of Glauber's ſalt rather greater than that contained in the Iceland waters. I then added five drops of purified aquafortis, and five drops of the ſolution of ſilver. The mixture remained tranſparent ſeveral days. I afterwards added gr. 0.7 more of the exſiccated Glauber's ſalt, without diminiſhing in the leaſt the tranſparency of the mixture. After a few days more, I added gr. 9 of the exſiccated Glauber's ſalt. This produced a diminution of tranſparency, and the ſediment ſubſided in a few days more. This ſediment being carefully collected and dried, weighed gr. 0.3; but the clear liquor which had been filtrated from it, ſtill retained the greater part of the ſilver. I therefore added to it ſome pure common ſalt, which precipitated all the reſt of the ſilver, and this laſt precipitate, being alſo collected and dried, weighed juſt one grain.

When I examined theſe two precipitates by means of the blowpipe, their qualities appeared to me ſo much the ſame, that I ſuſpect the firſt was produced by a ſmall quantity of common ſalt, contained imperceptibly in the Glauber's ſalt. If there were 12 or 13 parts of common ſalt in 1000 of the Glauber's ſalt, they were enough to produce the above quantity of the firſt precipitate; and as Glauber's ſalt is prepared from common ſalt, we can eaſily underſtand how a ſmall quantity of the common ſalt may remain in it.

For the ſake of thoſe who may have occaſion to undertake ſuch chemical inquiries as that deſcribed in the above paper, I ſhall here mention the method by which I collected and weighed the ſmall quantities of ſediments or precipitates, which I obtained in ſome of theſe experiments. In moſt caſes, the turbid liquor was left at reſt in a cylindrical glaſs, until the ſediment was ſo well collected at the bottom, that the greateſt part of the liquor was quite clear, and then this clear part was carefully decanted; the reſt, which could not be decanted without diſturbing the ſediment, was ſhaken, and poured gradually into a ſmall filtre, that the ſediment might be collected upon the filtre, and afterwards waſhed on it, by paſſing diſtilled water through it repeatedly. And this part of the proceſs was much facilitated by the preparation of the filtre, and ſome other little manœuvres. When, for example, I uſed for my filtre a piece of paper about four inches in diameter, I began by folding it, and giving it the proper form; then I ſpread it open again, and warming it, I applied melted tallow or bees wax to the margin of it all round, until it was ſoaked therewith to the breadth of a full inch from the margin inwards, the middle part of it being carefully preſerved clean. As ſoon as this was done, and while it was yet a little warm, it was folded again into the proper form of a filtre, and retained in that ſtate until it was cold. On a filtre prepared in this manner, it is much more eaſy to collect a ſediment together, and to waſh it clean, than on an ordinary filtre. In the firſt place, no part of the ſediment adheres to or is depoſited on that part of the paper which was ſoaked with tallow. The whole is collected on the clean part of the paper, and after it is collected there, I condenſe it into the centre as much as poſſible, by dropping the diſtilled water on the margin of that clean part all round, or a little above that margin, by which practice the ſcattered particles of the ſediment are waſhed down into the bottom. Sometimes I apply what may be called a capillary jet of the diſtilled water, directed with force to thoſe parts of the ſcattered ſediment which are more difficultly moved. Having thus condenſed the ſediment as much as poſſible, the filtre is left in a cool place to dry. When it is perfectly, or nearly dry, I ſpread it flat on a table, and cut away all that part which was ſoaked with tallow, and alſo thoſe parts of the clean paper to which the ſediment does not adhere. The reſt, with the ſediment on it, is then well dried before a fire, and weighed, and the weight of it marked down; and, laſtly, in order to know how much of this weight is made up by the paper, I take care, before I prepare the filtre, to chuſe another piece of the filtrating paper, equal in thickneſs to the one of which the filtre is made. This equality of thickneſs is judged of by holding the two pieces between the eye and the light; or, for greater ſecurity, bits of the two pieces may be cut off, exactly ſimilar, and equal in form and ſize, and their weight compared, and allowance may afterwards be made for their difference of weight, if there be a difference. After weighing the bit of paper with the ſediment on it, a proper bit of the reſerved paper is laid flat on a ſmooth table or plate of glaſs, and the paper on which the ſediment had been collected is laid over it, with the clean ſide undermoſt; then a bit of card, ſomewhat leſs, but nearly of the ſame form, is preſſed down on both the papers, and, with a pair of ſharp-pointed ſciſſars, or a pen-knife, the undermoſt paper is cut exactly to the ſame ſhape and ſize as the uppermoſt, and is afterwards weighed. The weight of it being deducted from that of the former, we thus learn the weight of the ſediment, with a greater degree of exactneſs, and with leſs trouble, than by any other method which I have been able to contrive. To complete this article, I beg leave further to add, that the moſt ready and convenient way to ſoak the margin of the filtrating paper with tallow or wax, is to hold it above a lighted candle, at a proper diſtance for warming it a little, and then melting the end of another candle, apply it immediately to the warmed paper, and repeat this, until the paper is prepared as above directed. The prominent part of the wick of the candle, which is thus melted, becomes a ſort of pencil, which holds the melted tallow or wax, and facilitates the application of it, and the wick of a tallow candle, on account of its being thicker, is fitter for this purpoſe than the wick of a wax one.

The laſt remark on theſe experiments I ſhall now make is, that in the trials with the ſolution of barytes, the barytes vitriolica was formed in particles ſo very minute, that they did not all remain at firſt upon the filtre. Some of them paſſed through it, and made the filtrated liquor a little muddy; but by making this muddy liquor paſs through the filtre a ſecond time, it was made quite clear, the whole ſediment being thus collected on the filtre.