EXPERIMENTS

ON

HEPATIC AIR.

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Read at the ROYAL SOCIETY, December 22, 1785.

LONDON:
Printed by J. NICHOLS.
MDCCLXXXVI.

E X P E R I M E N T S, &c.

HEPATIC Air is that ſpecies of permanently elaſtic fluid which is obtained from combinations of ſulphur with various ſubſtances, as alkalies, earths, metals, &c. It poſſeſſes many peculiar and diſtinct properties; among which the moſt obvious are, a diſagreeable characteriſtic ſmell emitted by no other known ſubſtance; inflammability, when mixed with a certain proportion of reſpirable or nitrous air; miſcibility with water, to a certain degree; and a power of diſcolouring metals, particularly ſilver and mercury. Theſe properties were firſt diſcovered by that incomparable analyſt M. SCHEELE.

This air acts an important part in the œconomy of nature. It is frequently found in coal-pits; and the truly excellent and ever to be regretted M. BERGMAN has ſhewn it to be the principle on which the ſulphureous properties of many mineral waters depend, and thus happily terminated the numerous diſputes which the obſcurity of that ſubject had occaſioned. There is alſo great reaſon to think, that it is the peculiar product of the putrefaction of many, if not all, animal ſubſtances. Rotten eggs and corrupt water are known to emit the ſmell peculiar to this ſpecies of air, and alſo to diſcolour metallic ſubſtances in the ſame manner. M. VIELLARD has lately diſcovered ſeveral other indications of this air in putrefied blood.

Yet, deſerving as this ſubſtance appears to be of a thorough inveſtigation, it has as yet been very little attended to. The experiments of M. BERGMAN have not been ſufficiently numerous, and thereby led him into ſome miſtakes. Dr. PRIESTLEY has intirely overlooked it. The reſearches of the ingenious M. SENNEBIER, of Geneva, have indeed been very extenſive; but as, for particular reaſons, he operated on this air over water (by which it is in great meaſure abſorbed) inſtead of quickſilver, his concluſions appear in many reſpects objectionable, as will be ſeen in the ſequel. The experiments I have now the honour of laying before the Society were all made over quickſilver, and ſeveral times repeated.

SECTION I.

Of the Subſtances that yield Hepatic Air, and the means of obtaining it.

It is well known, that *ſaline* liver of ſulphur is formed, in the dry way, of a mixture of equal parts of vegetable or mineral alkali and flowers of ſulphur, melted together by a moderate heat, in a covered crucible. I examined the circumſtances of its formation, and obſerved, that when this mixture was ſlightly heated, it emitted a bluiſh ſmoke, which gradually grew whiter as the heat was increaſed, and at laſt, when the mixture was perfectly melted, and the bottom of the crucible ſlightly red, became perfectly white and inflammable. To examine the nature of this ſmoke, I made a pretty pure fixed alkali, by deflagrating equal parts of cream of tartar and

nitre

nitre in a red-hot crucible in the usual way; and mixing this salt perfectly dry with flowers of sulphur in much smaller quantity, as I believe (for I did not weigh the salt, least it should, during the weighing, attract moisture) I gradually heated the mixture in a small coated glass retort, and received the air proceeding from it over quicksilver.

The first portion of air that passed with a very gentle heat was that of the retort itself, slightly phlogisticated. It amounted to 1,5 cubic inches, and with Dr. PRIESTLEY's nitrous test (that is, an equal measure of nitrous air) its goodness was 1,29. It contained no fixed air.

The second portion of air obtained by increasing the heat amounted to about 18 cubic inches. It was of a reddish colour, and seemed a mixture of nitrous and common air. It slightly acted on the mercury.

The third portion consisted of 20 cubic inches, and appeared to be of the same kind as the last, but mixed with a little fixed air.

This was succeeded by 64 cubic inches of almost perfectly pure fixed air; and the bottom of the retort being now red, some sulphur sublimed in its neck. When all was cold, liver of sulphur was found in the bulb of the retort.

Hence we see, that the blue smoke consists chiefly of fixed air, and the white or yellow smoke of sulphur sublimed; and that no hepatic air is thus formed; nor vitriolic air, unless the retort be so large as to contain a sufficiency of common air to admit the combustion of part of the sulphur.

2dly, That the aërial or any other acid, combined with the alkali, must be expelled before the alkali will combine with the sulphur. Liver of sulphur exercises a strong solving power on the earth of crucibles, and readily pierces through them.

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The above experiment feems to fhew that liver of fulphur will not yield hepatic air without the addition of an acid; and I believe this to be true when the experiment is made in the dry way, and nearly fo in the moift way; for having added 200 grains of fulphur to a concentrated folution of ftrong cauftic vegetable alkali, by a ftrong and long-continued heat I obtained only 1 cubic inch of hepatic air; yet it is well known, that a ftrong folution of liver of fulphur conftantly emits an hepatic fmell, even in the temperature of the atmofphere; and the fubftance fo emitted contains fo much hepatic air as to difcolour filver and lead, and even their folutions; which fhews, that an incomparably fmall quantity of this air is capable of producing this effect. To difcover whether this extrication of hepatic air might be caufed by the depofition of fixed air from the atmofphere, I threw fome pulverifed calcareous hepar into aërated water, and by the application of heat endeavoured to obtain hepatic air, but in vain: and, indeed, the very circumftance that the hepatic fmell, and its effects, are always ftrongeft the firft inftant that a bottle of the hepatic folution is opened, feems to indicate that fixed air is no way concerned in its production.

The beft liver of fulphur is made of equal parts of falt of tartar and fulphur; but as about one-fifth of the falt of tartar confifts of air which efcapes during the operation, it feems, that the proportion of fulphur predominates in the refulting compound; yet as fome of the fulphur alfo fublimes and burns, it is not eafy to fix the exact proportion. 100 grains of the beft, that is, the reddeft liver of fulphur, afford, with dilute marine acid, about 40 cubic inches of hepatic air, in the temperature of 60°: a quantity equivalent to about 13 grains of fulphur, as will be feen in the fequel.

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The *marine* acid is the beſt adapted to the production of hepatic air. If the concentrated *nitrous* acid be uſed, it will afford nitrous air; but having diluted ſome nitrous acid, whoſe ſpecific gravity was 1,347, with 20 times its bulk of water, I obtained, with the aſſiſtance of heat, as pure hepatic air as with any other acid.

The concentrated *vitriolic* acid, poured on liver of ſulphur, affords but little hepatic air without the aſſiſtance of heat, though it inſtantly decompoſes the liver of ſulphur; and it is partly for this reaſon that the proportion of air is ſo ſmall; for it is during the *gradual* decompoſition of ſulphureous compounds that hepatic air is produced.

Diſtilled *vinegar* extricates this air in the temperature of the atmoſphere; but it is not pure, its peculiar ſmell being mixed with that of vinegar.

The *acid of ſugar* alſo produced ſome quantity of this air in the temperature of 59°.

20 grains of *ſedative ſalt*, or acid (as it ſhould more properly be called) diſſolved in an ounce of water, being poured on liver of ſulphur, afforded hepatic air only when in a boiling heat, or nearly ſo.

Neither the *aërial* nor *arſenical* acids produce any.

Liver of ſulphur is ſoluble not only in water but in ſpirit of wine, and in cauſtic volatile alkalies; and the colour of both ſolutions is red. Sulphur is precipitable from the former by the addition of water or of an acid, but from the latter only by an acid.

Having made ſome liver of ſulphur, in which the proportion of ſulphur much exceeded that of the alkali, I poured on part of it ſome oil of vitriol, whoſe ſpecific gravity was 1,863: by this means I obtained hepatic air, ſo loaded

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with ſulphur, that it depoſited ſome in the tube through which it was tranſmitted, and on the upper part of the glaſs receiver. This air I transferred to another receiver; but though it was then perfectly clear and tranſparent, and amounted to 6 cubic inches, yet the next morning the inſide of the glaſs was thickly lined with ſulphur, and the air reduced to 1 cubic inch, which was pure vitriolic air. Hence it appears, firſt, that a ſpecies of elaſtic fluid may exiſt in a ſtate intermediate between the aërial and the vaporous, which is not permanently elaſtic like air, nor immediately condenſed by cold like vapour, but which, by the gradual loſs of its ſpecific heat, may be reduced to a concrete form. 2dly, That ſo large a quantity of ſulphur may be combined with vitriolic air, as to enable it to exhibit the properties of hepatic air, for ſome time at leaſt. A mixture of three parts pulveriſed quick-lime and one part ſulphur, heated to whiteneſs in a covered crucible for one hour, became of a ſtony hardneſs, and being treated with marine acid, afforded hepatic air. If a piece of this ſtone be heated in pure water it becomes bluiſh, and hence the origin of the blue marles generally found near hot ſulphurated waters.

A calcareous hepar may alſo be formed in the moiſt way, as is well known.

Magneſia free from fixed air, heated in the ſame manner with ſulphur, afforded no hepatic air when an acid was poured on it.

I alſo procured this air from a mixture of three parts *filings of iron* and one of ſulphur, melted together, and treated with marine acid. It is remarkable, that this ſulphurated iron, diſſolved in marine acid, affords ſcarce any inflammable, but moſtly hepatic air.

A mixture

A mixture of equal parts filings of iron and fulphur, made into a pafte with water, after heating and becoming black, afforded hepatic air when an acid was poured on it; but this hepatic air was mixed with inflammable air, which probably proceeded from the uncombined iron. After a few days, this pafte loft its power of producing hepatic air.

M. BERGMAN has remarked, that combinations of fulphur with fome other metals yield hepatic air.

I attempted extracting air from a mixture of oil of olives with cauftic vegetable alkali. It immediately whitened, and on applying heat effervefced fo violently as to pafs over into the receiver: nor had I better fuccefs on adding an acid, as I might well forefee. The event was different when on a few grains of fulphur I poured fome of the oil, and heated them in a phial with a bent tube; for as foon as the fulphur melted, the oil began to act on it, grew red, and emitted hepatic air, fimilar to that produced by other proceffes.

I alfo obtained this air in great plenty from a mixture of equal parts fulphur and *pulverifed charcoal*, out of which its adventitious air had been as much as poffible expelled by keeping it a long time heated to rednefs, in a crucible on which a cover was luted, with a fmall perforation to permit the air to efcape. This air was inflammable, as appeared by holding a lighted candle before it during its emiffion; yet it is hardly poffible to free charcoal wholly from foreign air, for it foon re-attracts it when expofed to the atmofphere.

This laft mixture, when diftilled, affording a large quantity of hepatic and fome inflammable air, without the addition of any acid, I imagined, that as the retort was only half full, it might contain a fufficiency of atmofpheric air to admit the combuftion of part of the fulphur, and thus furnifh the necef-

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ſary acid; but when I filled the retort with air phlogiſticated by the nitrous teſt unto 1,8, and in this air diſtilled the above mixture, the reſult was exactly the ſame as when the retort was filled with atmoſpheric air.

Six grains of *pyrophorus*, made of alum and ſugar, effervefced with marine acid, and afforded 2,5 cubic inches of hepatic air. This pyrophorus had been made ſix years before, and was kept in a tube hermetically ſealed, and for many ſummers expoſed to the ſtrongeſt light of the ſun. It was ſo combuſtible, that ſome grains of it took fire while it was introduced into the phial out of which the hepatic air was expelled.

A mixture of two parts *white ſugar* (previouſly melted in order to free it from water) with one part ſulphur, when heated to about 600 or 700 degrees, gave out hepatic air very rapidly. This air had a ſmell much reſembling that of onions. It contained no fixed air, nor ſaccharine, or other acid; but ſugar and ſulphur, melted together, gave out no hepatic air when treated with acids. Water, ſpirit of wine, and marine acid, decompoſe this mixture, diſſolving the ſugar, and leaving the ſulphur.

A mixture of ſulphur and *plumbago* afforded me no hepatic air.

I then tried whether ſulphur could combine with elaſtic fluids, and the reſults were as follows.

12 grains of ſulphur, heated in a retort, filled with metallic *inflammable* air, afforded no hepatic air; though when the retort was cold, and for ſome time expoſed to the air, it ſmelled of hepatic air. It is true, the heat I applied might be inſufficient; for the inflammable air paſſing over with a ſlight heat, the mercury aſcended ſo high into the neck of the receiver, that, fearing the rupture of the retort, I was obliged to interrupt

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the operation. I had no better fuccefs when the fulphur, previous to its diftillation, had been moiftened with marine acid.

Again, I expofed 18 grains of liver of fulphur to fix cubic inches of *fixed air*, thermometer 70°, for four days. The liver of fulphur was fomewhat whitened on the furface; the air had not an hepatic fmell, but rather that of bread. It was not converted into phlogifticated air, but feemed to have taken up fome fulphur, which lime-water feparated. It was not in the leaft diminifhed, and therefore feems to have received an addition of hepatic air, or rather of fulphur.

I alfo expofed a quantity of *fulphureo-martial pafte* to fixed air, for five days. The fixed air was not diminifhed, but received a flight acceffion of inflammable air. The pafte itfelf, taken out of this air, and expofed to the atmofphere, heated ftrongly.

Laftly, I expofed 3 grains of fulphur to about 12 cubic inches of *marine air*. It was not diminifhed in four days; nor was the fulphur fenfibly. On adding one cubic inch of water to this air, it was abforbed all to one inch, and this had an hepatic fmell; fo that neither was the fulphur decompofed, nor the marine acid converted into inflammable air. The water had alfo an hepatic fmell, and evidently contained fulphur; for it precipitated the folution of filver *brown* mixed with white, and the nitrous folution of copper *reddifh brown*, and when vegetable fixed alkali was dropped into it, let fall a white precipitate, namely, the fulphur.

SECTION II.

Of the general Characters of Hepatic Air.

I found the abſolute weight of this air by weighing it in a glaſs bottle, previouſly exhauſted by Mr. HURTER's new improved air-pump, whoſe effect is ſo conſiderable as to leave in general only $\frac{1}{800}$ and frequently but $\frac{1}{1000}$ part of unexhauſted air. This bottle contained 116 cubic inches nearly; and this quantity of hepatic air weighed 38,58 grains, the thermometer being then 67°,5, the barometer 29,94, and M. SAUSSURE's hygrometer 84°, the weight of 116 cubic inches of atmoſpheric air being at the ſame time 34,87 grains; hence a cubic foot of hepatic air weighs, in theſe circumſtances, 574,7089 grains, and 100 cubic inches of it weigh about 33 grains; and its weight, relatively to that of common air, is as 10000 to 9038 *. This hepatic air was extracted from artificial pyrites by marine acid.

The inflammability of this air has been already mentioned. It never detonates with common air; nor can it be fired, in a narrow-mouthed veſſel, unleſs mixed with a conſiderable proportion of this air. Mr. SCHEELE found it to inflame when mixed with two-thirds of this air. According to M. SENNEBIER

* Hence the weight which I have aſſigned to common air in my firſt paper, after M. FONTANA, is evidently erroneous; and, indeed, by that determination common air would not be even 700 times lighter than water, in the temperature of 55°, and the barometer 29,5, which contradicts all barometrical and aeroſtatic experiments: and I cannot omit mentioning the very near agreement of the weight of common air here found with that reſulting from the calculation of Sir GEORGE SHUCKBURGH, it is ſo great as to differ only by 2 grains in a cubic foot.

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it cannot be fired by the electric ſpark, even when mixed with any proportion of reſpirable air. I found a mixture of one part of hepatic air and 1,5 of common air to burn blue, without flaſhing or detonating. During the combuſtion ſulphur is conſtantly depoſited, and a ſmell of vitriolic air is perceived. A mixture of half hepatic and half nitrous air burns with a bluiſh, green, and yellow lambent flame; ſulphur is alſo depoſited, and in proportion as this is formed, a candle dipped in this air burns more weakly, and is at laſt extinguiſhed. A mixture of two parts nitrous and one of hepatic air partially burns, with a green flame, and a candle is extinguiſhed in the reſiduum, which then reddens on coming in contact with atmoſpheric air. I made a mixture of one part nitrous and one part hepatic air, and to this admitted one part alſo of common air; the inſtant the common air was introduced, ſulphur was precipitated, and the three meaſures occupied the ſpace of 2,4 meaſures; this burned on the ſurface with a wide greeniſh flame, but the candle was extinguiſhed when ſunk deeper.

A mixture of four parts common air and one part hepatic burned blue and rapidly; but a mixture of one part dephlogiſticated and one part hepatic, which had ſtood eight days, went off with a report as loud as that of a piſtol, and ſo inſtantaneouſly that the colour of the flame could ſcarce be diſcerned.

Every ſpecies of hepatic air turns the *tincture of litmus* red. M. Bergman ſeems to think, that, if this air were waſhed, it would not produce this effect; yet, when I had paſſed two meaſures of it through one of water, or when I had boiled it out of water impregnated with it, or even when I paſſed that which had already reddened litmus, into a freſh quantity of litmus, it ſtill preſerved the ſame property, which I therefore conſider as eſſential to it.

With refpect to *folubility in water*, hepatic airs extracted from different materials differ confiderably. In the temperature of 66°, water diffolves, by flight agitation, two-thirds of its bulk of alkaline or calcareous hepatic air, extracted by marine acid; three-fourths of its bulk of martial hepatic air, extracted by the fame acid; eight-tenths of that extracted by means of the concentrated vitriolic acid, or the dilute nitrous or faccharine acids in the temperature of 60°; feven tenths of fedative hepatic air; nine-tenths of acetous hepatic air, and of that afforded by oil of olives; and its own bulk of that produced from a mixture of fugar and fulphur. In general, I imagined that which required moft heat for its production to be moft foluble: though in fome inftances, particularly that of acetous hepatic air, that circumftance does not take place.

But the moft remarkable phænomenon attending the union of hepatic air with water is, that it is not permanent. Even water, out of which its own air had been boiled, in a few days after faturation with hepatic air grows turbid, and in a few weeks depofits moft of it in the form of fulphur, though the bottle be ever fo well ftopped, or ftand inverted in water or mercury. Yet water no way decompofes hepatic air by abforbing it; for the part left unabforbed by a quantity of water is abforbable by a larger quantity of water, and burns like other hepatic air. Heat does not expel this air from water, until carried to the degree of ebullition.

No fpecies of hepatic air, which I have examined, precipitates lime from *lime-water*, except the carbonaceous; and even this fcarcely produces a fenfible precipitation, unlefs a large quantity of it be made to pafs through a fmall quantity of lime-water.

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The ſolution of *acetous baro-ſelenite*, (that is, ponderous earth diſſolved in diſtilled vinegar) is rendered brown and turbid by this air, but that of *marine baro-ſelenite* is not altered; nor are the ſolutions of other earths. Metallic ſolutions are affected by it in the ſame manner as by hepatic water, of which I ſhall treat in the fifth ſection.

But of all the teſts of hepatic air, the moſt delicate and ſenſible is the *ſolution of ſilver in the nitrous acid.* This, according as the nitrous acid is more or leſs ſaturated with ſilver, becomes black, brown, or reddiſh brown, by contact with hepatic air however mixed with any other air or ſubſtance. When the acid is not ſaturated, or is in large proportion, the brown or black precipitate, which is nothing but ſulphurated ſilver, is re-diſſolved.

It ſhould alſo be remarked, that all hepatic air is ſomewhat diminiſhed by long ſtanding on mercury, whoſe ſurface is then blackened by it. This is particularly the caſe of carbonaceous hepatic air, which certainly carries over and volatilizes part of the charcoal from which it is extracted, eſpecially that portion of air which comes over in the greateſt heat; this it depoſits on the addition of water.

SECTION III.

Of the Action of Hepatic and other Aerial Fluids on each other.

Six cubic inches of common and ſix of hepatic air being mixed with each other, and ſtanding over mercury for eight days, were not in the leaſt altered in their dimenſions or otherwiſe; though a diminution of a $\frac{1}{120}$th part might be perceived. The mercury was ſlightly blackened. The event was the ſame when

when three meaſures of common and one of hepatic air were uſed. Water took up the hepatic air. No fixed air was found.

Five meaſures of hepatic, and five of *dephlogiſticated air* ſo pure that one meaſure of it and two of nitrous air made only three-tenths of a meaſure, remained unaltered for eight days, the mercury only being blackened. No fixed air was produced, nor the dephlogiſticated air phlogiſticated. When the mixture was fired, it went off all at once with a loud report.

Four meaſures of phlogiſticated and four of hepatic air remained undiminiſhed for ſixteen days: water then took up the hepatic, and left the phlogiſticated air.

Four meaſures of *inflammable* and four of hepatic air remained unaltered for ſix days.

Two meaſures of hepatic and two of *marine acid* air ſuffered no diminution in three days. The mercury on which they ſtood was not blackened. Water took up both, and precipitated the ſolution of ſilver black.

The ſame quantity of hepatic and *fixed air* remained four days without any ſenſible diminution. Four meaſures of water abſorbed the greater part of both, had an hepatic ſmell, precipitated lime from its ſolution, and alſo ſilver, as uſual. The reſiduum extinguiſhed a candle.

But *vitriolic*, *nitrous*, and *alkaline* airs had very remarkable effects on hepatic air.

Two meaſures of hepatic being introduced to two of *vitriolic air*, a whitiſh yellow depoſition immediately covered both the top and ſides of the jar, and both airs were, without any agitation, reduced to little more than one meaſure; but the opacity of the incruſted glaſs prevented my then aſcertaining the diminution with preciſion. Hence I repeated this experiment more at large, in the following manner. To five meaſures of vitriolic air (each meaſure containing a cubic inch) I added one

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of hepatic air. In lefs than a minute, without any agitation, the fides of the glafs were covered with a whitifh fcum, which feemed moift, and a diminution took place of more than one meafure. In four hours after, I introduced a fecond meafure of hepatic air, which was followed by a fimilar diminution and depofit. The next day I added three more meafures of this laft, at the interval of four hours between each; and ftill finding a confiderable diminution after each, I the following day added another meafure; the diminution produced by this laft appeared to me not to exceed one meafure. I then poured off the refiduary air into another jar, and found it not to exceed three meafures; fo that here eleven meafures, namely, five of vitriolic and fix of hepatic air, were reduced to three. Into one meafure of this refiduary air I introduced a lighted candle: it was immediately quenched. To the two remaining meafures I added one meafure of water: by agitation it took up four-tenths of its bulk. To part of the remainder I added nitrous air, which had no effect upon it. Another part of it extinguifhed a candle. It had not a vitriolic fmell.

The water which had taken up four-tenths of its bulk of this air did not precipitate lime; nor did it affect acetous baro-felenite in lefs than a quarter of an hour, and then produced a very flight cloud. It fenfibly reddened litmus, and precipitated the folution of filver white; and hence it appears to have taken up a very minute portion of vitriolic acid. And what was not taken up by water feems to have been mere phlogifticated air.

I afterwards wafhed the fulphur, which coated the jar, with diftilled water. This water flightly reddened litmus, precipitated not only the acetous, but alfo marine baro-felenite copioufly, as well as marine and nitrous felenite; alfo the nitrous folutions of filver, lead, and mercury, all white. It even precipitated

precipitated lime from lime-water, forming a cloud in it, which neither the fixed nor volatile acid of vitriol can produce. Hence this water contained nothing hepatic; but, on the contrary, a confiderable proportion of the aërial and vitriolic acids *.

With *nitrous air* I made the following experiments. Firft, I found that two meafures or cubic inches of nitrous and two of hepatic air were little altered when firft mixed, even by agitation; but after thirty-fix hours both were reduced to nearly one-third of the whole, but fomething more. Yellow particles of fulphur were depofited both on the mercury, and on the fides of the jar, but the mercury was not blackened. The refiduary air had ftill an hepatic fmell, and was fomewhat further diminifhed by water; and in the unabforbed part a candle burned naturally. The water had all the properties of hepatic water.

Perceiving by this experiment that I had not employed enough of nitrous air to condenfe the hepatic perfectly, to eight cubic inches of hepatic air I added nine of nitrous air, all at once; a yellowifh cloud inftantly appeared, a flight white fcum was depofited on the fides of the jar, and the whole feemed diminifhed about two cubic inches, or between one-ninth and one-eighth, the temperature of the room being then 72°. I then laid by the mixture, and in forty-eight hours after, I found the whole reduced to fix cubic inches, and the top and fides of the jar covered with a white cake of fulphur, the heat of the room being conftantly kept between 60° and 70°. Finding the diminution to reach no further in

* Note, the vitriolic acid air here employed was the pureft poffible; it was extracted from fulphur diftilled with precipitate *per fe*.

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twenty-four hours more, I examined the refiduary air. It exhibited the following appearances.

1°, It had the fmell of alkaline air pretty ftrongly; at leaft that fmell iffued from the jar that contained it after the air itfelf was poured into another jar.

2°, A candle burned in it naturally.

3°, It did not affect tincture of litmus or lime-water, or acetous barytes.

4°, No fpecies of air had any effect on it except the dephlogifticated, with which it produced a flight rednefs and diminution.

5°, It produced a flight white precipitate in folution of filver.

It is plain, this air is the fame as that which Dr. PRIESTLEY calls *dephlogifticated nitrous air*, and which, I think, may more properly be called *deacidified nitrous air*. A further examination of it would lead me too far from the prefent fubject: I fhall therefore defer it until another opportunity.

As it appeared to me, from the experiment mentioned in the fecond fection (in which I found fulphur precipitated from a mixture of nitrous and hepatic air, immediately after the admiffion of common air) that an uncombined acid in the nitrous air was the caufe of the precipitation of fulphur; I attempted depriving nitrous air of any loofe acid it might contain, before I fhould mix it with hepatic air.

1ft, I made fome nitrous air from filver very carefully over boiled and filtered water, and found it to contain an acid, for it ftrongly reddened tincture of litmus.

2dly, I admitted alkaline air to this nitrous air until it no longer caufed any cloud, and then wafhed out the ammoniacal compound in diftilled water; after which I transferred this purified nitrous air to the mercurial tub. It appeared to lofe, by privation of its acid, about one-fixth of its bulk; and it was diminifhed by common air juft in the fame manner as unpurified nitrous air is.

Then to 8 cubic inches of this purified nitrous air I admitted all at once 7 cubic inches of hepatic air. No cloud, diminution, or depofit, appeared; but in fix hours after (the temperature of the room being all the time at 76°), the whole was reduced to 5 cubic inches; the diminution went no further eighteen hours after. Sulphur, much whiter than in the former experiments, was depofited, and both in this and in the former experiments that part of it which, by the rifing of the mercury, was intercepted between it and the jar, was of a yellow and red fhining colour, and not black as that depofited on mercury ufually is. The refiduary air flafhed with fo much vehemence as to extinguifh the candle dipped into it, by the violence of the blaft. The flame was exceeding white and vivid; but it did not detonate in the leaft, but rather refembled dephlogifticated air. The jar out of which it had been transferred had a fharp alkaline fmell.

This air was not in the leaft diminifhed by nitrous air, even when heated to 150 degrees; which heat I contrived to produce by paffing the upper part of the jar that contained this air into another wider jar, furnifhed with a perforated cork bottom, and filling this with water heated to that degree.

Water poured into the jar in which the fulphur was depofited, produced a bluifh white cloud in folution of filver, though infipid to the tafte.

Hence it appears to me, that, whatever this air may be, it had been deacidified by hepatic air ftill more perfectly than

that

that in which a candle burns naturally; and that it is by no means dephlogifticated.

Laftly, *Alkaline* and hepatic airs, perfectly pure and mixed in proper proportions, would probably deftroy each other completely, though I have not been able to effect this intirely. Six meafures of hepatic air from liver of fulphur and 6 of alkaline air immediately throw up a white cloud, leave a whitifh fcum on the fides of the jar, and are reduced to about 1 meafure. On adding water this is reduced to about one-half; and in this I found a candle to burn naturally: but the following experiments, being made with more care, prove that this refiduary air was only the common air of the veffels.

To 6 cubic inches of calcareous hepatic air I admitted, all at once, 7 of alkaline air; a white cloud and a little white fcum at firft appeared; but in a few feconds the whole was reduced to fix-fevenths of a cubic inch; and on adding 2 meafures of water, only one-ninth of a cubic inch of air remained. This could not be inflamed. The water, thus impregnated, precipitated a folution of filver black. In this experiment great care was taken to have each of the mixed airs as pure as poffible, and the alkaline was admitted all at once, inftead of by different portions, merely with that view; and it is probable, that, if the due proportion were hit upon, nothing would remain. The fcum appears to be almoft liquid, and as foon as the jar is emptied of mercury, it breaks out into a white fmoke, with an exceeding fharp urinous fmell.

Five meafures of martial hepatic air were, upon the admiffion of 5¼ of alkaline air, reduced to fomething more than one meafure, and upon the addition of water there remained but half a meafure; and this was inflammable, with detonation; the

 inflammable

inflammable air undoubtedly proceeding from the ſolution of the iron.

Five cubic inches of ſaccharine hepatic air, mixed with 5 of alkaline air, were diminiſhed more ſlowly; for after five minutes there ſtill remained 4,5 cubic inches. I then added another meaſure of alkaline air: in three hours after there remained but 1,25 cubic inches. In paſſing this reſiduum through water it was reduced to about half a cubic inch; and this burned with a blue lambent flame, without leaving a vitriolic ſmell or any depoſit on the glaſs; ſo that it clearly was inflammable air from the ſugar.

I once imagined I had obtained inflammable air from a mixture of alkaline air with hepatic air drawn from liver of ſulphur; but I afterwards found this inflammable air proceeded from a very ſlight contamination of zinc in the mercury over which my airs had been produced; the alkaline air acted on this zinc, and muſt have produced the inflammable air; for when I afterwards received and mixed theſe airs over mercury, perfectly purified, I obtained no more inflammable air.

SECTION IV.

Of the Action of Hepatic Air, and Acid, Alkaline, and Inflammable Liquids, on each other.

One meaſure of *oil of vitriol*, whoſe ſpecific gravity was 1,863, abſorbed two meaſures of hepatic air all to one-tenth. The acid was whitened by a copious depoſition of ſulphur. I alſo introduced, over mercury, a meaſure of red *nitrous acid*, whoſe ſpecific gravity was 1,430, to an equal meaſure of hepatic air; red vapours

vapours inftantly arofe, and only one-tenth or one-twelfth of a meafure remained in an aërial form; but as the acid acted on the mercury, I was obliged to carry the jar into the water tub, by which means the whole was abforbed: no fulphur was here precipitated.

I repeated this experiment in another manner. Having produced 4,5 meafures of hepatic air over mercury, I transferred them to the water tub, and inftantly by means of a fyphon blew into them one meafure of the above concentrated nitrous acid; but though I managed as quickly as poffible, the hepatic air was fomething diminifhed by contact with the water, before the acid had entered the tube that contained the air. I then ftopped the tube with a ground glafs ftopper, and laid it by for twelve hours; after which interval I found the liquor in the tube white and turbid, and but weakly acid, much water having entered in fpite of my endeavours to exclude it. The remaining air flightly detonated on prefenting to it a lighted candle, and had an hepatic fmell. But as this hepatic air was obtained from fulphureo-martial pafte, it does not prove that inflammable air enters into the compofition of other hepatic airs, derived from the union of fulphur with fubftances that do not yield inflammable air.

Finding it fo difficult to fubject hepatic air to the direct action of the concentrated nitrous acid, I diluted it to that precife degree at which it could not act on mercury without the affiftance of heat, and then paffed through it an equal bulk of the fame hepatic air; the acid was whitened, and eight-tenths of the air abforbed, and the refiduum detonated. Repeating the fame experiment with hepatic air from liver of fulphur, I found ftill more of it abforbed by the acid; but the refiduum

no

no longer detonated, but burned with a blue and greeniſh flame, and ſulphur was depoſited on the ſides of the jar.

Obſerving this dilute acid to abſorb nearly three times its bulk of alkaline hepatic air, I expelled this air from it by heat, but obtained only one-ſixth of the air that had been abſorbed; and in this a candle burned naturally.

Two meaſures of alkaline hepatic air, being expoſed to one of ſtrong *marine acid*, were abſorbed, by ſlight agitation, all to one-fifth of a meaſure. A third meaſure of air being then added, there remained, after ſome agitation, but half a meaſure. Sulphur was precipitated as uſual; but the mercury over which the acid ſtood attracted it from the acid; for it was blackened, which did not happen when the former acids were uſed. The reſiduum burned juſt as pure hepatic air.

Diſtilled vinegar abſorbs nearly its own bulk of air, and becomes ſlightly whitened; but by agitation it may be made to take up about twice it bulk, and then becomes very turbid.

One meaſure of *cauſtic vegetable alkali*, whoſe ſpecific gravity was 1,043, abſorbed nearly four meaſures of alkaline hepatic air. It was at firſt rendered brown by it; but after ſome time it grew clear, ſulphur was depoſited, and the ſurface of the mercury blackened. This ſhews that alkalies are not dephlogiſticated by ſilver or other metals, as Mr. BAUMÉ imagined, but only cleared of part of the ſulphur, which they commonly contain, it being formed by the tartar vitriolate contained in the plant, and coal, during combuſtion.

One meaſure of *cauſtic volatile alkali*, whoſe ſpecific gravity was 0,9387, abſorbed 18 of hepatic air. If the cauſtic liquor contained more alkali, it would abſorb more hepatic air, as 6 meaſures of hepatic unite to 7 of alkaline air; and thus the ſtrength of alkaline liquors, and their real contents, may be determined

determined better than by any other method. Alſo the ſmoak-ing liquor of BOYLE, which is difficultly prepared in the uſual way, may eaſily be formed by placing the volatile alkali in the middle glaſs of Dr. NOOTH's apparatus for making artificial mineral waters, and decompoſing artificial pyrites, or liver of ſulphur, in the lower glaſs, by marine acid.

Oil of olives abſorbs nearly its own bulk of this air, and obtains a greeniſh tinge from it.

But *new milk* ſcarcely abſorbs one-tenth of its bulk of this air, which is very remarkable, and is not in the leaſt coagulated.

Oil of turpentine alſo abſorbs its own bulk of this air, and even more; but then becomes turbid. Water ſeems alſo to precipitate this air from it, for when ſhaken with it a white cloud appears.

Spirit of wine, whoſe ſpecific gravity was 0,835, abſorbed nearly three times its bulk of this air, and became brown. By this means ſulphur may be combined with ſpirit of wine much more eaſily than by Count LAURAGAIS' method, the only hitherto known. Water precipitates the ſulphur in part.

Sulphurated ſpirit of wine does not tinge litmus red; but it precipitates lime-water, as highly rectified ſpirit of wine ſingly does. It alſo precipitates and gives a brown colour to acetous baro-ſelenite, which ſpirit of wine alone alſo does. It turns the ſolution of ſilver black and reddiſh brown. Concentrated vitriolic acid precipitates the ſulphur from it, which neither the nitrous nor marine acids can effect.

When hepatic air is mixed with an equal bulk of *vitriolic æther*, the bulk of the air is at firſt increaſed; but afterwards half of it is abſorbed, and a ſlight precipitation appears. The ſmell of the æther is mixed with that of the hepatic air; but on adding

water

water it becomes very offenſive, reſembling that of putrefying animal ſubſtances.

To one meaſure of hepatic air I added 1,5 of the *nitrous ſolution of ſilver:* the air was immediately, without agitation, reduced to half a meaſure, and the ſolution blackened. The remaining air admitted a candle to burn naturally. Hepatic air was alſo abſorbed, but not ſo readily, nor in ſuch quantity, by the ſolution of *vitriols of iron and ſilver*; that of ſilver was blackened; that of iron at firſt becamewhite, but by agitation darker. The reſiduary air burned blue, as hepatic air uſually does.

SECTION V.

Of the Properties of Water ſaturated with Hepatic Air.

This water turns tincture of litmus red.

It does not affect lime-water.

It does not form a cloud in the ſolution of marine, though it does in that of acetous baro-ſelenite.

The ſolutions of other earths in the mineral acids are not altered by it.

When dropped into a ſolution of *vitriol of iron* or marine ſalt of *iron*, it produces a white precipitate.

In nitrous ſalt of *copper* it cauſes a brown precipitate, and the liquor is changed from blue to green. The precipitate rediſſolves by agitation. In vitriol of copper it forms a black precipitate.

The ſolution of *tin* in aqua regia is precipitated by it of a yellowiſh white colour; that of *gold*, black; that of *regulus of antimony*,

antimony, red and yellow; that of *platina*, red mixed with white.

The folution of *filver* in the nitrous acid, and alfo that of *lead*, whether in the acetous or nitrous acid, are precipitated black. If the folutions are not perfectly faturated with metal, the precipitates will be brown or reddifh brown, and may be rediffolved by agitation.

The nitrous folution of *mercury* is precipitated of a yellowifh brown; that of fublimate corrofive, yellow mixed with black; but by agitation it becomes white.

The nitrous folution of *bifmuth* becomes, by mixture with this water, reddifh brown, and even affumes a metallic appearance; that of *cobalt* becomes dark; that of *zinc*, of a dirty white; that of *arfenic*, in the fame acid, yellow mixed with red and white, orpiment and realgar being formed.

If *oil of vitriol*, whofe fpecific gravity is 1,863, be dropped into hepatifed water, it renders it flightly turbid; but, if the *volatile vitriolic acid* be dropped into it, a bluifh white and much denfer cloud is formed in the water.

Strong nitrous acid, whether phlogifticated or not, caufes a copious white precipitation; but *dilute* nitrous acid produces no change. *Green* nitrous acid, whofe fpecific gravity was 1,328, immediately precipitated fulphur from it.

Strong marine acid produced a flight cloud; but neither diftilled vinegar nor acid of fugar had any effect.

It is faid by Mr. BERGMAN, that hepatifed water in a well clofed veffel effects a folution of iron in a few days; but this experiment, on repeated trials, did not fucceed with me: nor could I diffolve any other metal in this water; the fulphur indeed unites to many of them, but forms an infoluble mafs;

ſo that, I preſume, metallic ſubſtances can never be found in hepatiſed mineral waters.

SECTION VI.

Of the Properties of Alkaline Liquors impregnated with Hepatic Air.

I have already mentioned the proportion of air they are able to take up. Colourleſs fixed alkaline liquors receive a browniſh tinge from this air. The reſiduum they leave is of the ſame nature as the part they abſorb.

A cauſtic fixed alkaline liquor, ſaturated with this air, precipitates *barytes* from the acetous acid, of a yellowiſh white colour. It alſo decompoſes other earthy ſolutions, and the colour of the precipitates varies according to their purity, and perhaps this teſt might be ſo far improved as to ſupply the place of the Pruſſian alkali.

It precipitates the ſolution of vitriol of *iron*, and alſo marine ſalt of iron, black; but this latter generally whitens by agitation. That which I uſed was very ſaturate.

The ſolutions of *ſilver* and *lead* are alſo precipitated black with ſome mixture of white; that of *gold* is alſo blackened; but that of *platina* becomes brown.

Solutions of *copper* let fall a reddiſh black or brown precipitate.

Sublimate corroſive by this teſt diſcovers a precipitate partly white and black, and partly orange and greeniſh.

In the nitrous ſolution of *arſenic* it forms a yellow and orange; and in that of *regulus of antimony*, in aqua regia, an orange precipitate mixed with black.

Nitrous

Nitrous ſolution of *zinc*, thus treated, ſhews a dirty white; that of *biſmuth* a brown mixed with white; and that of *cobalt* a brown and black precipitate.

As *Pruſſian alkali* always contains ſome iron, it gives a purple precipitate with this teſt, which precipitate is eaſily diſſolved.

It turns tincture of raddiſhes, which is my teſt for alkalies, green.

The action of liver of ſulphur on metallic ſubſtances in the *dry way* is deſcribed by many authors, and particularly in an excellent Diſſertation by M. ENGESTROM; but its action in the *moiſt* way has not been mentioned, as far as I recollect, by any. Hence I tried its effect on a few grains of iron, copper, lead, tin, zinc, biſmuth, regulus of antimony, and of arſenic. Putting each into a bottle, containing about three half ounces of liquid liver of ſulphur, ſo far diluted that its colour was yellow; in about fifteen days I found they all, except the zinc and tin, had attracted ſulphur from the fixed alkali. Iron, arſenic, and regulus of antimony and lead, were moſt altered; copper next, and biſmuth leaſt: but the liquors held none of the metals in ſolution; that which contained iron became green; on adding an acid ſulphur was precipitated; if it held iron it could not at that period be detected.

Water ſaturated with the condenſed reſiduum of alkaline and hepatic air, that is, with the pureſt volatile liver of ſulphur, does not precipitate marine *ſelenite*, though it forms a ſlight brown and white cloud in that of marine *baro-ſelenite*.

It produces a black precipitate in the ſolution of vitriol of *iron*, and a black and white in that of marine ſalt of iron; but by agitation this laſt becomes wholly white.

It precipitates both vitriol of copper, and the nitrous ſalt of copper, red and brown.

Tin in aqua regia gives a yellowiſh precipitate; *gold* a dilute yellow and reddiſh brown; *platina* a fleſh-coloured precipitate; and *regulus of antimony* a yellowiſh red.

Silver is precipitated black; and ſo is *lead* both from the nitrous and acetous acids.

Sublimate corroſive appeared for an inſtant red; but ſoon after its precipitate appeared partly black and partly white.

The nitrous ſolution of *biſmuth* affords alſo a precipitate, partly black, partly white, and partly reddiſh brown, and of a metallic appearance; that of *cobalt* is alſo black or deep brown.

Arſenical ſolutions give yellow precipitates more or leſs red; but thoſe of *zinc* only a dirty white.

All theſe colours vary in ſome degree, according as the liquors are more or leſs ſaturated previous to and after their mixture, and the time they have ſtood together.

SECTION VII.

Of the Conſtitution of Hepatic Air.

From an attentive conſideration of the above experiments, which I purpoſely diſengaged from all theory, it is difficult to conclude, that hepatic air conſiſts of any thing elſe than ſulphur itſelf, kept in an aërial ſtate by the matter of heat. Every attempt to extract inflammable air from hepatic air, when drawn from materials that previouſly contained nothing inflammable, namely, from alkaline or calcareous hepars, proved

proved abortive: on the contrary, when the materials could previoufly fupply inflammable air, as when martial carbonaceous and faccharine compounds were employed, inflammable air, in ever fo fmall a proportion, was detected: nor could hepatic air be procured from the direct union of inflammable air and fulphur, as we have feen.

Some have imagined, that this air confifts of liver of fulphur itfelf volatilized, and confequently that an alkali enters into its compofition; but many weighty reafons oppofe this fuppofition. In the firft place this air is evidently, though weakly acid, fince it reddens litmus, and precipitates acetous baro-felenite. 2dly, It may be extracted from materials that either contain no alkali at all, or next to none, as iron, fugar, oil, charcoal: and, laftly, it is not decompofed by marine or fixed air, by which, neverthelefs, liver of fulphur is decompofable.

I formerly thought that fulphur was held in folution in hepatic air, either by vitriolic or marine air; yet though both of them may hold fulphur in folution, as we have feen, ftill neither of them is effential to the conftitution of hepatic air as fuch, fince it is producible from materials that contain neither of thefe acids; and, from whatever fubject it is obtained, it exhibits the characters of one and the fame acid, namely, the *vitriolic exceedingly weakened*; and fuch an acid we may fuppofe fulphur itfelf to be.

In effect, fulphur, even in its concrete ftate, affords many characters of acidity. It unites with alkalies, calcareous and ponderous earths, and moft metals, as a weak acid might: and except a manifeft folubility in water (a property which fome other concrete acids alfo poffefs in a very weak degree) it exhibits every character of acidity. But its acidity is the weakeft poffible, fince it decompofes only acetous, and not marine baro-

felenite,

ſelenite, and is ſeparable from alkalies and earths by all other acids.

That the matter of heat enters into the compoſition of this air, is evident from the experiments of M. SCHEELE, who paid particular attention to that object. He found, that acids excite much leſs ſenſible heat in uniting with *liver of ſulphur*, whether alkaline or calcareous, than while uniting with a proportion of cauſtic fixed alkali or lime equal to that which enters into the compoſition of thoſe *livers*; whence he juſtly infers, that the *difference* enters into the compoſition of the hepatic air produced. I have proved the ſame thing another way: for, inſtead of decompoſing an *alkaline* hepar by marine acid, I tried to decompoſe it by a ſaturate ſolution both of marine ſelenite and marine Epſom. The decompoſition indeed took place, but no hepatic air was produced: for the acid having given out its ſpecific heat on uniting to the earths, had none to loſe or communicate on uniting to the alkali, and conſequently the ſulphur receiving none could not be thrown into an aërial ſtate.

It is remarkable, that bodies capable of an aërial form receive the latent heat neceſſary for that form, much more readily from a body that parts with its ſpecific heat than by the mere application of ſenſible heat. Thus aërated barytes cannot be decompoſed by mere heat, as Dr. WITHERING has ſhewn, though its air is eaſily ſeparated from it by an acid; and in the ſame manner antimony cannot be deſulphurated even by vitrefaction, though it may by acids: ſo liver of ſulphur will not give hepatic air by mere heat, though it will by the intervention of an acid, even the weakeſt. The reaſon of which ſeems to be this: the matter of heat has no particular affinity with any ſubſtance, as is evident from its paſſing indifferently

indifferently from any hot body to a colder, of whatever fort or kind the bodies may be; but it is determined to unite with this or that body in a latent ftate, in greater or leffer quantity, in proportion to the greater or leffer *capacity* of thefe bodies to receive it. Now acids, by uniting to the alkaline bafis of liver of fulphur, expel the fulphur, and give it their heat, at the *inftant* the fulphur, by its feparation, has the capacity to receive it; whereas fenfible external heat, acting alike on both the conftituent parts of liver of fulphur, feparates neither; or if it feparates them, yet, by its *fucceffive* action, it throws one of them into a *vaporous* ftate firft, and bodies that *firft* acquire this ftate can never after acquire an aërial ftate by any *fubfequent* acceffion of heat.

The vitriolic and nitrous acids are lefs adapted to the production of hepatic air than the marine acid, though they contain more fpecific heat than the mere acid part of the marine acid: the moft probable reafon of which is, becaufe they have a ftronger attraction to fulphur itfelf, and fo detain it.

Hepatic air is much difpofed to give out its latent heat, particularly when in contact with fubftances to which it has any affinity; thus it is condenfed in water in a few days; it is alfo condenfed by long expofure to frefh furfaces of mercury or filver or other metals, particularly if they are moift. M. BERGMAN found it in great meafure condenfed into fulphur, when inclofed alone in a bottle *. In this cafe it probably contained an excefs of fulphur; for hot hepatic air is capable of keeping a farther quantity of fulphur in folution, and depofing it when cold, as I have frequently obferved.

* See a note in the fecond volume of M. MORVEAU's tranflation of the fecond volume of BERGMAN's Works, p. 341.

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The precipitation of metallic ſubſtances by this air is owing partly to the union and phlogiſtication of the acids by this air, and partly to its union with the metals themſelves, for it evidently unites in moſt caſes to both.

As alkalies and ſulphur are known to have an affinity to each other, we eaſily underſtand why hepatic and alkaline airs are condenſed when mixed with each other; nor is there any difficulty in conceiving why hepatic air is not condenſed by common, dephlogiſticated, inflammable, or phlogiſticated airs, or remarkably by marine air; but it ſeems very extraordinary, that hepatic air and vitriolic air ſhould be condenſed, and in great meaſure converted into ſulphur by their mutual action on each other, particularly as they both ſeem nearly of the ſame ſpecies, or at leaſt nearly allied to each other. The attraction of two bodies, thus circumſtanced, is certainly very extraordinary; yet that their union proceeds from attraction ſeems pretty evident, for concentrated vitriolic acid, and particularly volatile vitriolic acid, precipitates ſulphur copiouſly from hepatiſed water. Volatile vitriolic acid frequently holds ſome ſulphur in ſolution, as appears from the experiments of Dr. PRIESTLEY and M. BERTHOLLET; and hence it depoſits ſome when it loſes its aërial form, or by mere length of time; but the whole of this condenſed air is not turned into ſulphur, for the water that waſhed the precipitated ſulphur took up a quantity of volatile acid and fixed air, as has been ſhewn.

The condenſation of hepatic air by nitrous air ſeems owing to the ſame cauſe; for when the nitrous air was in great degree deprived of ſuperfluous acid, the condenſation of the hepatic was much ſlower; and that which after all took place ſeems to have been effected by the decompoſition of the nitrous air, and the conſequent extrication of an acid.

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The decompofitions effected by fixed and volatile livers of fulphur obviouſly proceed in moſt caſes from a double affinity.

SECTION VIII.

Of Phoſphoric Hepatic Air.

As phoſphorus, in reſpect to its conſtituent parts, bears a ſtrong reſemblance to ſulphur, I was naturally led to examine its phænomena when placed in the ſame circumſtances: I therefore gently heated about 10 or 12 grains of phoſphorus, mixed with about half an ounce of cauſtic fixed alkaline ſolution, in a very ſmall phial, furniſhed with a bent tube, and received the air over mercury. Upon the firſt application of heat two ſmall exploſions took place, attended with a yellow flame and white ſmoke, which penetrated through the mercury into the receiver; theſe were followed by an equable production of air. At laſt the phoſphorus began to ſwell and froth, and fearing the rupture of the phial, I ſtopped the tube to prevent the acceſs of atmoſpheric air, and removed the phial to a water tub, intending to throw it in; but in the mean while the phial burſt with a loud exploſion, by reaſon of an obſtruction in the tube, and a fierce flame immediately iſſued from it. However I obtained about 8 cubic inches of air.

This air was diminiſhed very ſlightly, by agitation with an equal bulk of water, and then became cloudy like white ſmoke, but ſoon after recovered its tranſparency. Upon turning up the mouth of the tube to examine the water, the unabſorbed air inſtantly took fire, and burned with a yellow flame without exploding, leaving a reddiſh depoſit on the ſides of the tube.

Water impregnated with phofphoric air, and over which this air had burned, flightly reddened tincture of litmus:

Did not affect Pruffian alkali:

Had no effect on the nitrous folutions of *copper* or *lead*, *zinc* or *cobalt*, nor on marine folution of *iron* or *tin*, or of tin in aqua regia, nor on the vitriolic folutions of *iron*, *copper*, *tin*, *lead*, *zinc*, *regulus of antimony*, *arfenic*, or *manganefe*; nor on the marine folutions of *iron*, *copper*, *lead*, *zinc*, *cobalt*, *arfenic*, or *manganefe*.

But it precipitated the nitrous folution of *filver* black, and vitriol of filver brown; alfo nitrous folution of *mercury* made without heat brown and black; but vitriol of mercury firft became reddifh, and afterwards white; and fublimate corrofive yellow and red mixed with white.

Gold diffolved in aqua regia is precipitated purplifh black, and from the vitriolic acid brownifh red and black; but *regulus of antimony* in aqua regia is precipitated white by this phof-phorated water.

The nitrous folution of *bifmuth* fhewed firft a white, and prefently after a brown precipitate. Vitriol of bifmuth and marine falt of bifmuth were alfo precipitated brown; this latter re-diffolved by agitation.

The nitrous folution of *arfenic* alfo became brown, but re-diffolved by agitation.

I afterwards impregnated fome water with this air, without fuffering the air to burn over it: it fcarcely affected litmus, did not precipitate lime-water; but it caufed a black precipitate in folution of *filver*, a white precipitate of *regulus of antimony* in Æ, and a whitifh yellow in that of *fublimate corrofive*.

To a meafure of this air I let up a meafure of water, and through this fome fmall bubbles of *common air*; every bubble flamed

flamed and produced a white ſmoke until about half as much common air was introduced as there was originally of phoſphoric; and yet the original bulk did not appear increaſed; the flame each time produced a ſmall commotion, and a ſmoke deſcended after inflammation into the water: when flame ceaſed to be produced, ſmoke ſtill followed the introduction of more common air. Bubbles of phoſphoric air, eſcaping through mercury into the atmoſphere, flame, crackle, and ſmell, exactly like the electric ſpark *.

To a meaſure of phoſphoric air I let up a half meaſure of *nitrous air*: a white ſmoke appeared, with an exceeding ſlight diminution, and the tranſparency was ſoon reſtored, a ſlight ſcum being depoſited on the ſides of the jar. Another half meaſure of nitrous air produced no ſmoke or diminution; but on adding water, and agitating the air in it, much more of it was abſorbed. Upon turning up the jar the nitrous air firſt eſcaped in the form of a red vapour, and this was followed by a whitiſh ſmoke. The water had a phoſphoric ſmell, and precipitated the ſolution of ſilver brown. In this experiment the acid of the nitrous air ſeems to have acted the ſame part that it does in hepatic air.

Phoſphoric air was ſcarce at all diminiſhed by the addition of an equal meaſure of *alkaline air*; and water being put up to theſe, took up in appearance little elſe than alkaline air, yet on turning up the mouth of the jar, the reſiduary air ſmoked without flaming.

* A few months after I made theſe experiments on phoſphoric air, the tenth volume of the Mémoires des Savans Étrangers was publiſhed; and in this I found, that the ſpontaneous inflammation of this air was known to M. Gingembre in the year 1783. His experiments are now publiſhed in Rozier's Journal for October, 1785.

The water, thus impregnated, had exactly the ſmell of onions. It turned tincture of radiſhes green.

It precipitated ſolution of *ſilver* black; and that of *copper* in the nitrous acid brown; but this precipitate was re-diſſolved by agitation, and the liquor became green. *Sublimate corroſive* was precipitated yellow mixed with black.

Iron was precipitated white, both from the vitriolic and marine acids; but a pale yellow ſolution of it in the nitrous acid was not affected; and a red ſolution of it in the ſame acid was only congrumated.

Regulus of antimony in aqua regia gave a white, *cobalt* in nitrous acid a very ſlight reddiſh, and *biſmuth* in the ſame acid a brown precipitate.

But neither the nitrous ſolution of *lead* or *zinc*, nor that of *tin* in marine acid or aqua regia, nor that of *regulus of antimony* in aqua regia, were any way affected.

Fixed air, mixed with an equal proportion of phoſphoric air, produced a white ſmoke, ſome diminution, and a yellow depoſit. On agitating the mixture in water, the fixed air was taken up all to one-tenth. The reſiduum ſmoked, but did not inflame ſpontaneouſly.

To a ſmall portion of phoſphoric air I introduced ſome *precipitate per ſe*. It ſoon grew black, and a white ſmoke appeared. In two days the precipitate remained ſolid, yet acquired a ſhining pale white colour, like that of ſteel: the air loſt its ſpontaneous inflammability; but I am not certain that this want of inflammability did not proceed from ſome other cauſe; for two days after I made this air, I found a quantity of it, which had reſted all night on water, had depoſited a yellow ſcum on the ſides of the jar, and loſt its ſpontaneous inflammability next morning. The temperature of the air was then

then 53°; and when it inflamed before, the temperature was 68°.

From theſe few experiments, which the ſmall quantity of air I then obtained did not ſuffer me to repeat, I think we may conclude, that phoſphoric air is nothing elſe but phoſphorus itſelf in an aërial ſtate, and differs from ſulphur in this, among other points, that it requires much leſs latent heat to throw it into an aërial form, and hence may be diſengaged from fixed alkalies, without the aſſiſtance of an acid.