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Mr. David Mushet

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hinder the absorption to continue, while there remains gas proper for maintaining combustion.

If it be common air or vital air mixed with any other gas, you must, after cooling, measure the quantity of water which has entered the retort, and which will exactly represent the bulk absorbed. You must not neglect to confine the remaining gas under the same pressure, by immersing the retort in the pneumatic tub, till the internal and external water be on the same level, before you close the orifice by a stopper. This operation, very easy when you have graduated vessels, may be made in common practice by means of a piece of paper cemented along the neck of the retort, and having traced out on it divisions determined by experiment, and which may be covered with varnish to defend it from the action of the water.

C. Chauffier has constructed, for eudiometric experiments by phosphorus, an apparatus somewhat different, composed of a long tube all of one piece, one end of which is bent and blown into a bulb, and having, as at *e*, a tubulure shut with a stopper after the water has been made to ascend in the inside of the tube to two-thirds of its height. This instrument would serve also for experiments with the sulphuret of potash; but I must observe, that the execution of it is not so easy as on the first view might appear. Besides, if the tubulure renders it very convenient for trying atmospheric air, the case is not the same in regard to other gases which cannot be introduced but by transmission.

XVI. *On the Component Parts of Iron-stones, and how these in the manufacturing affect the Quality of Crude Iron.*
By Mr. DAVID MUSHET, of the Clyde Iron Works. Communicated by the Author.

IRON-STONES, though commonly denominated ores of clay, contain notwithstanding a variety of mixtures, and may with propriety be divided into the following classes:

1. Iron-stone that has clay for its chief component earth, and this clay comparatively pure and free from sand.

2. Iron-stone possessing lime for its chief mixture, and this lime also comparatively destitute of sand.

3. Iron-stone that unites clay and lime, containing large proportions of siliceous iron-stones. I shall therefore, in naming these varieties, use the following terms as they are arranged in succession. Argillaceous, calcareous, and siliceous iron-stones. None of these earths exist singly with the iron. All iron-stones contain a mixture of the three, in various proportions; from which arise the supposed variety of the qualities of crude iron, which each respective stone is said to contain. There are some, however, which are composed of nearly the same proportions of clay, lime, and siliceous iron; and these commonly afford, when compared with themselves, a similar quality of crude iron.

Nature, in the formation of these secondary ores of iron, has invariably impressed characters upon them, easily to be developed: by which means their qualities, and the consequent effects produced in the blast-furnace, may be accurately and distinctly prejudged. The source of this information is, the study of the nature of the united earths; by ascertaining the quantity and proportion of which, we are enabled to pronounce exactly upon the quality of the iron likely to be obtained from the ore. We must not, however, consider these characteristic features as a consequence of the metal existing of a variety of qualities; but, *a priori*, we ought to consider, that, as a consequence of the nature and proportions of the mixture, the iron will be called into existence in a state more or less oxygenated or carbonated.

When iron-stones are said to contain *good* or *bad* iron, the expression ought to be understood, which by the bye is seldom the case, only as a comparative assertion, confined to local rules, and judged by certain fixed local standards; into the account of which many things must be taken, which are frequently overlooked. At every iron-work, a certain proportion.

portion of fuel, coaks or wood char, by weight, is understood to be sufficient to smelt, and give principle to a determinate weight and quality of iron-stones combined together, in order that a certain quality of crude iron may be produced. In this case, should a new iron-stone be substituted for one whose quality and effects are already known, and should its application be productive of iron less carbonated than formerly, it would instantly be denominated a *bad* iron-stone, or an iron-stone containing bad iron—an assertion only true comparatively so far as it would affect the interest of the manufacturer, unless corrected by an addition of fuel, a change of the mixtures of ores, or a varied application of the lime-stone used as a solvent or flux. But this is no proof that the quality of iron, as it exists in the ore, is bad, since a larger proportion of coaks, or a change of mixture, which incurs no additional expence, can correct the evil. It rather furnishes a demonstration that the iron in all ores is the same; but that, in calling it into a metallic form, the quality is affected chiefly by the reduction of those mixtures originally united with it.

As the quality of the fuel is improved in a direct ratio to the quantity of carbon which the coal contains, and its purity, hence arise the great variety of coaks used in smelting iron-stones; some of which will smelt, and give principle to the iron contained in double the weight of the same ores that others will. From this then may be deduced another proof, that *good* and *bad* iron are terms of comparative meaning only, confined to situation. Let it be conceived that a change of fuel opposite in its quality to that now mentioned was to take place; the same quantity of ore, which with the good coaks would have afforded metal richly carbonated, would now yield its produce in a partial degree, and that highly oxygenated—almost unfit for any purpose. The consequences here entailed are the same, though they may be attributed to different causes; the former as derived from the hostile mixture of the ore, but the latter as arising from a deficiency in the quality of the coaks.

Besides these two leading instruments of alteration in the smelting process, inherent in and derived from the materials, good and bad effects may be produced from an unjust proportion and quality of the lime-stone, which is added, in order that the proper equilibrium may be restored, and the iron properly and beneficially revived.

Taking this then for a general principle, that the crude iron contained in all iron-stones is the same, and that it can be called into existence as a metal of all the various degrees of carbonation, by regulating the proportion of fuel, and of the solvent; I shall proceed to mention those mixtures which I have always observed determine the future quality of the crude iron.

1. Argillaceous iron-stone having fine clay as its chief component earth, lime in the next proportion, and both these nearly destitute of sand; which, when properly torrefied, exhibits fibres on its internal surface, of a brown, dark-brown, or claret colour, running either in streaks or radiated, and adhering tenaciously to the tongue, will afford, with a moderate proportion of coaks and lime-stone, iron of the finest quality, possessing strength conjoined with an intimate degree of fusibility.

2. Calcareous iron-stone, that which contains lime as its principal earthy mixture; holding clay in the next proportion, and both these comparatively unallayed (totally they never are) with sand; which, when regularly torrefied, assumes a variety of shades generally lighter in the colour than the former class; which sometimes, and sometimes not, presents internal fibres, and which adheres less tenaciously to the tongue; always contains iron, which can be revived, richly carbonated with a comparatively small quantity of coaks, and with a trifling addition of lime. Under this class of iron-stones are found those which produce iron of a fusible nature, seldom connected with strength, but valuable for its utility in fine castings, which require ornament more than durability. It is also from this source of mixture that I would trace the red short quality of bar-iron. The

nature

nature imposed upon crude iron in the blast-furnace by the development of its mixtures, most commonly accompanies it through all its subsequent stages of existence as a metal.

3. Those iron-stones whose component parts are nearly an equalised mixture of clay, lime and sand, which torrefy with a slight degree of adhesion to the tongue, assuming a dark-red or brownish colour, void of internal fibre, always afford, with the local proportion of fuel, iron of an intermediate quality for fusibility and softness, but generally possessing strength in an eminent degree. Such iron is excellently adapted for the manufacture of great guns, mortars, and the large species of machinery. Its application to the purpose of bar-iron making, would also be attended with the most beneficial effects, possessing neither the extreme of fusibility nor of infusibility: it would greatly prevent, in the manufacturing, a tendency, which iron possessed of these extremes has, to become red or cold short.

4. Iron-stones which unite a large proportion of sand with sparing proportions of clay and lime, which, upon being slightly exposed to heat, exhibit masses of semivitrification, neither obedient to the magnet, nor adhesive to the tongue, having a refractory disposition to part, and possessing a dark-blue or black colour, always afford, with the usual proportion of fuel, crude iron of the worst quality, either as to strength or fusibility. Such metal is commonly highly oxygenated, and brittle; incapable of being used alone for any melting purpose; and, when applied to the use of the forge, affords malleable iron, which possesses the cold short quality.

These are the four principal classes under which I have arranged our iron-stones, with regard to their tendency to afford their iron carbonated, possessing strength, or otherwise, when smelted in the blast-furnace with a determinate quantity of fuel. As this classification is exactly analogous to the results obtained in the large way, it may serve as a ground-

work to those who may wish to attain a practical knowledge of these ores, so far as it relates to their manufacture.

It is however easy to counteract the natural tendency which every iron-stone has in this case, to afford its iron of a certain quality, and to make each of them yield crude iron of all the different degrees of fusibility and strength. Is it not obvious, that since the qualities of crude iron depend upon the mixtures and their kinds composing the stones, that if nature be assisted by adding or subtracting from them in the blast-furnace, every quality of crude iron may be produced from the same iron-stone? I have seen most of these results determined in the large way, and the whole of them beautifully confirmed in the assay-furnace.

It remains with the present manufacturer to consider whether it will be more his interest to reject such iron-stones as are of difficult carbonation, or to apply the necessary additional proportions of fuel, capable of correcting the quality of siliceous iron-stones. Not so, however, to those who may at some future period succeed him; necessity, at all times ingenious, assisted by the increasing light which science daily sheds over our manufactures, will devise the means of calling into profitable existence the metal contained in all those ores which may have fallen into disrepute in the present day, or from which at this time it is thought impracticable to extract metal in the large way.

The usual criterions by which iron-stone is judged, whether it be sufficiently rich in iron for the purpose of smelting, are the following:

1. The degree of tenacity with which it adheres to the tongue after torrefaction:
2. Its colour:
3. The obedience to the magnet when pulverised:
4. By depriving of its iron a given weight of the ore, in contact with charcoal and fusible earths in the assay-furnace.

The first and third of these methods are liable to great error. The adhesion to the tongue will be more in proportion

tion to the quantity of clay and its kind contained in the stone, than to its real contents in iron. Iron-stone may also be torrefied in such a manner as to deprive its internal surface of this property; as it is only peculiar to the stone at a certain stage of torrefaction.

The influence which the magnet possesses over some ores of iron is no direct proof of the quantity of iron contained; as some ores which contain 15 parts in 100 are completely magnetic, while others again that contain 60 to 70 parts of iron in 100 are not in the smallest degree affected with this property. The magnetic test is more used to ascertain the existent state of the metal, whether mineralised with an acid, combined with sulphur or with oxygen, or existing in a disengaged state more or less metallic. No iron-stones which in their native state contain their iron mineralised with oxygen, or in the state of an oxyde, completely dispersed through an intimate combination of clay, lime and silice, containing water, carbonic acid, and sometimes concrete sulphur, are obedient to the magnet till such time as torrefaction has passed upon them, either exposed to open air, or in contact with charcoal in close vessels. If this process is continued for a short time, the whole mass will become obedient; but this affection will still depend upon the relative quantity of concrete oxygen fixed with the iron. Individually, however, iron-stones are affected by the proportion of heat conveyed to them while torrefying. If the quantity communicated has been sparing, so as not to have carried off all the water, carbonic acid, &c. the magnetic virtue will also be proportionally absent: if the dissipation of these substances has been complete, the magnet will possess an influence in the exact ratio of the quantity of oxygen which remains combined with the metal. Should it happen that a degree of heat capable of exciting fusion is applied, the mass will then rapidly lose its magnetic obedience by an extra-fixation of oxygen; if driven so far as to make it exhibit a semi-vitri-

fied appearance, this principle would be found to be entirely annihilated.

Although the colour which iron-stones assume in torrefying intimately depends upon the degree of heat presented to them in the operation of burning, yet, by regulating this agent in a proper manner, an accurate knowledge may be formed, not only of the probable quantity of iron, but even of its tendency to become carbonated in smelting. The expulsion of the water and acid leaves the combined earths more exposed to determination. The small specula of flint are distinctly discerned; adhesion to the tongue develops the presence of clay; and lime is indicated by its assuming a whitish colour, either striated, or disseminated, approaching towards the surface of the stone.

The last method mentioned, namely, that of depriving a given portion of ore of its iron, is the most consonant to truth and to the ideas of the manufacturer. Acids may be used as a check upon the assay by fusion; but this intricate, or rather this slow process is chiefly resorted to by chemists, and seldom goes beyond the bounds of the laboratory. In assaying by fusion, not only the quantity of iron may with precision be ascertained, but also the quality of crude-iron likely to be produced from the ore, with the local proportions of fuel in the large way. The earths formerly united with the iron, now become fused with those added for solvents. These float upon the surface of the extracted metal, and, when cold, may afford information, from their colour and transparency, concerning the regulation of future proportions upon a more extended scale. This subject I shall more minutely illustrate in a subsequent paper on the assaying of iron-ores by fusion.

The burning or torrefying of iron-stones, known in the large way by the rather improper term of *calcination*, consists in exposing the stone to a certain degree of heat in contact with air, in order to dispel those substances which it
contains,

contains, capable of assuming the aëriform state by the combination of caloric. This operation ought to be performed in a progreffive heat, always short of fusion. The water is then slowly evaporated without being decomposed; the caloric unites to the carbonic acid, which soon assumes the gaseous state; and lastly, the sulphur, if any, sublimes.

This process is essentially necessary to be performed before the iron-stone is introduced into the blast-furnace. Were raw iron-stone, or ore, precipitated in the violent heat of the smelting-furnace, the water and acid would instantly be decomposed; the oxygen would partly unite to the iron in addition to the fixed quantity peculiar to each ore, and part of it would oxygenate the sulphur, either of the ore, or of the pit-coal, a portion of which is always present in the furnace. The whole mass would then be precipitated in fusion, and a dark porous lava obtained, containing iron more difficult to be revived than ever, owing to the great quantity of oxygen combined with it. In cases of this kind, the disengaged hydrogen manifests its escape, by changing the colour of the flame from a mellow white to a pale sickly blue.

It must from all this appear obvious, that, when torrefaction has been properly conducted, a very considerable part by weight of the whole will be dissipated: the absence of these volatile substances always leaves the iron-stones more or less magnetic. The loss of weight, however, is very different in the various classes of iron-stones, even when they are all exposed for the same length of time to a degree of heat capable of expelling those mixtures, which, under such circumstances, assume the gaseous state.

1. Calcareous iron-stone, when properly exposed to torrefaction, loses more of its weight than either of the other two classes. Where the lime is abundant, I have found this iron-stone lose 38 per cent. but more commonly 35 and 36 per cent. of water, carbonic acid, and sulphur.

2. Ar-

2. Argillaceous iron-stones, exposed to a similar degree of heat, and treated in the same manner, commonly lose in weight, from 32 to 35 per cent.

3. Siliceous iron-stones always give out less weight when exposed to torrefaction under similar circumstances with other stones. In common they lose from 27 to 30 per cent. I have, though rarely, found them to give out 25 per cent. only.

The extreme loss of weight in each class must be considered as the utmost point to which torrefaction can with safety be urged, without exposing the iron-stone to an accumulation of weight by the combination of oxygen.

From the variously compounded natures of iron-stones arise the various calculations of the loss which they are said to sustain in burning, at different iron-works. Fields of iron-stone are commonly impressed with a general distinguishing characteristic feature: some are of the calcareous genus; some of the argillaceous; and others again have a more intimate alliance with flint than the former two. Hence we find, at those works where the chief supply is drawn from the argillaceous iron-stones, that the loss in torrefaction on the great scale is computed from 30 to 33 per cent. Where calcareous iron-stones form the chief supply, the loss is estimated at from 35 to $37\frac{1}{2}$ per cent. Few or no iron-works are obliged to have recourse to iron-stones abounding with sand for their chief consumption: a general estimation of the loss sustained by this stone in the large way is therefore difficult to be made, though, I have heard, that at some works 25 per cent. was all that was allowed to be expelled during burning. Nature has been extremely kind in the formation of our secondary ores of iron; as the bulk of them, that contain iron sufficient to entitle them to be melted, are combined with superior proportions of clay and lime.

As the burning or torrefying of iron-stones is of great importance

portance to the manufacturer, and as it may be in some respects gratifying to the man of science, I shall particularly enter into the various phenomena attending the operation; dividing torrefaction into two classes: that which deprives iron-stones of certain substances capable of becoming aëri-form by the combination of caloric in contact with atmospheric air; and that which deprives ores of their oxygen—hence called de-oxygenation—by heating them in contact with charcoal, in closed vessels, or in cavities impervious to the external air.

1. The consequences of heating iron-stone exposed to air is a loss of water, sulphur, and carbonic acid*. A small portion of oxygen may at times be unfixed, when the fuel may chance to come into contact with the heated iron-stone under a partial exclusion from air. But the association of circumstances necessary to effect this can so seldom be the effect of chance, that it is never to be looked for with certainty. When the operation is properly performed, the last particle of acid and water may be expelled. But this point is difficult to be ascertained with any degree of exactitude: for, in proportion as these gaseous substances are carried off, the metal becomes more and more revived, of course more and more liable to attract, and fix oxygen by the decompo-

* I have seen some iron-stones in torrefying deposit a beautiful oxyde upon their surface, of a lake colour, and light as down. The same substance, I have observed, effloresced upon the surface of the fracture of highly oxygenated crude iron, which had been broken immediately after the metal had lost its fluidity. From this coincidence of effect, I am inclined to suppose, that the oxyde deposited on the iron-stone in burning is the consequence of the decomposition of the sulphuric acid; a portion of which had been mineralised with the stone, holding iron in solution; and that in the latter it was occasioned by a superabundance of oxygen in the blast-furnace, probably from the introduction of raw iron-stone, which had escaped the effects of the fire: that the sulphur, as formerly stated, had become oxygenated, dissolving a portion of the metal; which was again deposited in the state of a calcined sulphat, when the acid was suffered to escape, by being freely exposed at a high degree of heat to open air.

sition of the ignited gas; and, as the last portions of the acid and water are distilling, the stone is apt to gain weight by the calcination (oxygenation) of its iron. This will positively be the case when the heat is carried beyond the necessary degree, and is indicated by the iron-stone swelling in bulk, becoming specifically lighter and porous on the surface, but gaining weight in a great degree internally. As oxygenation goes on, the magnetic virtue decreases, until at last it becomes entirely annihilated.

The first stage in torrefaction is indicated by the first general change of colour in the iron-stone. This is commonly a faded blood colour, more or less dark according to the quantity of lime present.

I have repeatedly made use of all the various iron-stones, in the state of a fine powder, in order to ascertain what was the weight lost by each class in its transition from its native hue to the first stage of an assumed colour. And I am enabled to state the following as an average of the results obtained on this head: Calcareous iron-stones give out 6 parts in 100 of the raw mineral; argillaceous iron-stones, 5; and siliceous iron-stones, $4\frac{1}{2}$.

If the pulverised iron-stone is thrown into a vessel red hot, this loss will be effected in two minutes. The change of colour is immediately effected on those parts in contact with the heated iron. The whole is brought into contact with it; and when thrown out, the magnet will be found to have acquired a perceptible influence over it. When the powder is first thrown in, a slight decrepitating noise is heard for a few seconds. This operation may also serve to shew the presence of sulphur, or of its acid. When in the former state it instantly takes fire, and burns with a dark lambent flame. When the acid is present, it is easily known by the suffocating fumes disengaged by the action of heat.

The application of heat beyond the first stage of colour, causes the iron-stone to pass through a variety of shades.

These,

These, as in metallic substances, are the effects of the presence of air at certain degrees of heat *. As the progressive dissipation of the volatile mixtures takes effect, the colour deepens; and, according to the nature of the iron-stone, becomes fixed, of a brown, dark brown, or deep claret colour. These indicate the almost entire expulsion of the water, acid, &c. In this state all iron-stones are possessed of magnetic attraction, and exhibit the various phenomena already described, as being peculiar to their respective natures.

The methods commonly in use for torrefying iron-stone, in the large way, are of two different kinds: that of burning in kilns or conical furnaces; and that of exposing iron-stone in open air, stratified with coals, to combustion. The former is used in some places in Wales; the latter is almost universally adopted in England, and totally so in Scotland.

In the operation with furnaces, they become filled entirely with iron-stone, except a stratum of coals in the bottom, which is afterwards inflamed. The combustion is then carried on by means of a current of air passing through the furnace, and forcing the heat along with it. When the iron-stone is deemed sufficiently burnt, the register is shut up; and the combustion, no longer maintained by means of external air, soon dies away, and leaves the furnace to cool.

The most common method, however, of burning iron-stones, consists in levelling a piece of ground, and covering it with a layer of small pit-coals. This is of various thicknesses, 4, 6 or 8 inches, according to the height the pile is to be built, and the nature of the iron-stone. Upon this stratum of coals the pieces of iron-stone are imbedded, as near to the same size as possible, in order that all may be equally acted upon. These are reared to various heights,

* From smooth-surfaced iron-stones and ores, when exposed to heat partially sheltered by charcoal dust from the action of air, I have obtained all the shades of colour peculiar to polished iron and steel; but with less of the metallic lustre, owing to the surface being more porous.

18, 20 to 24 inches, the determination of its height depending upon circumstances. The surface is a second time levelled, by introducing small pieces of iron-stone betwixt the interfices occasioned by the angles of the larger. This again receives a covering of small coals, seldom exceeding 2 inches in thickness. Upon this is reared the subsequent building, always gradually narrowing itself till it has assumed the shape of a stout wedge, with its base resting upon the ground. After this is effected, the whole of the external surface receives a complete covering of the smallest sort of coals. The pile is kindled by applying burning coals to the ground stratum. This creeps slowly along; heats the stone upwards; kindles the second layer of small coals, and ultimately inflames the whole mass from top to bottom.

When the coals are consumed, the pile gradually cools, and in 8 or 10 days may be wheeled away to the furnace.

The quantity of iron-stone burnt at one time is various at different and even at the same places; some kinds require to be burnt in smaller heaps, owing to their nature and fusibility. At some works the fires extend from 50 to 60 yards; and it is not uncommon to see skilful workmen, at one end, adding fresh materials to the burning pile; while others, at the opposite end, are employed wheeling away that which the fire has left sufficiently burned for the purpose of the furnace. Fires that extend from 30 to 60 feet in length are more common; from 10 to 16 feet wide, and about 5 feet high.

At most iron-works a local opinion exists, to what degree of heat iron-stone ought to be exposed before it is properly fit for the blast-furnace. All, however, agree that burning is necessary; though few give an accurate reason why. The only one I have heard adduced is, that iron-stone is *calcined* in order to burn out the sulphur and other *heterogeneous* mixtures. Hence arise a diversity of opinions, chiefly founded upon individual notions of the fixity or volatility of sulphur.

fulphur. Some contend that fulphur is easily displaced, and that therefore the iron-stone should be moderately *calcined*; left the fulphur from the coal used in burning it should enter, and again hurt the quality of the iron. On the other hand, it is said that fulphur is of difficult expulsion from the centre of the stone, as it is never seen going off till a bright red heat forcibly expels it; and therefore it is highly requisite the iron-stone should be long and violently exposed till the last portion is got rid of. To effect this, therefore, the heat, say they, ought to be urged till such time as the stone has indicated signs of fusion, or has partially suffered thereby. In order to give strength to this opinion, those who adopt it add, that, by such severe *calcination*, the volume of stone is reduced, becomes heavier, and that it will consequently occupy less room in the blast-furnace; of course it is imagined that, bulk for bulk, the iron-stone becomes richer in iron than when in a raw state.

Those who are acquainted with the oxydation of metals, and the consequent increase of weight, will at once discover the source of this error, and readily conceive, that, after the metal in the iron-stone has become partially disengaged by the expulsion of water, carbon acid, fulphur, &c. forming frequently a third part of the whole weight, it will become an object of attack to the oxygen of the atmospheric air; the combination of which with the iron alone adds to the actual increase of weight, and not the transposition of the particles of metal from one piece of iron-stone to another. It must also be obvious that, where such fallacious prejudices have taken root, the consequences must frequently be fatal to the interests of the manufacturer; as such iron-stones, literally calcined, must require an additional portion of fuel to furnish carbon to carry off the superadded oxygen.

It is somewhat remarkable that the phenomena attending the oxydation of iron should be entirely unknown at iron manufactories. Such a process is never dreamt of, and even the declaimers against severe torrefaction only account
for

for the increase of weight, by asserting that the earthy parts are burnt out and nearly consumed, and that the metallic parts only remain, destroyed however in their nature and *reduced to a cinder*.

We are not to wonder, therefore, at the uncertain results which the untutored manufacturer obtains, until such time as a long course of experience has taught him, that, by combining certain causes, good or bad effects are the consequence. Even at last he still rests upon an unstable basis: destitute of the correct operation of principle, and incapable of preventing an evil from a total ignorance of its real source of action, he can only in the end avoid it after a multiplicity of movements, wherein he finds his practical knowledge increased at the expence of a considerable sacrifice of property.

How much more enlightened would be the mind of the manufacturer, were he to attend minutely to the phenomena developed in all the stages of his process, and satisfy himself as to the radical principles of action in each individual stage! In doing this, chemical minuteness, the terror and butt of the unphilosophised mind, is not absolutely indispensable; and yet every thing may be ascertained necessary to be known for the production of certain determinate qualities of crude iron.

He would then easily comprehend that all iron-stones contain less or more water of crystallisation, and that, being combined with a certain proportion of lime neutralised with carbonic acid, it is necessary that they be exposed to a heat sufficient to expel the first and last of these as well as sulphur. The reason has already been given, and the consequence shall be once more stated. The evil effects produced by introducing raw iron-stones into the blast-furnace, are less owing to the small portion of sulphur contained in most of them, especially in balls, (the vapours of which arise even from the softest crude iron when fluid,) than to the decomposition of water and acids, each of which gives up
a pro-

proportion of oxygen to the metal, chiefly before separation is effected.

Does it not then unquestionably follow, that if the quantity of charcoal in the furnace formerly was sufficient to take up the oxygen existing in the ore, and to afford carbonated crude-iron, that if a further quantity of this principle is added, by whatever means, part of the charcoal which formerly went to carbonate the iron now combines with the superadded oxygen to form carbonic acid; of course the metal will be deprived of its carbon, become white in the fracture, and may then justly be denominated oxygenated crude-iron. The same application to principle would also inform the merely practical man, that when iron-stone is completely deprived of those substances which assume the gaseous state by the combination of caloric at a moderate temperature, it is then sufficiently prepared for the furnace. This is always indicated by the colour which the stone assumes varying from a brown to a dark claret. Blues always succeed this shade; and the smallest appearance of blue, however light, is a certain sign that the external air has made an impression upon the particles of metal, by superoxygenating them. Instead therefore of expelling a further quantity of *heterogeneous* matter, a principle is added the most noxious and destructive to the existence of iron in a metallic form.

The phenomenon of iron-stone becoming heavier in the fire, would no longer be explained by assuming vague assertions incompatible with and inadmissible to common sense. Upon finding two pieces of iron-stone in the same fire, which have to appearance been affected in a widely different manner by the heat; the one heavy, of a black blueish colour; the other light and porous: the practical man would now no longer say that the metal from the porous piece had escaped by these pores, and entered into the ponderous one; and that the accumulation of weight in the latter was entirely owing to it abstracting the metal

from the former. Widely different indeed would be the conclusion. He now would have learned that metals are combustible bodies; that under certain circumstances iron is one of the most inflammable in the group; that, during its combustion, it decomposes the air that maintains the combustion, and fixes one of its elements in spite of the powerful affinity exerted upon it by the caloric; and that by this process alone it increases its volume and weight. The porous mass of iron-stone would now be described as having had its iron completely saturated with oxygen at a very high temperature; that an imperfect state of fusion had been the consequence; and that a combination of these circumstances, acting for a considerable length of time, had volatilised and carried off a very considerable portion of the metal.

On the same principle would be explained the increase of weight in the more ponderous piece; it would then readily be conceived, that the same association of circumstances had not been present; but that the iron had gained in weight by the addition of oxygen at a temperature short of fusing and volatilising the oxyd.

What I have further to state on this subject shall be forwarded for the next Number of the Philosophical Magazine. In the mean time I shall subjoin a few remarks which may be considered in the light of a

Postscript to the Paper on the Principles of Iron and Steel.

In that paper (Phil. Mag. Vol. II. p. 165) I stated that the carbon which exists in steel is in an elastic or æriform state. In a long series of experiments which I made on the dissolution of crude-iron and steel in various acids and in water, I always obtained carbon from the former in a crude concrete form; but the carbon in steel always eluded my search, and never appeared till some days afterwards, in the manner of a greasy pellicle, thin and transparent upon
the

the surface of the fluids. This circumstance confirmed what had long been evident to me, from a knowledge of the principles and the mode of conveying them in manufacturing both these states of iron, that the carbon in crude iron and that in steel existed in a widely different mode of union. And as in the latter it existed not in a crude state, I was led to conclude that an aeriform chemical union was effected, during the process of cementing the steel, by the agency of the caloric on the charcoal, which stratifies the bars during the operation.

In my correspondence, however, with the Editor of the Philosophical Magazine, he threw out some hints that a different kind of chemical union might be effected by the same agency, and that in steel the carbon might exist in a concrete state, though not crude—neutral, though not aeriform. This combination, which I had overlooked, (*humanum est errare!*) appeared so highly probable that I resumed my experiments; and I am happy in now stating that this idea was just, as I have since obtained from steel carbon in the state of an impalpable powder, by the following simple operation.

I introduced into a glass vessel a plate of polished steel, and poured upon it as much clear rain water as covered it three inches. In this state it remained for 50 days, during which time I carefully observed the agency of the water upon the metal. Twenty-four hours after introduction, minute flakes were observed floating lightly in the water; they increased on the second and third days, and fell gradually towards the bottom. As these accumulated, the surface of the water became covered with the same carbonaceous pellicle mentioned above*, exactly resembling the coloured film which is frequently found floating upon the surface of springs where iron is precipitated from the carbonic acid.

* A plate of pure malleable iron underwent a similar immersion in a separate vessel, but exhibited no disengagement of carbon in this state.

During the immersion of the steel, a double affinity was exerted; part of the oxygen of the decomposed water united to the carbon to form carbonic acid: this union was at any time highly facilitated by raising the temperature of the water. The precipitate and oxyd upon the surface of the plate then became covered with transparent bubbles, which remained if the temperature was decreased; but on the contrary rose to the top and escaped, if the heat was augmented. The other affinity excited was that of the oxygen upon the iron; which it slowly oxydated, covering the surface at first with a slight yellow membrane of the thickness of gold leaf. This daily increased, and at the end of fifty days had acquired firmness and consistency. After carefully drying the plate, I began to separate the oxyd from the surface. This easily parted in scales, and under it I found the surface of the plate entirely covered with fine carbon, without grease or the smallest asperity. When strewed in the fire, it sparkled and exhibited the same characters as charcoal.

This experiment proves clearly that carbon exists in steel in a concrete state, though not crude—in chemical union, however, and not as a mere mixture as in crude iron.

I cannot conclude this note without ————*, and expressing a hope that the confirmation of this fact may lead to a solution of many of the phenomena attending the manufacture of iron.

* The author here pays us a compliment to which we have no claim, and having already inferred enough of what respects ourselves to shew that we would not willingly disobey his commands, we hope he will excuse this small chaff. EDIT.