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XXIV. *On the different Proportions of Carbon which constitute Crude Iron and Steel.* By DAVID MUSHET, *Esq. of the Calder Iron Works**.

MY laſt communication contained ſeveral experiments to prove the quantity of carbon abſorbed by pure malleable iron in paſſing into the carbonated crude ſtate. The object of the preſent will be to exhibit the proportions of carbon which enter into the compoſition of the other varieties of crude iron and caſt ſteel. I continue the numeration of the experiments from my laſt:

	Grs.
Exp. VII. Swediſh bar iron - -	1174
Charcoal $\frac{1}{15}$th part, or 78 grs.	

A fuſion was obtained from this mixture, after which there remained only a ſmall portion of charcoal, too minute for weighing.

The metallic button weighed -	1213
Gained in weight by the combination of charcoal equal to $\frac{1}{30}$th part the weight of the iron.	39
Weight of the iron 1174, and charcoal 78, =	1252
Weight of the button - -	1213
Total loſs of weight in the fuſion	39

equal to that gained by the iron. Upon minute inſpection, no part of the ſurface of this button was carbonated. The colour was blueiſh black, ſmooth in the centre but a little oxidated towards the edges. Its fracture preſented cloſe dark gray crude iron. The cryſtals much cloſer and more minute than in thoſe experiments where richly carbonated crude iron was obtained. Appreciating its real quality by compariſon with crude iron manufactured for ſale, it occupied that rank generally known by the names of No. II. gray melting pig iron.

	Grs.
Exp. VIII. Swediſh bar iron - -	922
Charcoal $\frac{1}{20}$th part, or 46 grs.	

From the expoſure of this mixture there reſulted a very perfect metallic button whoſe upper ſurface preſented a partial degree of radiated cryſtallization. It was found to weigh - - - - 950

Gained in weight by the combination of carbon 28 equal to $\frac{1}{33}$d part the original weight of the iron. The fracture of this button was ſmooth, ſilvery white, occaſionally ſtudded with carbonaceous ſpecks in the form of ſmall

* Communicated by the Author.

grains,

grains, an exact refemblance to mottled pig iron. In this experiment there remained not the moft diftant trace of carbonaceous matter. A fmall portion of amber-coloured glafs was formed round the edges of the metal.

	Grains.
Weight of the iron 922, charcoal 46, = -	968
Metal refulting - -	950
Total lofs of weight	18.

	Grains.
Exp. IX. Swedifh bar iron - -	1330
Charcoal $\frac{1}{25}$th part, or 53 grs.	
From this mixture a perfect fufion and metallic button was obtained, which weighed - -	1351
Gained in weight by the combination of carbon	21

equal to $\frac{1}{63}$d part the weight of the iron. In this experiment alfo the charcoal had completely difappeared. The upper furface of the button was fmooth, the under furface confiderably pitted. The concaves chequered with a rude cryftallization peculiar to caft iron. The fracture of this metallic mafs was bright filvery white, deftitute of grain, and exhibiting a very perfect ftreaky cryftallization flightly radiated. Its refemblance was ftrikingly fimilar to that of highly blown caft iron prepared in the finery for the purpofes of bar iron making; an operation commonly in ufe for the purpofe of decarbonating the iron, that it may, in the fubfequent procefs, fooner pafs into the ftate of malleability. The weight of iron and charcoal in the experiment amounted to grs. 1383

Iron obtained - -	1351
Total lofs in the fufion	32

Exp. X. Swedifh iron - -	1348
Charcoal $\frac{1}{30}$th, or 45 grs.	
From this proportion of mixture in half an hour a perfectly fufed button of metal was obtained, which was found to weigh - - -	1359
Gained in weight by the combination of carbon	11

equal to $\frac{1}{124}$d part the original weight of the iron. The upper furface of this button was fmooth without configuration. Below the furface was uneven, and covered with minute but perfect cryftallization. Its fracture was blueifh filvery white, compofed of flat dazzling cryftals, proceeding in lines

lines from a centre to the edges of the button. Here it was moſt obvious, that from the ſmallneſs of the proportion of carbon preſented to the iron, the reſulting product was found aſſuming the earlieſt ſtage of granulation approaching to the ſteely ſtate. The brilliant concretions obſervable in the ſurface of the button were too indiſtinct and flat for ſteel capable of withſtanding the hammer.

	Grains.
The joint weight of the iron and charcoal amounted to	1393
Iron obtain - - -	1359
Total loſs of weight in the fuſion	34

Exp. XI. Swediſh iron - - 1502
Charcoal $\frac{1}{40}$th, or 37 grs.
The metallic button obtained by the fuſion of this mixture weighed - - - 1505

Gained in weight by the union of carbon 3
equal to $\frac{1}{500}$th part the firſt weight of iron. The upper ſurface of this button was ſmooth, with a faint impreſſion of a chequered cryſtallization. The under ſurface poſſeſſed ſome large pits, ſimilarly, though more perfectly cryſtallized.

The fracture poſſeſſed one ſhade of blue beyond that of No. X. A regular granulated ſurface compoſed of flat oblong cryſtals was obſervable, ſtill too indiſtinct and too much on edge for workable ſteel. The weight of charcoal and iron in this experiment amounted to grs. 1539
Metal obtained - - 1505

Total loſs of weight in the fuſion 34

Exp. XII. Swediſh iron - - 1537
Charcoal $\frac{1}{50}$th, or 31 grs.
From the expoſure of this mixture, a metallic button was obtained, which weighed - - 1533

Loſt in fuſion, equal $\frac{1}{384}$th part. 4
The ſurfaces of this button were uniformly ſmooth. The fracture was denſe, and diſplayed a grain peculiar to highly ſaturated bliſtered ſteel. When put under the hammer, with a low red heat, it ſtood a few blows, but afterwards parted.
Weight of mixture employed in the experiment grs. 1568
Steel obtained - - 1533

Total loſs of weight 35

Exp.

Exp. XIII. Swedish iron - - 1362

Charcoal $\frac{1}{90}$th, or 15 grs.

A very fine fusion was produced from the exposure of this mixture. The metallic button was found to weigh 1319

Lost in fusion, equal to $\frac{1}{31\frac{6}{10}}$th part, 43

This button presented a wavy crystallized surface. The under surface was rough, and contained one large pit accurately crystallized. The fracture was regularly granulated, small, but distinct, of a light blueish colour. The crystals, though distinct, were not so prominent as those of easy drawing cast steel. It, however, hammered with the usual degree of caution necessary to the working of cast steel. The bar of steel formed from the button possessed all those properties requisite for file making, and other purposes requiring a quality highly charged with carbonaceous matter.

	Grains.
Weight of the mixture - -	1377
Steel obtained - - -	1319
Loss of weight in this experiment	58

Exp. XIV. Swedish iron - - 1372

Charcoal $\frac{1}{100}$th, or 14 grs.

The button obtained weighed - - 1312

Lost in the fusion 60

equal to $\frac{1}{22\frac{8}{10}}$th part the original weight of the iron. The surface of this button was smooth, without crystallization. The under surface rough, and possessed of one large pit in the centre, faintly marked with the usual crystalline appearance. The fracture presented regular light blue grains, distinct, and more prominent than No. XIII. One-half of the button was drawn into a neat square bar, and proved steel of an excellent quality. One end of the bar being loose and shaled, welded tolerably well, and hardened afterwards with a low heat. In appreciating the quality of this result, it appeared to be that kind of steel suitable for penknives, razors, &c., possessed of neither the extremes of hardness nor of softness.

Beyond the proportion of $\frac{1}{100}$th part of charcoal to iron, I continued the experiment till the proportion was reduced to $\frac{1}{200}$th part. It would appear tedious to detail these experiments, the most interesting being already minutely described. In the same progressive manner, by diminishing the

the dofe of carbon, the metallic refult approached more and more to the foftnefs of malleable iron, though by no means poffeffed of all its properties. In this feries of experiments, iron prefented with $\frac{1}{150}$th part its weight of charcoal was found to form very foft fteel fit for making fciffars, &c., which, in a good workman's hands, would have doubled, welded, and formed a very perfect point, afterwards hardening fo as to difplay a beautiful clofe break of fteel. By ufing the following precaution, it was even found capable of welding perfectly to iron. Two flat bars of a fimilar fhape, one of this quality of fteel, and one of good malleable iron, were put under the hammer with a good welding heat. After a few light blows, the junction was completely made. The united bars were allowed to cool without further hammering till the fhade of heat was bright red. The whole piece was then drawn out in a folid compact form, whofe fracture, when cold, prefented a complete junction of the iron and fteel, exhibiting at the fame time their refpective grains.

When iron is prefented in fufion to $\frac{1}{140}$th or $\frac{1}{150}$th part of its weight of charcoal, the refulting product occupies a kind of middle ftate betwixt malleable iron and fteel. It then welds with facility, and, provided the precaution formerly mentioned is attended to, may be joined either to iron or fteel, at a very high welding heat. Thus combined with carbon, it is ftill fufceptible of hardening a little, but without any great alteration in the fracture. It poffeffes an uncommon degree of ftrength and tenacity, capable of an exquifite degree of polifh, arifing from its complete folidity and the purity of fracture conveyed to it by fufion.

When the dofe of carbon is further diminifhed, and in the ratio of this diminution, the fame fteel or iron becomes more and more red fhort, and lefs capable of cohefion under a welding heat, fo that, when the proportion is reduced to $\frac{1}{200}$th part the weight of the iron, the quality refulting is nearly analogous to the fufion of iron *per fe*, or that obtained by the fufion of iron and earths.

It will appear evident from the refult of thefe and former experiments, that crude iron and fteel only differ from each other in the proportions of the carbon they contain. In the details now before us, charcoal alone is ufed in addition to the malleable iron as pure as is ever made, to effect every principal ftage or modification of the metal. Hence we conclude, that

Iron femi-fteelified is made with, charcoal,	$\frac{1}{150}$th part.
Soft caft fteel, capable of welding, with, -	$\frac{1}{120}$th
Caft fteel, for common purpofes, with, -	$\frac{1}{100}$th

Caft

Caſt ſteel requiring more hardneſs, with, of charcoal, - - - $\frac{1}{90}$th part.
Steel capable of ſtanding a few blows, but quite unfit for drawing, - - $\frac{1}{50}$th
Firſt approach to a ſteely granulated fracture, is from - - - $\frac{1}{30}$th to $\frac{1}{40}$th
White caſt iron - - $\frac{1}{25}$th
Mottled caſt iron - - $\frac{1}{20}$th
Carbonated caſt iron - - $\frac{1}{15}$th
And ſupercarbonated crude iron - $\frac{1}{12}$th, or when any greater quantity is uſed.

Although this is the quantity of charcoal neceſſary to form theſe various qualities of metal by this mode of ſyntheſis, yet we are by no means authorized to conclude that this is the proportion of real carbonaceous matter taken up by the iron, ſeeing that in experiments No. I. to No. VI. incluſive, the weight gained by the iron was upon the average equal only to $\frac{1}{21\frac{8}{10}}$th part; whereas the charcoal which diſappeared in the different fuſions amounted to 61.1 per cent. of the original quantity introduced along with the iron.

In the ſucceeding experiments the following differences are remarkable:

No. VII.	Charcoal uſed $\frac{1}{15}$th	-	Iron gained	$\frac{1}{30}$th part.
No. VIII.	- $\frac{1}{20}$th	-	-	$\frac{1}{33}$d
No. IX.	- $\frac{1}{25}$th	-	-	$\frac{1}{63}$d
No. X.	- $\frac{1}{30}$th	-	-	$\frac{1}{122\frac{1}{2}}$
No. XI.	- $\frac{1}{40}$th	-	-	$\frac{1}{500}$th
No. XII.	- $\frac{1}{50}$th	-	Iron loſt	$\frac{1}{384}$th
No. XIII.	- $\frac{1}{90}$th	-	-	$\frac{1}{36\frac{5}{10}}$th
No. XIV.	- $\frac{1}{100}$th	-	-	$\frac{1}{22\frac{8}{10}}$th

From this we ſee that when a proportion of charcoal equal to $\frac{1}{40}$th part, and above, the weight of the iron is uſed, the latter always gains in weight; but when a more ſparing proportion is introduced, room is left for the exertion of another affinity upon the metal, and it conſequently and invariably loſes in weight proportioned to the diminution of the carbon. I have here further to remark upon the foregoing experiment, and upon the nature of experiments by ſyntheſis performed in this way in general, that the reſults as to quality will differ materially when different portions of matter are uſed. So that an operator repeating the above experiments either in crucibles ſmaller or larger, or with a greater or leſs weight of mixture, would not obtain the ſame reſults.

The formation of caſt ſteel in the large way, founded upon the reſults of the foregoing experiments, affords an inconteſtable proof of this. In fuſions of 18, 22, and 25 lbs. of iron each, we are obliged to increaſe the doſe of carbon conſiderably beyond that requiſite in ſmall experiments. To form ſteel equal to that obtained in experiment XIII. wherein $\frac{1}{90}$th of charcoal was uſed, $\frac{1}{55}$th part is requiſite to be introduced. For ſteel ſimilar to that in experiment XIV. $\frac{1}{65}$th and $\frac{1}{70}$th part are uſed. For ſofter ſteel $\frac{1}{90}$th, whereas in the ſmall experiment $\frac{1}{120}$th part was ſufficient. If in the manufacturing a ſmall extra quantity of carbon is requiſite, this is ſaved by the comparatively ſmall loſs ſuſtained in the tranſmutation of the iron into ſteel.

Many inſtances have occurred in the firſt fuſion from a caſt ſteel pot in the large way, where 25 lbs. of iron, and its requiſite proportion of carbon, not exceeding $\frac{1}{70}$th, have afforded an ingot of caſt ſteel weighing 24 lbs. 12, 13, 14, and 15 ounces, being a loſs equal to no more than $\frac{1}{110}$th, $\frac{1}{200}$th, $\frac{1}{300}$th, $\frac{1}{400}$th part the weight of the iron, whereas in experiments No. XIII. and XIV. the loſs of metal amounted to $\frac{1}{31\frac{5}{10}}$th, and $\frac{1}{22\frac{8}{10}}$th part the weight of the iron.

I ſhall conclude this paper with a few remarks upon the ſtate in which carbon exiſts in ſteel and in crude iron.

When malleable iron is fuſed with $\frac{1}{130}$th or $\frac{1}{140}$th part of its weight of carbon, the reſulting product is conſiderably ſteeliſied. The fracture is lighter in the colour than it formerly was in the ſtate of iron. When fuſed with an 80th to $\frac{1}{100}$th, ſteel of an ordinary quality is produced, the fracture of the metal ſtill becoming whiter. When the doſe of carbon is increaſed beyond this, the ſteel becomes ſo hard and denſe as to be unfit for hammering. The fracture now will be found approaching to the colour of ſilver, and loſing its granulated appearance, aſſuming, however, a cryſtallized form. In this ſtate the metal will be found to reſiſt the hammer and file, and to be unfit for any purpoſe. Increaſe, however, the quantity of carbon to $\frac{1}{12}$th or $\frac{1}{15}$th, the reſulting product is no longer deſtitute of grain, nor poſſeſſed of the ſame degree of hardneſs. The fracture will be found gray, and the ſurface eaſily reduced by the pile. A further increaſe of the carbon is accompanied by an increaſe of theſe properties. At 1-8th or 1-6th, the filings of the metal, when thrown into water, leave a carbonaceous pellicle covering the whole ſurface, and of a conſiderable thickneſs.

Thus

Thus we find that carbon hardens iron till it arrives at the higheſt pitch of denſity, which is indicated by the metal loſing grain, and aſſuming a cryſtallized ſilvery fracture. At this point or maximum we may conceive that the reſpective proportions of mixtures are ſo nearly balanced that the affinity exerted by the iron is juſt ſufficient to deoxidate the charcoal, and that hitherto nothing but pure carbon ſimilar to the diamond has combined with the iron. If, however, the equilibrium is deſtroyed by a larger portion of charcoal, then we find the affinity too weak to deoxidate the whole, and part of it unites in the ſtate of an oxide of carbon; at firſt conſtituting a mottled fracture, and afterwards, as the doſe is increaſed, all thoſe deepening blueiſh gray ſhades peculiar to ſoft caſt iron. Hence carbon or its oxide again ſoftens iron. It never, however, reſtores the properties of forging or of hammering. One invariable law, however, is maintained, that the fuſibility of iron under every circumſtance and modification is in the ratio of the quantity of carbon united.

XXV. *Reſearches relative to the Moon's Influence on the Atmoſphere and on the Variations of the Barometer.* By C. Cotte, *Member of different Learned Societies* *.

DURING forty years ſtudy of meteorology I have conſtantly viewed, with a peculiar degree of intereſt, the influence of the moon upon our atmoſphere.

The opinion of this influence is founded upon a prejudice ſo antient, that I thought it worth while to endeavour, by means of reſearches and combinations of facts, eſtabliſhed on the baſis of obſervations contained in our regiſters, to diſcover, not a complete ſyſtem, but the proper data to conduct us, by degrees, to the ſolution of the problem.

The reſults of my endeavours in this way may be peruſed, 1ſt, in my Treatiſe on Meteorology, publiſhed in 1774, p. 186, 302, 317, note; 280, 606: 2dly, in my Memoirs on Meteorology, publiſhed in 1788, vol. i. p. 100, &c. vol. ii. p. 80: 3dly, in the *Journal de Phyſique* 1782, part ii. p. 249; 1786, part i. p. 276; 1792, part ii. p. 272; 1793, part i. p. 279; 1800, part i. p. 358, part ii. p. 337; 1801, part i. p. 338, part ii. p. 221, 409.

The new reſearches which I now offer to the public have

* From *Journal de Phyſique*, &c. tom. liv. Prairial, an. 10.