XIII. *On the aëriform compounds of Charcoal and Hydrogen; with an account of some additional experiments on the gases from oil and from coal.* By WILLIAM HENRY, *M. D. F. R. S. &c.*

Read February 22, 1821.

THE experiments on the aëriform compounds of charcoal and hydrogen, described in the following pages, are supplementary to a Memoir on the same class of bodies, which the Royal Society did me the honour to insert in their Transactions for 1808, as well as to other papers on the same subject, which have been published in Mr. NICHOLSON's Journal, and in the Memoirs of the Manchester Society. Of these essays, I beg leave to offer a very brief recapitulation, with the view merely of connecting them with what is to follow.

In the first of these essays (NICHOLSON's Journal, 8vo. June, 1805), I detailed a series of experiments on the gases obtained by the destructive distillation of wood, peat, pit-coal, oil, wax, &c. from which it appeared that the fitness of those gases for artificial illumination was greater, as they required for combustion a greater proportional volume of oxygen; and that the gases generated from different inflammable bodies, or from the same inflammable substance under different circumstances, are not so many distinct species, which under such a view of the subject would be almost infinite in number, but are mixtures of a few well known gases, chiefly of carburetted hydrogen with variable proportions of olefiant, simple hydrogen, sulphuretted hydrogen, carbonic acid, carbonic oxide, and azotic gases; and that the elastic fluids obtained from coal, oil, &c. have probably, in addition to these, an inflammable vapour diffused through them when recent, which is not removed by passing them through water.* In the same paper I explained certain anomalies that appear in the experiments of the late Mr. CRUICKSHANK, of Woolwich, which are not at all chargeable as errors upon that excellent chemist, and could only be elucidated by farther investigation of the gases to which they relate. Of his labours it would be unjust, indeed, to speak in any terms but those of approbation, for they may fairly be considered as the foundation of most that is now known respecting this species of aëriform bodies. To Mr. DALTON, also, we are indebted for an accurate acquaintance with carburetted hydrogen gas, and for much information that is valuable in assisting us to judge of the composition of mixed combustible gases, by the phenomena and results of firing them with oxygen.†

In the second Memoir (Philosophical Transactions, 1808), I described a series of experiments on the gases obtained from several different varieties of pit-coal, and from the same kind of coal under different circumstances. Various species of that mineral were found to yield aëriform products, differing greatly in specific gravity, combustibility, and illuminating power; the cannel coal of Wigan, in Lancashire, being best adapted to the purpose, and the stone-coal of South Wales the least so. In decomposing any one species of coal, the

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* NICHOLSON's Journal, 8vo. XI. 72.

† New System of Chemical Philosop y ; *passim.*

gaseous *fluids* were ascertained not to be of uniform quality throughout the process, but to vary greatly at different stages; the heavier and more combustible gases coming over first, and the lighter and less combustible afterwards. By subsequent experiments on the gases obtained from coal on the large scale of manufacture, it was found that a similar decline in the value of the products takes place, but not to the same extent, owing, probably, to the greater uniformity of temperature, which is attainable in large operations.*

On the practical conclusions, which it was the object of the last mentioned Essay to establish, I forbear to dwell, because they are unconnected with my present purpose, which is limited to the chemical constitution of these compound gases, and to the methods of separating them accurately from each other. The view of their nature and composition, which was taken in the first Essay, was opposed by those able philosophers, M. BERTHOLLET, and Dr. MURRAY, of Edinburgh, who both contended for greater latitude as to the proportions in which hydrogen and charcoal are capable of uniting, and considered these proportions indeed as subject to no limitation. The facts, however, which have since been multiplied in this, as well as in other departments of chemistry, tending to prove, that bodies capable of energetic combination unite in a few definite proportions only, leave little doubt that the same law holds good with respect to the compounds of hydrogen and charcoal. Not that it is meant that the known compounds of those elements are the only possible ones; for others will probably be discovered, which will still be found conformable to the general law, *that when one body combines with another in*

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* Manchester Society's Memoirs, new Series, vol. III.

different proportions, the greater proportions are multiples of the less by an entire number.

A different view of the subject has lately been taken by the ingenious author of the Bakerian Lecture, published in the Philosophical Transactions for 1820. In that paper, Mr. BRANDE has endeavoured to prove, that the gas called light carburetted hydrogen, or simply carburetted hydrogen, or hydro-carburet, is not entitled to be considered as a distinct species; that the only aëriform compound of charcoal and hydrogen, which is with certainty known to exist, is the gas called olefiant, or bi-carburetted hydrogen; and that the gases evolved by heat from coal and oil, are in fact nothing more than mixtures of olefiant and simple hydrogen gases in various proportions.

In assuming, in the first Essay, the existence of light carburetted hydrogen as a definite compound, characterized by its requiring, for the complete combustion of each volume, two volumes of oxygen, and giving one volume of carbonic acid, I relied on the sole authority of Mr. DALTON; for the gas of marshes, though before known to be inflammable, had not been subjected to accurate examination by any other chemist. Mr. CRUICKSHANK, indeed, speaks of it as "pure hydro-carbonate;"* but since he classes it in that respect with the gas obtained by the destructive distillation of camphor, from which it differs essentially in composition, it is plain that he was not correctly acquainted with the properties of pure carburetted hydrogen. Previously to the second set of experiments, I satisfied myself by the careful analysis of a specimen of the gas from stagnant water, for which I

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* NICHOLSON's Journal, 4to. vol. V. p. 6.

was indebted to Mr. Dalton, that it really has the properties which have been ascribed to it by him as characteristic; and in 1807 I found precisely the same characters in the fire-damp of coal-mines.[*] Dr. Thomson, also, from experiments in 1811,[†] on the gas from stagnant water, and Sir Humphry Davy,[‡] from the analysis of the fire-damp in 1815, drew the same conclusions. It is in the power, indeed, of every chemist to investigate for himself the properties and composition of carburetted hydrogen gas, since it may easily be procured in considerable quantity, by stirring the bottom of almost any stagnant pool, especially if composed of clay. During the last summer, I obtained it from a source of this kind, which afforded it in such abundance, that several gallons might have been collected in a few minutes. This gas I submitted to repeated and most careful examination. It contained $\frac{1}{20}$th its volume of carbonic acid, but no sulphuretted hydrogen whatever, and no proportion of oxygen gas that could be discovered by attentively testing it with nitrous gas. The results of its combustion with oxygen gas, effected in a Volta's eudiometer in the usual manner, showed that it was contaminated with $\frac{1}{15}$th its volume of azotic gas. Apart, however, from this, the pure portion, in a great number of trials, required, as nearly as can be expected in experiments of this sort, two volumes of oxygen for combustion, and gave one volume of carbonic acid. Its specific gravity, taken on quantities procured at three several times, varied only from ·582 to ·586, the mean of which is ·584; and this, allowing for $\frac{1}{15}$th of azotic gas of specific gravity ·972,

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[*] Nicholson's Journal, 8vo. XIX. 149.

[†] Mem. of the Wernerian Society, I. 506.

[‡] Phil. Trans. 1816, p. 5.

gives ·556 for the specific gravity of pure carburetted hydrogen gas, a number which coincides almost exactly with that found by Dr. THOMSON.* Since, therefore, the same results have been obtained from the examination of gases similarly collected at distant times and places, there appears to me no reason for refusing to consider carburetted hydrogen gas as a true chemical compound, characterized by perfect uniformity of properties and composition. At the temperature of 60° Fahrenheit, and under 30 inches pressure, 100 cubical inches must weigh 16·95 grains, and be composed (taking the weight of 100 cubic inches of carbonic acid at 46·5 grains, and the charcoal in 100 grains of that acid at 27·3 grains) of

	Grains.	Grains.	Grains.
Charcoal	12·69	74·87	100
Hydrogen	4·26	25·13	33·41
	16·95	100.	133·41

And olefiant gas (giving twice its volume of oxygen by combustion, and weighing 29·64 grains for 100 cubical inches†) must be constituted of

	Grains.	Grains.	Grains.
Charcoal	25·38	85.63	100
Hydrogen	4·26	14.37	16·71
	29·64	100.	116·71

And as 16·7 is to 100, so very nearly is 1 to 6, which

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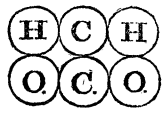
* Annals of Philosophy, Vol. XVI. p. 252.

† I adopt this result of Dr. THOMSON from its near coincidence with that of an experiment of my own, on the specific gravity of olefiant gas, published in the Phil. Trans. 1808, p. 293.

last number is the weight of the atom of charcoal, as deduced from the constitution of olefiant gas. It is true, that this determination a little exceeds that which is derived from the composition of carbonic acid (viz. 5·65), the atom of oxygen being taken at 7·5. But if 8 be the true number for oxygen, which now seems to be most probable both from experiment and analogy, we shall then find an exact coincidence between the relative weight of the atom of charcoal, as deduced from olefiant gas, and as determined from carbonic acid. Perhaps the true specific gravity of hydrogen gas, on which depend the relative weights of the atoms of hydrogen and oxygen, may be fully as correctly ascertained from the composition of carburetted hydrogen, as by direct attempts to weigh so light a fluid. Now, as the hydrogen in 100 cubic inches of hydro-carburet weighs only 4·26 grains, and is equivalent to 200 cubic inches of hydrogen gas, we have 2·13 grains for the weight of 100 cubic inches of hydrogen gas, from which may be deduced ·0698 for its specific gravity, that of air being 1. And if the specific gravity of oxygen gas be 1·111, it will be found that the two volumes of hydrogen, required to saturate one volume of oxygen gas, have as nearly as possible the relative weight of 1 to 8.

Were any additional argument necessary to establish the existence of carburetted hydrogen as a distinct species, it might be derived from the action of water on that gas, which, besides being absorbable in a constant proportion, admits of being expelled again by the application of heat, not otherwise changed than in having acquired a small quantity of those gases which are always present in water, and of which it is impossible to deprive it even by long continued boiling.

The process, by which carburetted hydrogen gas is evolved in natural operations, is no doubt the decomposition of water, and admits of being explained on the atomic theory of Mr. Dalton, by supposing two atoms of charcoal to act at once on two atoms of water. One atom of charcoal attracts the two atoms of hydrogen, forming carburetted hydrogen gas, and the other atom of charcoal unites with two atoms of oxygen, constituting carbonic acid. This is illustrated by the annexed figure, in which two atoms of charcoal C.C. are represented as interposed between two atoms of water, each consisting of an atom of hydrogen and an atom of oxygen. Dividing the diagram vertically into three parts, we have the original substances; and separating it horizontally, we obtain the two new compounds. This theoretical view of the subject is confirmed by the fact, that the carburetted hydrogen, formed at the bottom of stagnant pools, is never accompanied by carbonic oxide, but always by carbonic acid, the full quantity of which is prevented from appearing, in consequence of the absorption of a great part of it by the mass of water, under which the changes are taking place.



Being provided with such an abundant supply of carburetted hydrogen, I availed myself of it to examine the mutual action of that gas and chlorine on each other, principally with a view to ascertain, how far reliance may be placed on the latter as an instrument in the analysis of mixed combustible gases. This is a part of the subject that was first investigated, though with a different view, by Mr. Cruick-

SHANK.* He observed that a mixture of chlorine with hydrogen, carburetted hydrogen, or carbonic oxide in certain proportions, kept in a bottle entirely filled with the mixture, and furnished with an air-tight stopper, did not exhibit any immediate action, but that in twenty-four hours, on withdrawing the stopper, the fluid immediately rushed in, and filled most of the space originally occupied by the gases. But he was not aware of the influence of light on these changes, which was discovered about the same time by GAY LUSSAC† and by DALTON.‡ It does not, however, appear to have been ascertained by either of them, whether the complete exclusion of light prevents any degree of action of chlorine and carburetted hydrogen on each other. I mixed, therefore, those two gases in different proportions in well stopped vials, which were completely filled with the mixture, and covered by opake cases. When the stoppers were removed under water, at various intervals after the mixture, from a few minutes to 39 days, no diminution whatever of volume was found to have taken place; and after having removed the chlorine by liquid potash, the carburetted hydrogen gas gave the usual products of carbonic acid, and consumed the usual proportion of oxygen. Mixtures also of hydrogen and chlorine, and of carburetted hydrogen and chlorine, standing over water in graduated tubes, which were shaded by opake covers, sustained no loss of bulk, except what arose from the absorption of chlorine by the water, the combustible gas remaining wholly unaltered. It may be

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* NICHOLSON's Journal, 4to. V. 202.

† Mem. de la Soc. d'Arcueil. II. 349.

‡ New System of Chemical Philosophy, p. 300.

considered, therefore, as quite essential to the mutual agency of these gases, that they should be subjected to the influence of light. But it is not necessary that the direct rays of the sun should fall on the mixture, the light of a dull and cloudy day being fully adequate to the effect. On a day of this sort, I filled several stoppered vials, graduated into hundredths of a cubic inch, with a mixture of 30 volumes of carburetted hydrogen with from 80 to 90 of chlorine, and uncovering them all at the same moment, exposed them to the feeble light which was then abroad. By exposure of one of the vials during half a minute, no diminution of volume was found to have been effected; another vial, opened under water when one minute had elapsed, showed an absorption of five parts; a third in two minutes had lost 15 parts; a fourth in four minutes 25 parts; and a fifth, opened in five minutes, contained only 50 volumes out of the original 110.

The products, resulting from the contact of carburetted hydrogen and chlorine, under circumstances favourable to their mutual action, have been described by Mr. CRUICKSHANK, with whose experience on this point my own entirely agrees When rather more than four volumes of chlorine are kept in mixture with one volume of gas from stagnant water, the products are muriatic acid gas, and a volume of carbonic acid equivalent to that of the pure carburetted hydrogen; and this, whether the mixture be exposed to direct or indirect solar light; the only difference being that the less intense the light, the more slowly is the effect produced. When less than four volumes of chlorine are employed, the residue consists of muriatic and carbonic acids, carbonic oxide, and undecomposed carburetted hydrogen, the proportions of the two last increasing as, within certain limits, we reduce the relative quantity of chlorine. These changes were ascertained, both by Dr. DAVY and the late Dr. MURRAY,* to depend on the presence of moisture, which is unavoidably introduced in the common mode of operating; for when the gases, first perfectly dried, were mixed in an exhausted glass vessel, and exposed even to the direct rays of the sun, no mutual action was found to ensue. In the theory of these changes there is, it must be confessed, a little uncertainty. Does the chlorine, it may be asked, act simultaneously on the hydrogen of water, and on that of the combustible gas; or does it decompose water only? The former view of the subject appears to me most probable, because, if the chlorine acted on water only, free hydrogen would be evolved from that portion of the hydrocarburet which abandons its charcoal to the oxygen of the water; which is not consistent with experience. When it is required to form carbonic acid, four volumes of chlorine must be used for the decomposition of each volume of carburetted hydrogen. In this case, two atoms of chlorine unite with the two atoms of hydrogen existing in the combustible gas, and the two other atoms of chlorine with the two atoms of hydrogen from the water. But to convert carburetted hydrogen into carbonic oxide, three atoms of chlorine are sufficient, two of which are employed, as in the first case, and the third is expended in saturating the hydrogen of one atom of water, which supplies to the charcoal an atom of oxygen for the formation of carbonic oxide. Calculating in the same

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* NICHOLSON's Journal, xxviii. 143, and 201.

manner, we shall find, also, that three atoms of chlorine are adequate to convert one atom of carbonic oxide into carbonic acid.

The facts which have been stated sufficiently prove, that chlorine cannot be employed as a means of correctly analyzing mixtures of olefiant gas, either with hydrogen or with carburetted hydrogen, if light be admitted, even though of feeble intensity, and for the short interval during which such an experiment may be expected to continue: and they explain that uncertainty as to the results of analyses of mixed gases made in this way, which was first remarked by Mr. FARADAY* and subsequently by myself.† Chlorine becomes, however, a most useful agent in separating olefiant gas from such mixtures, provided light be entirely excluded during its operation, as I have found by subjecting to its action, mixtures of those gases with known proportions of olefiant gas. In these analytical experiments, I admitted into a graduated tube standing over water, a volume of chlorine exceeding by about one half what was known to be sufficient, and noted its bulk when actually in the tube, which was immediately shaded by an opake cover. A measured quantity of the mixture was then passed up, and in about ten minutes the outer cover was cautiously lifted, till the surface of the water appeared. The diminution of volume thus ascertained, divided by 2, was found to give pretty correctly the quantity of olefiant gas known to be contained in the mixture. But the greatest precision was attained by waiting 15 or 20 minutes, and then quickly washing the remaining gas with dilute solution of potash, in order to remove the excess of chlorine.

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* Journal of Science, &c. vi. 358.

† Manchester Memoirs, new Series, vol. iii.

From the volume of the residuary gas, it was necessary to deduct the amount of impurity previously ascertained to exist in the chlorine; and the remainder, taken from the volume of mixed gases which had been operated on, showed how much olefiant gas had been condensed by the chlorine. When very narrow tubes were employed, and the column of gases mixed with chlorine was of considerable length, a longer continuance of the experiment was found necessary, and the gases were suffered to remain in contact during an hour or more. In this way it was ascertained, that olefiant gas may be accurately separated by chlorine from hydrogen, carburetted hydrogen, or carbonic oxide gases, or from mixtures of two or more of those gases, which are left quite unchanged in volume and in chemical properties, when light has been carefully excluded from the mixture.

This property of chlorine is the foundation of a fresh analysis, to which I have thought it expedient to submit the gases from coal and oil, in order to decide what aëriform fluids remain after the separation of that portion which is condensible by chlorine;—whether the residue consists, as I have heretofore maintained, of carburetted hydrogen chiefly, with variable proportions of hydrogen and carbonic oxide; or whether, according to the new view of the subject, it consists of hydrogen gas only.

In the experiments made for this purpose, I operated generally on from 60 to 80 cubic inches of oil gas or coal gas, assaying a small specimen first, as a guide to the quantity of chlorine which it would be necessary to employ. The volume of chlorine thus found to be requisite, and about half as much more, was passed into an air receiver standing over water, and completely shaded by an opake cover which was fitted over it. The oil or coal gas was then added by degrees, if much condensation was expected, because in that case a considerable increase of temperature would have been produced by the sudden admixture of large quantities; or at once, if only a moderate action had been indicated by the previous assay. The mixture was allowed to stand, completely guarded from the light, during 30 or 40 minutes, or even longer, and the residue was expeditiously washed with liquid potash, and a small portion again assayed, to ascertain that the action of the chlorine was complete. The specific gravity of the washed gas was then carefully taken, that of the entire gas having been previously determined: and the results of its combustion with oxygen examined, and compared with those of the gas in its original state.

Experiments on the gas from oil.

In obtaining this gas at different times, I used the same kind of whale oil, which had been heated a little below its boiling point during two hours, in order to deprive it of water. The oil was admitted by drops into an ignited iron tube filled with fragments of broken crucibles, and no difference, that I am aware of, existed in the circumstances under which the decomposition was effected, except that the degree of heat was purposely lowered in the latter processes, till that temperature was attained, which was barely adequate to the production of gas. The oil gas procured from London, I obtained through the kindness of Mr. Richard Phillips. It had been prepared from cod oil, at the manufactory of Messrs. John and Philip Taylor, and having been conveyed to Manchester in bottles accurately stoppered and tied over with a double fold of bladder, it was found not to have acquired any admixture with atmospheric air. The results are contained in the following table, in which the expression *entire gas* is applied to the gas precisely as it came over, except that the carbonic acid had been removed by liquid potash, applied in the smallest quantity and with the least agitation that were adequate to the effect.

Table I. *Containing the results of experiments on the gas obtained from whale oil.*

Entire Gas.					Residue left by chlorine.		
			100 vols.			100 vols.	
No. of Experiment.	Sp. Gr.	100 vols. lose by chlorine.	take oxyg.	give carb. ac.	Sp. Gr.	Take Oxyg.	Give Carb. ac.
1	.464	6	116	61	.4107	94	46
2	.590	19	178	100	.4400	108	58
3	.758	22.5	220	130	.6160	145	85
4(London)	.906	38	260	158	.6060	152	91

From the foregoing table it appears, that the gas obtained at different times from oil of the same quality, is far from being of uniform composition, and that great differences, as to its specific gravity and chemical properties, are occasioned by the temperature at which it is produced. So far as my experience goes, no temperature short of ignition is sufficient for the decomposition of oil into permanent combustible gases; but the lower the heat that is employed, provided it be adequate to the effect, the heavier and more combustible is the gas, and the better suited to artificial illumination.

From the experiments which I published in 1805, and which were made on a single specimen of oil gas, I was led to consider it as constituted of one volume of olefiant gas with seven volumes of mixed gases, of which the greatest part was carburetted hydrogen. Mr. DALTON has since favoured me with a specimen of oil gas prepared by himself, which contained in 100 parts, 40 of a gas condensible by chlorine; and it appears from the table that oil gas, manufactured on the large scale, may contain in 100 parts, 38 parts of a gas similarly characterized.* It is not improbable indeed that by a temperature carefully regulated, the whole of the aëriform fluids may be obtained from oil, of such quality as to be entirely condensible by chlorine; and from the great superiority of the light which such a gas would afford, and the reduction that might be effected in the capacity of the gasometers, the discovery of a mode of producing it in this state, would be an important practical improvement.

The inferences respecting the nature of the gas from oil, I reserve till after the account of the experiments on coal gas, as the same remarks, with some slight modifications, will apply to both cases.

Experiments on the gas from coal.

The numerous experiments and observations on the gas from coal, which I have already published, appear to me to preclude the necessity of going much into the subject on this occasion. What I have lately had in view, has been to render the analysis of this gas more complete, by a careful exami-

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* Since this Paper was written, I have received from Mr. PHILLIPS a second specimen of oil gas prepared by Messrs. TAYLOR. It contains in every 100 volumes, 42 or 43 parts of gas condensible by chlorine; but in other respects very nearly agrees, (making allowance for the greater proportion of that ingredient) with the gas described in the text.

nation of that portion of it which remains after the action of chlorine. The gas, submitted to these recent experiments, was prepared from Wigan cannel, at the manufactory of Messrs. Philips and Lee. It was collected from an opening in a pipe between the retort and the tar-pit, generally about an hour after the commencement of the distillation, except in the instance of the gas No. 4, which was taken five hours, and No. 5, which was taken ten hours, from that period. Before using it, the carbonic acid and sulphuretted hydrogen, which were always present in the early products, were separated by careful ablution with liquid potash. As the gas No. 5, was not at all diminished by chlorine, it was obviously unnecessary to examine it in any but its entire state.

Table II. *Containing the results of experiments on the gas obtained from coal.*

Entire Gas.					Gas left by Chlorine.		
		100 volumes.				100 volumes.	
Experiment.	Sp. Gr.	Take oxyg.	Give car. ac.	Loss by Chlorine.	Sp. Gr.	Take oxyg.	Give car. acid.
1	.650	217	128	13	·575	178	92
2	.620	194	106	12	·527	160	82
3	.630	196	108	12	·535	148	80½
4	·500	166	93	7	·450	140	75
5	·345	78	30	0			

Inferences respecting the composition of that part of the gases from coal and from oil, which is not condensible by the action of chlorine.

The analytical experiments, which I have described on the action of chlorine on artificial mixtures of olefiant with hydrogen and carburetted hydrogen gases, afford no room for doubt that by that agent the quantity of olefiant gas in any mixture of these gases may be accurately determined. We are not, however, acquainted with any chemical agent, either liquid or aëriform, which, from a mixture of hydrogen, carburetted hydrogen, and carbonic oxide, is capable of separating one of those gases, leaving the others in their original state and quantity.* The only method at present known of determining the composition of such a mixture is by firing it with oxygen gas, and, from the phenomena and results of the process, deducing the proportion of its ingredients. In drawing conclusions of this kind, it is necessary to have distinctly in view the properties of those gases in their separate state. The following Table contains an abstract of their leading characters, which will be found very useful in such investigations. Though not strictly necessary, I have included olefiant gas, in order to render the Table more complete.

TABLE III. *Exhibiting the characteristic properties of different combustible gases.*

Names of Gases.	Sp. Gr. Air 1000	100 Volumes require Oxygen.	Total.	Diminished by Firing.	Carb. Acid produced.
Olefiant Gas	·970	300	400	$200 = \frac{1}{2}$	200
Carburetted Hydrogen	·556	200	300	$200 = \frac{2}{3}$	100
Hydrogen Gas	·069	50	150	$150 = \frac{3}{3}$	0
Carbonic Oxide	·972	50	150	$50 = \frac{1}{3}$	100

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* I have not found that chlorine can be employed with any success in analyzing such mixtures; for when placed in contact with two or more of those gases, and exposed to light, it does not act upon one exclusively, but upon all that compose the mixture.

As an illustration of the method of investigating the proportions of mixtures of the three last gases, we may take the instance of a mixed gas, free from olefiant gas, of specific gravity ·534, of which 100 volumes consume 110 of oxygen, and afford 70 of carbonic acid, the diminution of the whole 210 after firing being 140 volumes. Now it must be obvious from inspection of the Table, that the 70 parts of carbonic acid cannot all have resulted from the combustion of carburetted hydrogen, since, for the saturation of 70 measures of that gas, 140 of oxygen would have been required, whereas only 110 have been expended. We may therefore safely infer the presence of carbonic oxide, a gas which, by combustion, gives its own volume of carbonic acid, with the expenditure of only half its volume of oxygen. The specific gravity of the specimen being lower than that of carburetted hydrogen, indicates also an admixture of simple hydrogen gas; and of this the proportion must necessarily be considerable, to countervail the weight of the heavy carbonic oxide. The following proportions of the three gases will be found to coincide with the properties of the mixture.

	Consume Ox.	Give Carb. Ac.	Dimin. by Firing.
40 vols. of carb. hydrogen	80	40	80
30 ———carb. oxide	15	30	15
30 ——— hydrogen gas	15	0	45
100	110	70	140

No reliance, however, can be placed on the accuracy of such estimates, unless the specific gravity of the specimen agrees with that of the hypothetical mixture, as deduced from the proportion of its ingredients. But when this coincidence takes place, we have all the evidence, which the subject at present admits, of the nature of the mixture; and as this agreement between experiment and calculation was found to take place very nearly, in all the instances comprehended in the two following Tables, we may consider the numbers composing them, as expressing, with sufficient exactness, the relative proportion of different gases in the residues of oil and coal gas left by the action of chlorine.

TABLE IV. *Showing the composition of* 100 *volumes of the gas remaining after the action of chlorine on oil gas.*

Exp.	Azote.	Carb. Hydr.	Carb. Oxide	Hydr. Gas.	Total.
1	7	30	15	48	100
2	5	40	15	40	100
3	5	65	20	10	100
4	5	75	15	5	100

TABLE V. *Showing the composition of* 100 *volumes of the gas remaining after the action of chlorine on coal gas.*

Exp.	Azote.	Carb. Hydr.	Carb. Oxide	Hydr. Gas.	Total.
1	1.5	94·5	4	0	100
2	6	82	2	10	100
3	2	66	14	18	100
4	5	60	12	23	100
5	10	20	10	60	100

It appears from the two foregoing Tables, that the portion of oil gas and coal gas, which is not condensible by chlorine, is in every case a mixed gas, consisting in most instances of carburetted hydrogen, carbonic oxide, and hydrogen, with a little azote, part of which may be traced to the impurity of the chlorine. In the best specimens of oil gas, the carbonic oxide is in greater proportion than in the best kinds of gas from coal, and the carburetted hydrogen is most abundant in the latter gas. This, however, is more than compensated, so far as their illuminating power is concerned, by the greater richness of the aëriform products of oil in that denser species of gas, which is separable by chlorine. The proportion of hydrogen, both in oil gas and coal gas, appears to increase as they are formed at a higher temperature, and is always greatest in the latter portions of the gas from coal. But no instance has ever occurred to me of a gas obtained from oil or from coal, which, after the action of chlorine upon it with the exclusion of light, presented a residuum at all approaching to simple hydrogen gas; nor do I believe that such a gas can be generated under any circumstances of temperature, by which the decomposition of coal or of oil is capable of being effected.

Inferences respecting the composition of that part of the gas from coal and oil, which is condensed by contact with chlorine.

When a given volume of a mixture of olefiant and carburetted hydrogen gases is fired with oxygen, and an equal volume of the same mixture is first deprived of olefiant gas by the action of chlorine, and then fired with oxygen, it must necessarily happen that the excess of oxygen spent in the first combustion, above that consumed in the second, will be three times the volume of the olefiant gas, and that the excess of carbonic acid formed in the first experiment above that generated in the second, will be double the volume of the olefiant gas. A remarkable anomaly however, was, during the last summer, observed by Mr. Dalton in the results of the combustion of a quantity of gas, which he had himself prepared from oil. One volume was found to consume three volumes of oxygen, and to yield little short of two volumes of carbonic acid, in those respects agreeing nearly with olefiant gas; but when mingled with more than the requisite proportion of chlorine, it was not, as olefiant gas would have been, entirely condensed, but suffered a diminution of only four tenths of its bulk, the remaining six tenths, after being freed from the redundant chlorine, agreeing in its properties with carburetted hydrogen. For example, 10 volumes of this gas (containing four of gas condensible by chlorine and six of carburetted hydrogen) consumed 30 volumes of oxygen, and gave 18 of carbonic acid. But of the oxygen, 12 volumes are due to the six of carburetted hydrogen, leaving 18 volumes for the combustion of the four volumes of gas condensible by chlorine, which is in the proportion of 4½ to 1. Of the 18 volumes of carbonic acid, also, six may be traced to the combustion of the carburetted hydrogen, leaving 12 volumes as the product of four of the condensible gas, or in the proportion of 3 to 1. The portion of gas, condensed by the action of chlorine presents, therefore, decided differences from olefiant gas, in requiring not three only, but 4½ volumes of oxygen for combustion, and in affording 3, instead of 2 volumes of carbonic acid. Nearly the same relation of the oxygen consumed, and carbonic acid produced, to that part of the gases from coal and oil which is condensible by chlorine, existed also not only in other experiments of Mr. DALTON, but in all those which I have myself made. The proportions I have found to vary in different cases from 4½ to 5 volumes of oxygen, and from 2½ to 3 volumes of carbonic acid for each volume of the condensible gas.

On comparing also the specific gravity of the gases from coal and oil, as ascertained by experiment, with that which ought to result from mixtures of the residue left by chlorine, with such a proportion of olefiant gas as is deducible from analysis, I have invariably found, that the real specific gravity has considerably exceeded the estimated. For instance, the London oil gas was composed of 38 volumes of a gas condensible by chlorine, and 62 volumes of mixed gases not characterized by that property, and having the specific gravity .606. But 62 volumes of gas of specific gravity .606, mixed with 38 volumes of olefiant gas of specific gravity .970, should give a mixture of the specific gravity .754, instead of .906, which was the actual specific gravity of the entire oil gas. It will be found on calculation that the 38 volumes of gas, in order to make up the real specific gravity of the oil gas, must have had the specific gravity of 1.4 very nearly. This is the highest number that is deducible from my experiments for the specific gravity of that portion of oil gas or coal gas, which is condensed by the action of chlorine. In other instances, it varied from that number down to 1.2, but in every case its weight surpassed that of common air.

It is evident from these facts that the aëriform ingredient of oil gas and coal gas, which is reducible to a liquid form by chlorine, is not identical with the olefiant gas obtained by the action of sulphuric acid on alcohol, but considerably exceeds that gas in specific gravity and combustibility. Two views may be taken of its nature; for it may either be a gas *sui generis*, hitherto unknown, and constituted of hydrogen and charcoal in different proportions from those composing any known compound of those elements;—or it may be merely the vapour of a highly volatile oil, mingled in various proportions with olefiant gas, carburetted hydrogen, and the other combustible gases. Of these two opinions, Mr. Dalton is inclined to the first, considering it as supported by the fact that oil gas, or coal gas, may be passed through water, without being deprived of the ingredient in question; and that this anomalous elastic fluid is absorbed by agitation with water, and again expelled by heat or other gases, unchanged as to its chemical properties, as we have both satisfied ourselves by repeated experiments. On the other hand, I have found that hydrogen gas, by remaining several days in narrow tubes in contact with fluid naphtha, acquires the property of being affected by chlorine precisely as if it were mixed with a small proportion of olefiant gas; and I am informed by Dr. Hope, that oil gas, when forcibly compressed in Gordon's portable gas lamp, deposits a portion of a highly volatile essential oil. The smell also of the liquid which is condensed on the inner surface of a glass receiver, in which oil gas or coal gas has been mixed with chlorine, denotes the presence of chloric ether, evidently however mingled with the odour of some other fluid, which seems to me to bear most resemblance to that of spirit of turpentine. This part of the subject is well worthy of farther investigation; but having devoted to the enquiry all the leisure which I am now able to command, I must remain satisfied at present with such conclusions as are safely deducible from the foregoing investigation. These may be briefly recapitulated as follows:

1. That carburetted hydrogen gas must still be considered

as a distinct species, requiring for the perfect combustion of each volume two volumes of oxygen, and affording one volume of carbonic acid; and that if olefiant gas be considered as constituted of one atom of charcoal united with one atom of hydrogen, carburetted hydrogen must consist of one atom of charcoal in combination with two atoms of hydrogen.

2. That there is a marked distinction between the action of chlorine on olefiant gas, (which, in certain proportions, is entirely independent of the presence of light, and is attended with the speedy condensation of the two gases into chloric ether), and its relation to hydrogen, carburetted hydrogen, and carbonic oxide gases, on all which it is inefficient, provided light be perfectly excluded from the mixture.

3. That since chlorine, under these circumstances, condenses olefiant gas without acting on the other three gases, it may be employed in the correct separation of the former from one or more of the three latter.

4. That the gases evolved by heat from coal and from oil, though extremely uncertain as to the proportions of their ingredients, consist essentially of carburetted hydrogen, with variable proportions of hydrogen and carbonic oxide; and that they owe, moreover, much of their illuminating power to an elastic fluid, which resembles olefiant gas in the property of being speedily condensed by chlorine.

5. That the portion of oil gas and coal gas, which chlorine thus converts into a liquid form, does not precisely agree with olefiant gas in its other properties; but requires, for the combustion of each volume, nearly two volumes of oxygen more than are sufficient for saturating one volume of olefiant gas, and affords one additional volume of carbonic acid. It is

probably, therefore, either a mixture of olefiant gas with a heavier and more combustible gas or vapour, or a new gas *sui generis*, consisting of hydrogen and charcoal, in proportions that remain to be determined.

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