XVIII. *Description of an Apparatus for the Analysis of the Compound Inflammable Gases by slow Combustion; with Experiments on the Gas from Coal, explaining its Application. By* William Henry, *M. D. Vice-Pres. of the Lit. and Phil. Society, and Physician to the Infirmary, at* Manchester. *Communicated by* H. Davy, *Esq. Sec. R. S.*

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The aëriform compounds of hydrogen and carbon, which were already entitled to accurate investigation, as objects of scientific research, have derived an additional claim to the attention of the chemist, from their application to an important economical purpose, described in a late communication to the Royal Society.* Yet there is, perhaps, no part of chemistry, the investigation of which is beset with greater difficulty, or with more numerous sources of error; insomuch, that the actual state of the science enables us to attain scarcely more than approximations to the truth, and degrees of probability of greater or less amount. It was the object of the experiments, which are described in the following pages, rather to remove some of the obstacles, which present themselves to a successful enquiry into the nature of these bodies, than to acquire such facts, as may enable the chemical philosopher to decide the controverted question respecting their composition. Results, sufficiently multiplied

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* See Mr. Murdoch's paper, p. 124.

and precise for this purpose, would require a larger appropriation of time, than I have the prospect of being able to bestow; and I can only on the present occasion, offer an example of the method, in which it appears to me that the analysis of this class of substances will be most successfully attempted.

When a vegetable substance, composed (as may be assumed to simplify the statement) of oxygen, hydrogen, and carbon, united in the form of a ternary compound, is submitted to distillation, at a temperature not below that of ignition, the equilibrium of affinities, which constituted the triple combination, is destroyed; and the elements, composing it, are united in a new manner. Those, which are disposed to enter into permanently elastic combinations, escape in the state of gas. The carbon, uniting with oxygen, either composes carbonic acid gas, or, stopping short of that degree of oxygenation, which is essential to change it into an acid, is converted into carbonic oxide. The hydrogen, combining with a portion of carbon, constitutes a binary compound of those two ingredients, forming either what has been called *carbureted hydrogen gas*, or *super-carbureted hydrogen*, better known by the appellation of *olefiant gas*. Towards the close of the process, a portion of simple hydrogen gas is also mingled with the products. Perhaps in no instance is any one of the gases, which have been enumerated, obtained perfectly pure, by the distillation of a vegetable substance. The aëriform fluids, which are thus generated, are found to be possessed of almost every degree of specific gravity; and to yield, by combustion, extremely different results, according to the temperature at which they have been formed; the stage of the process at which they have been separated; and other modifying circumstances. It becomes an interesting question, whether these gases, so much diversified in their physical and chemical properties, are mixtures of a few binary compounds, with which chemists are already acquainted; or whether, on the contrary, their elements are capable of uniting in indefinite proportions, and of composing ternary compounds of oxygen, hydrogen, and carbon, or varieties of *oxy-carbureted* hydrogen. It would encroach too much on the time of the Royal Society, to enter upon this controversy. And, as neither opinion admits, at present, of demonstrative evidence, I may be permitted, in explaining the following experiments, to assume that theory, which appears to me most probable; viz. that the aëriform products of the distillation of vegetable substances, are mixtures of carbonic acid, carbonic oxide, olefiant, carbureted hydrogen, and simple hydrogen gases; or of two or more of these in various proportions.

The analysis of these compound gases has hitherto been attempted solely by their rapid combustion with oxygen gas, in the following manner: a mixture of the inflammable gas with oxygen gas in known proportions, is admitted into a Volta's Eudiometer, inflamed over mercury by the electric spark; and the diminution ascertained. To the remainder caustic potash or lime water is added, by which it sustains a second diminution of bulk; and the amount of this denotes the quantity of carbonic acid formed by the combustion. The quantity of nitrogen gas, in the oxygen employed, as well as in the residue left by potash, being determined by a fit eudiometrical test, it is easy to infer what quantity of oxygen has been absorbed by the detonation. And as it is proved that oxygen gas sustains no change of bulk by conversion into carbonic acid, we may conclude that, after deducting from the volume of oxygen gas expended, that of the carbonic acid which has been formed, the remaining number shews how much oxygen has been employed in the saturation of hydrogen. If, for example, 100 measures of carbureted hydrogen consume 200 of oxygen gas, and give 100 of carbonic acid, it follows, that the carbonic acid holds in combination 100 measures of the oxygen gas consumed; and that the remaining hundred have been applied to the saturation of hydrogen. In this estimate it is assumed, that the carbon has acquired, by combustion, the whole of the oxygen necessary for its acidification, and that no part of it existed previously in the state of carbonic oxide, a proposition, in many cases, perhaps, very far from being consistent with the truth. This, however, admits of being decided by an accurate comparison between the weight of the gases consumed and that of the products.

For the purpose of obtaining a general approximation to the nature of a combustible gas, it may be sufficient to examine its coincidence with those, the properties of which have been already determined. The following table exhibits the results of the combustion of the few gases, that appear entitled to be considered as distinct species. They are deduced from the experiments of Mr. CRUIKSHANK and Mr. DALTON.

Kind of Gas.	Sp. Grav. (air = 1000.)	100 measures,		
		Take meas. of oxygen.	Give carb. acid.	Are diminished by firing.
Olefiant	909	300	200	200
Carbonized hydrogen, from stagnant water,	600	200	100	200
Carbonic oxide	967	45	90	55
Hydrogen gas	84	50		154

The inflammability of the compound gases, and their fitness for the purpose of affording light, are directly proportionate to the quantity of oxygen required for their saturation. The olefiant gas, therefore, burns with the greatest brilliancy; carbureted hydrogen gas, though inferior, affords a dense and compact flame; but the carbonic oxide and hydrogen gas are entirely unfit to be employed as the means of artificial illumination.

In the execution of a series of experiments on the compound combustible gases, which are described in the 11th volume of Mr. Nicholson's Philosophical Journal, I had reason to be dissatisfied with the above method of effecting their decomposition, and to distrust the results which were obtained. The products of the combustion of the same gas varied considerably in different experiments; and, with respect to some, it was evident that the full proportion of their carbonaceous ingredient was not oxygenised, in consequence of the precipitation of charcoal in the act of detonation. The quantities, also, that can be submitted in this way to experiment, are extremely minute; and the inflammation of highly combustible gases is attended, as I have more than once experienced, with considerable danger from the bursting of the glass tubes. It was desirable, therefore, to employ a process not liable to these objections; and after many alterations of the apparatus, contrived with this view, I at length fixed upon one, which I shall now proceed to describe.

The principal parts of the apparatus, are two glass cylinders, or air receivers,* *b b* and *o o*, of which the larger one is intended to contain oxygen gas, and the smaller one, the inflammable gas submitted to experiment. They are connected

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* I am indebted to Mr. H. Creighton, of Soho, not only for a drawing of the apparatus but for much valuable assisance in the performance of the experiments.

by a bent glass tube *s s*, the diameter of which should not be less than $\frac{1}{10}$ of an inch, to the upper extremity of which is cemented an iron burner, *t*, the orifice of which is about $\frac{1}{30}$ of an inch, while to the lower end a socket is fixed, on which may be occasionally screwed the cock *r*. The receiver *o o* is contained in a larger glass jar *n n*, and is closed at the top by a brass cap *p*, and stop cock *q*. The oxygen gas receiver is, also, closed by a brass cap *e* and cock *f*, the lower orifice of which is tapped internally, for the purpose of receiving a small screw at the end of the copper wire *g*. This wire is in two parts, each of which screws into a moveable socket, connecting the two; and, by this contrivance, the wire may be lengthened or shortened at pleasure. To prepare the apparatus for use, the receiver *o o* is partly filled with the combustible gas; and is secured by wedges of cork *v v*, in the jar *n n*, the level of the water in the latter being regulated by opening the cocks *x* or *z*. The bent pipe *s s*, with its cock *r*, is screwed upon the top of the receiver, and partly immersed in the water of a pneumatic cistern, *a a*, so that the orifice of the burner may rise a few inches above the surface of the water. The receiver *b b* detached from the situation in which it is represented in the drawing, is then exhausted by an air pump; and, being filled with oxygen gas, is transferred (its mouth being closed during the act of removal with a piece of leather) to the cistern *a*, and quickly inverted over the burner *t*. By a little practice, this may be done with the admission of very little common air. A transferring vessel is then screwed upon the cock *f*; and a portion of oxygen gas removed for eudiometrical examination. To allow room for the expansion of the oxygen gas, the water is raised by a syphon to a proper height within the receiver *b*, as appears in the drawing.

The apparatus being thus disposed, the cock *f* is connected by the chain *h*, with the prime conductor of an electrical machine; and a rapid succession of sparks is made to pass between the copper ball at the end of the wire *g*, and the orifice of the burner. The cocks *q* and *r* being now opened, the stream of gas is kindled; and in order to prevent the flame from playing upon the wire, the jar *n n* is moved a little nearer to the cistern *a*, which brings the point of the burner into the axis of the receiver. At the same time, by opening the cock *x*, water flows into the jar *n n*, and finds its way into the receiver, through two small holes *w w* drilled near its mouth.

The combustion continues, until either the whole of the inflammable gas is consumed, or till the cocks *q* and *r* are shut. The wedges *v v* are removed; the receiver *o o* unscrewed; and the bent tube removed from its place It is at this moment, that the cock *r* is useful, by preventing the escape of the gas from the receiver *b* through the tube *s s*. The upper part of the receiver is cooled by the application of a wet sponge. Without waiting, however, till the gas has attained the temperature of the atmosphere, a very small and sensible thermometer is introduced into it; and the height of the mercury is noted, as soon as it becomes stationary. The volume of the residuary gas is then observed, and is reduced by calculation, to the bulk which it would occupy at 60° of FAHRENHEIT. Either the whole, or an aliquot part of it, is removed by a transferring vessel, screwed upon the cock *f*, to a mercurial cistern, where the proportion of carbonic acid is determined by liquid potash. The proportions of oxygen and nitrogen gases, in the unabsorbed residue, are learned by agitation with sulphuret of lime, observing the precautions which have been stated by De Marti. The residuary oxygen being deducted from the quantity at the outset of the experiment, shews how much oxygen has been expended in the combustion of the inflammable gas. It is scarcely necessary to observe, that the gases are carefully reduced, at each stage of the operation, to a mean temperature and pressure, (60° of the thermometer, and 30 inches of the barometer).*

The process of combustion, as thus stated in general terms, appears sufficiently simple. It is often, however, rendered complicated by the imperfect combustion of the inflammable gas, a part of which escapes through the orifice of the burner, either wholly unaltered, or only partially burned. As this portion is not absorbed by sulphuret of lime, it gives a fallacious appearance of an actual addition of nitrogen to the oxygen gas remaining in the receiver *b*. I am unacquainted with any method of entirely obviating this difficulty; but its amount may be diminished by an attention to certain precautions. With this view, the pressure upon the gas, contained in the receiver *o o*, should, on first opening the cocks *q* and *r*, be no more than is sufficient for its gentle expulsion through the tube *s s*. When, however, the stream is once kindled, the larger the flame, and the more active the combustion, within certain limits, the more completely is the gas consumed. It is necessary, also, to stop the combustion, before it is rendered

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* The rules observed in these calculations, are stated in my Epitome of Chemistry, 5th edition, p. 441.

languid by the admixture of carbonic acid with the gas in the receiver *b*, and by the diminished purity of the oxygen gas. If this be not attended to, a large proportion of the inflammable gas, towards the close of the process, makes its escape unaltered into the receiver *b*. In general I have found, that setting out with oxygen gas of equal purity, the more combustible the inflammable gas submitted to experiment, the more complete is its decomposition by slow combustion. The apparatus, therefore, is better adapted to the analysis of olefiant gas, of carbureted hydrogen gas, or of mixtures of these two, than of carbonic oxide, or any gas of which that oxide forms a large proportion.

The inflammable gas, which has found its way into the receiver *b*, is always present in too minute a quantity to compose, with the residuary oxygen, after the removal of the carbonic acid, a mixture capable of being inflamed by the electric spark. To ascertain its precise quantity, it is necessary to have recourse to another operation. After trying, eudiometrically, the quality of an aliquot part of the gas in the receiver *b*, let a similar aliquot part be deprived of its carbonic acid, and then mixed with a portion of pure hydrogen gas, not exceeding one third or one fourth the estimated bulk of the oxygen which it contains. Detonate the mixture, and observe the amount of the diminution after the explosion; the products of the combustion; and the quantity of oxygen gas consumed. After subtracting, from the total expenditure of oxygen, half the bulk of the added hydrogen gas, the remaining number shews how much oxygen has been absorbed by the combustible gas contained in the residue. By the rule of proportion, it may be determined, how much carbonic acid would have been produced, by the oxygenation of the whole of the combustible gas, and what quantity of oxygen it would have saturated.

The most obvious objection to this method of analyzing the compound gases is, that the real proportion of the products, resulting from their combustion, may perhaps be disguised, in consequence of the absorption of a part of the carbonic acid by the water, over which the experiment is made. By frequent trials, however, I find that this is a source of error too trivial to be deserving of consideration; and that the proportion of carbonic acid, thus generated, exceeds what is composed by the rapid combustion of the same gas over mercury. When the operator has acquired sufficient dexterity, the interval of time, between the completion of the combustion and the admeasurement of the residue, is too small to allow an absorption to any notable amount. It must be observed, also, that the carbonic acid constitutes only a small part of the residue; and is, for that reason, very little acted on by water, conformable to a principle which I have explained in the Philosophical Transactions for 1803, p. 274. I believe, therefore, that with an attention to those observances, which are required in all delicate experiments on gases, and to the changing circumstances of temperature and pressure, this apparatus is fully adequate to the purpose for which it is intended. It will be easy, however, for those who have the command of a sufficient quantity of mercury, to adapt the apparatus to that fluid. As an exemplification of the method of using it, in the simplest possible case, I shall state the results of the combustion of hydrogen gas,

At the outset of the experiment, there was contained in the receiver *o o*, a quantity of hydrogen gas, equal, when reduced to a mean temperature and pressure, to 15.8 cubic inches

Of these, there remained unconsumed 2.5

Hydrogen gas burned - - 13.3

In the receiver *b* were 49 cubic inches of oxygen gas, consisting of - - 33.5 oxygen, 15.5 nitrogen

At the close of the experiment, there remained, in *b*, 43.5 *c. i.* composed of - - } 27.25 16.25

Cubic inches of oxygen gas consumed - - - } 6.25

But estimating from the first diminution (viz. 49—43·5) only 5.5 cubic inches of oxygen would appear to have been absorbed; and the nitrogen gas, by eudiometrical experiments, would seem to have been increased 0.75 of an inch. As the hydrogen gas, however, had been prepared from zinc and sulphuric acid with extreme caution, and did not contain an appreciable quantity of common air, no such addition of nitrogen could have taken place. The apparent increase, then, may be fairly imputed to the escape of 0.75 of an inch of hydrogen gas, which is to be deducted from the 13.3 cubic inches at the outset of the experiment; and hence the real quantity consumed will be 13.3 — 0.75 = 12.55. The true consumption, also, of oxygen gas was 5.50 + 0.75 = 6.25, or pretty exactly, as it ought to be, half the bulk of the hydrogen gas, which was actually burned.

An example of the analysis of a highly combustible species of elastic fluid is furnished by the following experiments on the olefiant gas, obtained from alcohol and sulphuric acid.

Of this gas 100 cubic inches, at a mean of the barometer and thermometer, were equal to 30 troy grains; hence its specific gravity was 967.

In the receiver *o o*, were contained of this gas	6.3 cub. in.
Residue	2
Gas consumed - - - -	4.3

In the receiver *b*, were 43.4 inches of oxygen gas. After the combustion, there remained 38.2 cubic inches of mixed gases, of which 8.6 were carbonic acid. None of the inflammable gas, which passed through the bent tube, had escaped being burned, for the quantity of gas in *b*, not absorbable by sulphuret of lime, so far from having been increased, was found to have sustained a trifling diminution. The oxygen gas, which was consumed, amounted to 13.8 cubic inches. Reducing these results to centesimal proportion, 100 cubic inches of this gas would give 200 of carbonic acid, and absorb 325 of oxygen gas. This experiment agrees with Mr. Dalton's, as to the proportion of carbonic acid from the combustion of olefiant gas, but assigns a larger consumption of oxygen. It may be observed, however, that the specific gravity of the gas, which I employed, exceeded a little the statement of the Dutch chemists, who found its specific gravity to be 909, common air being 1000.

Having satisfied myself, by repeated experiments, of the accuracy of the results which may be thus obtained, I proceeded to the combustion of the gases from a variety of vegetable substances, and especially from those which it seemed probable might become economical sources of light. In the present memoir, I shall describe those only, which were made on coal and a few similar substances, reserving the rest for a future communication.

Gas from Cannel Coal.

This was received in two separate portions. Of the first product, 100 cubic inches, corrected to a mean temperature and pressure, weighed 24.28 grains. Hence its specific gravity was to that of atmospheric air as 783 to 1000. The second product was much lighter, 100 inches weighing only 10.4 grains, and having, therefore, the specific gravity of 335. The results are comprehended in the following table. The carbonic acid, stated to have been generated by the second combustion, was formed by adding to an aliquot part of the residue, after the removal of the carbonic acid, a proportion of hydrogen gas; detonating the mixture by the electric spark; and proceeding as already directed. The two first lines contain the minutes of actual experiments; the third and fourth these results reduced to centesimal proportion.

Sp. Grav.	Cub. inches burned.	Oxyg. gas. consumed.	Carb. acid. generated.	Carb. acid formed by second combustion.	Oxygen consumed by second combustion.	Total oxygen consumed.	Total, carb. acid formed.
783	7.3	16.5	8.3	1.9	0.9	17.4	10.2
335	9.8	9.4	4.8	0	0	9.4	4.8
783	100	222	113.7	2.6	12	234	139.7
335	100	96	49	0	0	96	49

The early product of the gas from cannel coal, before being washed with lime water or caustic potash, is a mixture of several different gases, viz. carbonic acid, sulphureted hydrogen, olefiant, and a fourth, which is either a gas *sui generis*, or a mixture of carbureted hydrogen, and carbonic oxide. To ascertain the proportion of these gases in any mixture, is a problem of some difficulty. Sulphureted hydrogen and olefiant gases experience, it is well known, an immediate condensation, when mingled with oxy-muriatic acid gas, and in this way they may be separated from carbonic acid. Again, sulphureted hydrogen and carbonic acid are absorbed by liquid potash, which has no action on olefiant gas. If, therefore, two equal portions of the gas from coal be mixed with oxy-muriatic gas, the one in its recent state, the other after being washed with potash, the condensation of the former will be found to exceed that of the washed portion. By the combined use of these agents, we may attain an approximation, at least, to the proportions in which carbonic acid, olefiant, and sulphureted hydrogen gas are mingled with the aëriform product of coal. The rule may be stated as follows; to a measured quantity of oxy-muriatic acid gas, contained in a graduated tube, add twice its bulk of the recent coal gas, and at the expiration of one or two minutes observe the diminution which has taken place. Wash an equal quantity with caustic potash; note the loss; and submit the residue to the action of oxy-muriatic acid as before. The second diminution, thus effected by oxymuriatic gas, divided by 2.2, gives the proportion of olefiant gas. Deduct this absorption from the first, and, dividing the remainder by 1.8, we obtain the quantity of sulphureted hydrogen. Lastly, to know the quantity of carbonic acid gas, substract, from the diminution effected by potash, the amount of the sulphureted hydrogen gas. An example, taken from actual experiment, will best explain the application of this rule.

One hundred measures of the first product of gas from cannel coal lost, by agitation with liquid potash, 9.7 measures.

The remainder, being mingled with one fourth its bulk of oxy-muriatic acid gas, the mixture lost 10.4 measures. This diminution, 10.4, divided by 2.2, gives 4.9 for the proportion of olefiant gas. But 100 measures of the unwashed gas sustained, by admixture with oxy-muriatic acid, a diminution of 20 measures. Now, deducting, from this diminution, that occasioned by the condensation of olefiant gas, (viz. 20 — 10.4,) there remain 9.6, which, divided by 1.8, gives 5.3 for the proportion of sulphureted hydrogen gas. And the diminution by potash (= 9.7) — 5.3 gives 4.4 for the proportion of carbonic acid gas. Hence 100 measures of the first product of gas from cannel coal contain,

1. Of inflammable gas, not affected by the foregoing agents - -	85.4
2. Of sulphureted hydrogen gas, -	5·3
3. Of olefiant gas - - -	4·9
4. Of carbonic acid gas - - -	4·4
	100

The proportion of common air, in the foregoing specimen of gas, and in all cases when care was taken to exclude it, was too small to deserve being taken into the account, not appearing, by the test of nitrous gas, to exceed 1 per cent.

The following table exhibits the composition of gas from various kinds of coal. In the last column, under the term inflammable gas, is comprehended that portion, which is neither suddenly condensed by oxy-muriatic acid gas, nor absorbed by potash. A name more descriptive cannot be applied to it, because it varies essentially in different cases, and the proportion of its components is still matter of doubt.

TABLE I.

Kind of Coal.	No. of the product.	One hundred measures consisted of			
		Sulph. Hydr.	Carb. acid.	Olefiant.	Inflam.
Wigan cannel.	1	5.3	4.4	4.9	85.4
	2	0.	1.8	0.	98.2
Wednesbury, Staffordshire.	1	4.9	3.4	0	91.7
	2	0.	2.8	0	97.2
Newcastle on Tyne.	1	2.9	2.8	2.7	91.6
	2	2.2	1.7	0	96.1
Newcastle, Staffordshire.	1	3	2.7	0	94.3
	2	1.4	2	0	96.6
	3	0	1.4	0	98.6
Middleton, near Leeds.	1	3	2.	1	94
	2	1.4	1.7	0	96.9
	3	0	2	0	98.
Black Mine, near Manchester.	1	3.3	3.2	2.5	91
	2	2	1.1	0	96.9
	3	2	1.	0	97
	4	0.5	1.2	0	98.3
	5	0	1.2	0	98.8
	6	0	0	0	100
Merthyr, Glamorganshire.	1	1	1.7	0	97.3
	2	0	1.7	0	98.3
	3	0	1.6	0	98.4
	4	0	1.5	0	98.5
	5	0	1.	0	99
	6	0	0	0	100
Native coal tar.	-	13	6	15	66
Caoutchouc.	-	0	4.9	17	78.1

After separating the sulphureted hydrogen and carbonic acid gases by agitation with liquid potash, the residue, consisting of the inflammable gas mixed with the proportion of olefiant gas produced along with it, was submitted to combustion. The following table shews the average results of a number of these experiments.

TABLE II.

Kind of Coal.	No. of the product.	Weight of 100 cubic inches (Ther. 60°. Bar. 30.)	Spec. Grav. (Air 1000.)	100 cubic inches	
				consume oxyg. gas.	give carbonic acid.
Wigan cannel,	1	24.28 Grs.	783	234	139·7
	2	10.4	335	96	49
Wednesbury coal,	1	20.9	674	190	97·5
	2	9.8	316	85	46
Newcastle on Tyne,	1	19.3	622	190	100
	2	9.8	316	86	45
Newcastle Stafford-shire,	1	19.6	632	195	98
	2	17.7	570	165	80
	3	12.1	390	100	60
Leeds,	1	20.7	670	190	100
	2	15·1	487	lost by accident.	
	3	9.8	316	85	42
Black-Mine, Lanca-shire,	1	19·4	627	186	97
	2	15	484	137	65
	3	11.3	364	100	50
	4	10	322	90	47
	5	9·5	307	85	45
	6			80	40
Merthyr,	1	12	387	117	62
	2	9·5	307	90	47
	3	8	261	75	39
	4	5·9	190	60	31
	5	5·8	187	57	26
	6	5·5	177	50	20
Coal tar,	–	24.2	780	233	150
Caoutchouc.	–	—	—	204	121

An attentive examination of the results, contained in both the tables, suggests the following general remarks.

1. The olefiant gas is a very sparing product of the distillation of pit-coal. It is found only in the first portions, and even of these it does not compose more than 5 per cent. Its quantity, however, is very much influenced by the temperature employed. This remark, indeed, may be extended to all the aëriform products of coal; insomuch that from equal weights of the same coal it is difficult to obtain by different operations conducted on a small scale, products which are the

same either in quantity or quality. The gas from *Coalbrookedale* tar, and that from *Caoutchouc*, have a larger proportion of olefiant gas, which in them amounts to about one-sixth their bulk.

2. Sulphureted hydrogen gas is, also, most abundantly produced at the early stages of the distillation. Its proportion then varies from 1 to 5 per cent; and towards the close of the process it disappears entirely. It increases the illuminating power of the coal gas; but is by no means a desirable product; since it yields by combustion, a gas (the sulphurous acid) which is extremely offensive and irritating to the lungs. By the distillation of coal, more sulphureted hydrogen is pro-produced, than is discovered among the aëriform products; for a part, uniting with the ammonia which is generated at the same moment, forms sulphuret of ammonia, a compound which I have found among the condensed products.

3. Carbonic acid gas, like the two preceding ones, appears only at an early stage of the process, and in small proportion, never amounting to 5 per cent. A portion of this gas, also, unites with ammonia, and hence carbonate of ammonia is found in the condensed fluid.

4. The gas from coal undergoes a gradual diminution of specific gravity and combustibility, from the commencement to the close of the process. This is best shewn by inspecting the results of the experiments on the *Black-Mine* and *Merthyr* coal gas in Table II. because they were reserved in a greater number of separate portions than usual. The progression would, perhaps, have been more regular, in these as well as in the other instances, if much of the gas had not been allowed to escape, in consequence of the immense quantity

which was produced. The specific gravity of the coal gas appears to afford a measure of its fitness for illumination, sufficiently accurate for practical uses ; but does not bear an exact correspondence to the chemical properties of the gas, as ascertained by combustion. It may be remarked, also by comparing the two last columns of the second table, that the carbonic acid produced does not always bear the same proportion to the oxygen expended. Thus the first product of gas from cannel coal combines with 234 measures of oxygen gas ; and gives 139.7 of carbonic acid. But the gas from coal tar, with only an equal consumption of oxygen, yields 150 measures of carbonic acid.

5. The aëriform product of coal does not precisely answer to the characters of any one of the combustible gases, with which we are acquainted. The first product, however, of the distillation of common pit coal, after being washed with potash, approaches very nearly in its properties to carbureted hydrogen gas. The gases, which surpass this in specific gravity, are mixtures of carburetted hydrogen with olefiant gas, and perhaps a small proportion of carbonic oxide. The lighter gases, in addition to carbureted hydrogen, probably contain a variable proportion of hydrogen gas and a small quantity of carbonic oxide. The extreme levity of some of the products, especially of the gas from *Merthyr* coal, cannot be explained on any other supposition.

6. The products of the combustion of a cubic foot of coal-gas, of medium quality, viz. of the specific gravity 622, (such as the first products from *Newcastle on Tyne* coal) may be stated as follows:

	Grains.
A cubic foot, at a mean of the barometer and thermometer, - - - -	333.5
By combustion, it yields 817.3 grains of carbonic acid, the carbon in which may be estimated * at	233.7
Grains of hydrogen in a cubic foot of coal gas	99.8

But 99.8 grains of hydrogen are equivalent to the saturation of 554.9 grains of oxygen, with which they form 654.7 grains of water. Hence the oxygen consumed ought from calculation to be $817.3 - 233.7 = 573.6 + 554.9 = 1128$

And the quantity actually consumed appears by experiment to be - - -	1110.3
Error	17.7

The difference, in this example, between experiment and calculation is not greater, than, in such delicate processes, may always be expected. A part of the deficiency in the oxygen actually consumed may be ascribed, also, to a small portion of the inflammable gas being already in the state of carbonic oxide.

Without repeating the particulars of a similar calculation made on gas of inferior quality, I shall annex a comparative statement of the specific gravities and composition of the good and inferior gases.

Source of the Gas.	Weight of a Cubic Foot.	A Cubic Foot consists of		Oxygen Gas consumed by a Cubic Foot.	Gives	
		Carbon.	Hydr.		Carb. Acid	Water
Newcastle coal	333.5gr.	233.7	99.8	1110.3	817.3	621
Ditto, last product	169.3	111.5	57.8	560.	400	384.9

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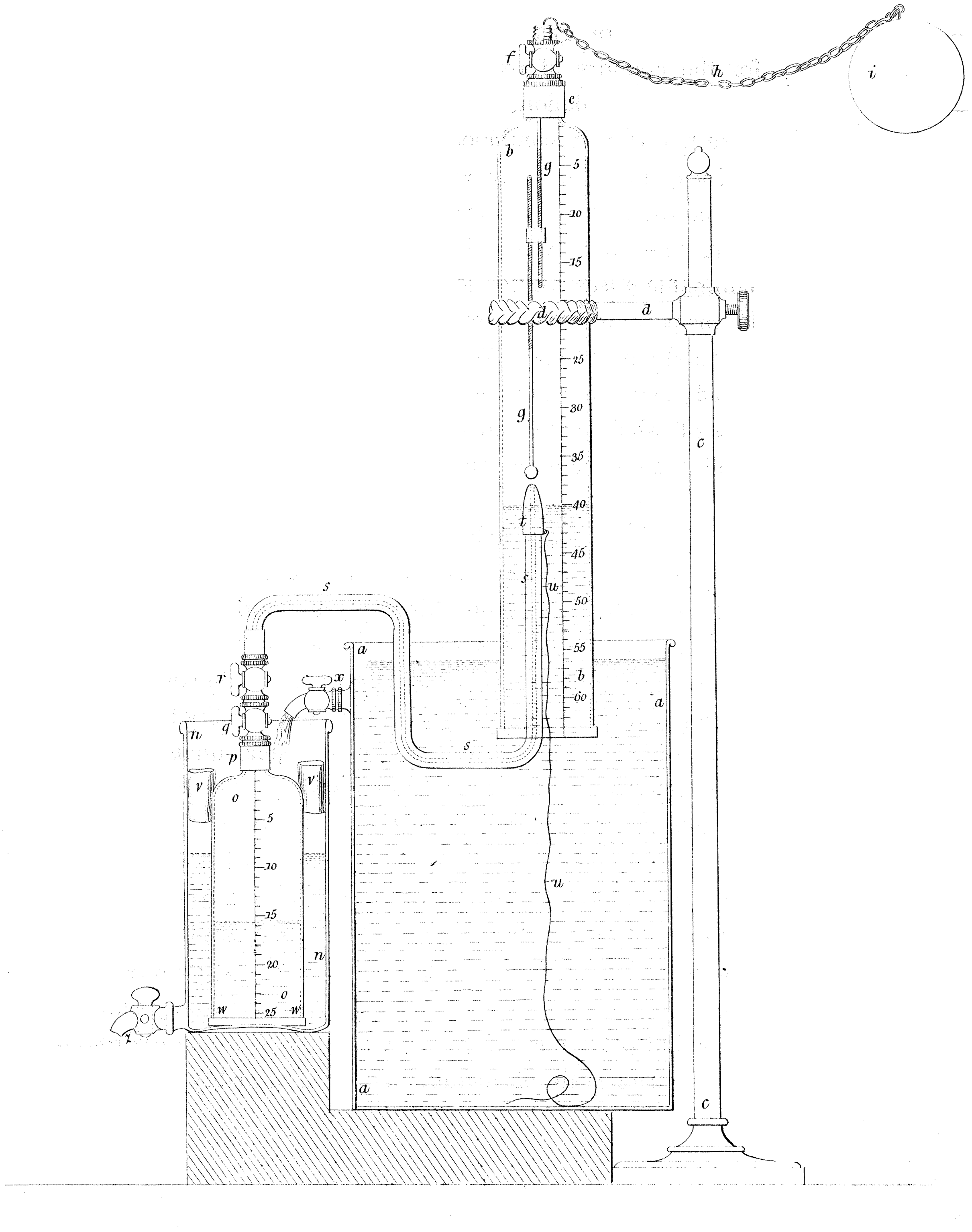
* Assuming the carbon to be 28.6 grains in 100 grains of carbonic acid, as is satisfactorily proved by the experiments of Messrs. ALLEN and PEPYS.

The inferior gas, also, probably contains carbonic oxide; for the quantity of oxygen gas, actually consumed, will be found, on calculation, less than it ought to be, if the carbon were not already combined with a portion of oxygen.

The quantity of water, which was generated by combustion, was not determined experimentally, but is merely estimated. It must be acknowledged that the decomposition of the inflammable gases cannot lead to unquestionable results, until the proportion of water, produced by their combustion, be also accurately ascertained. With the view of effecting this, I have already spent much time, and employed many contrivances, none of which have satisfactorily answered the purpose for which they were intended.

7. There appears to be a considerable difference in the specific gravity and combustibility of gas from various specimens of coal, even when taken at similar periods of the distillation. The coal from Merthyr in South Wales, which burns without flame or smoke, yields a gas which contains, in an equal volume, scarcely half as much combustible matter as the gas from Wigan cannel. This will probably be found to be the case with respect to all coal of similar quality, among which may be reckoned the Kilkenny coal. The most important difference among the varieties of this mineral, connected with their application as sources of light, consists in the quantity of sulphureted hydrogen gas, which is mixed with their aëriform products; and it unfortunately happens that the coal, otherwise best adapted to this purpose, yields generally the largest proportion of this offensive gas. The only effectual method of purifying the coal gas from sulphureted hydrogen, on the large scale of manufacture, will probably be found to

Philos. Trans. MDCCCVIII. *Plate* VIII. *p.* 302.



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consist in agitation with quicklime and water, composing a mixture of the consistence of cream. Simple washing with water by no means effects the complete separation.

In the experiments which were made on the products of the distillation of coal, I purposely neglected the amount and analysis of the condensible fluids, because they cannot be advantageously ascertained by the same operation with the elastic ones. They may also be much better determined on the large scale of manufacture, than by limited experiments. For the same reason I was not solicitous to measure even the aëriform fluids; and on this subject, I believe, more accurate information has been communicated by Mr. MURDOCH, than it was in my power to acquire.

Manchester, May 19, 1808.