

December 6, 1860.

Major-General SABINE, Treasurer and Vice-President,
in the Chair.

The Chairman announced that the President had appointed the following Members of the Council to be Vice-Presidents :

The Treasurer.

Sir John P. Boileau, Bart.

Thomas Graham, Esq.

Sir Henry Holland, Bart.

The Earl de Grey and Ripon was admitted into the Society.

In accordance with Notice given at the last Ordinary Meeting, the Right Hon. George Granville Francis Egerton, Earl of Ellesmere, was proposed for Election and immediate ballot.

The ballot having been taken, his Lordship was declared duly elected.

The following communications were read :—

- I. "On Coal-Gas." By the Rev. W. R. BOWDITCH. Communicated by Professor WILLIAM THOMSON. Received June 10, 1860.

A distinguished Fellow of the Royal Society discovered coal-gas, when Rector of Crofton, about two miles from my present parish, and nearly all our knowledge of this complex substance is derived from the labours of chemists who have been, or are, Fellows of the Society. I feel assured, therefore, that an attempt to extend the knowledge of the reaction of coal-gas with various substances will be favourably received, and that the application to practice of the facts made known, will not render a memoir less acceptable to the Society which rewarded alike the abstract researches of Leverrier and the practical ones of Arnott.

Six years ago I introduced the use of clay into gas-works, for the purpose of improving the purification of coal-gas, and now,—after so long an experience, the purification of many hundreds of millions of

feet of gas, and the use of many thousand tons of the refuse as manure,—I venture, for the first time, to submit the grounds upon which my process is based.

Coal-gas may conveniently be considered under the heads of carbon compounds required for the production of heat and light, which generate water and carbonic acid by their combustion; and sulphur and nitrogen compounds which are not necessary for heat and light, and ought to be removed from gas on account of the injurious nature of the substances produced by their combustion.

The former of these classes will be treated of incidentally; the latter class forms the principal subject of this paper. When speaking of *gas*, I always refer to that which has undergone the ordinary condensation of gas-works, wherefore no mention is made of the complex compounds removed by condensation.

When coal is distilled, its nitrogen is evolved in some forms of combination which are generally familiar, while others are almost unsuspected. Under certain conditions of distillation, much nitrogen leaves the retorts and passes the condenser as ammonia or some of its salts. These are all removed from gas by clay, so that no trace of ammonia can be discovered after gas has passed through purifiers charged with an adequate quantity of clay, and with lime or some equivalent substance to remove sulphide of hydrogen. Clay is thus entitled to be classed with acids and some metallic salts as a purifier of gas, for these, of course, remove ammonia and its salts. But between clay and acids there is an important difference, in regard to the action which takes place upon the most valuable light-giving constituents of the gas; acids remove a large quantity of these, clay does not. We have experimental proof that clay does not remove the valuable hydrocarbon vapours from gas, in the fact that strong spirit of wine digested upon foul clay for days, does not thereby become much more luminous than it was before being so treated. The very slight light-giving power which it has obtained is due to tar; for if the spirit be evaporated, and the tar so obtained be redissolved in fresh spirit, the same kind of flame will be obtained as before; whereas the addition of a small portion of coal-oil to spirit gives a flame of considerable illuminating power. To this I may add, that long and extensive experience shows that the employment of clay in the purifying process improves the light-giving power of gas, by

removing substances which are not otherwise removed, and which, if allowed to be burnt with the gas, lessen its illuminating power. These light-damaging compounds are produced during the later portion of the distillatory process, as I have proved by experiment. The same retort was charged twice with the same weight of the same coal. The gas produced by one charge was purified by lime only, that produced by the other charge was purified by lime and clay. The illuminating power of the gas passing at each half hour's end was determined, and it was found that the purification made no difference for the first three or four half-hours. About the middle of the charge, that purified by my process had slightly the advantage, and at the close the difference in favour of that purified by the addition of clay has been found as much as ten or twelve per cent. Thus it is shown that the compounds removed by clay from gas produced during the early stages of distillation—however objectionable on other accounts—do not lessen the light-giving power of gas, whereas those removed during the later periods of distillation reduce the light-giving powers considerably.

If conjecture be allowable, I would venture an opinion that cyanogen compounds, and other nitrogenized substances with which foul clay abounds, are those which lessen light. My own investigations lead directly to this inference, and, I think, explain an old Table by Dr. Henry in this sense. In the 'Philosophical Transactions' for 1808, he shows that the gas produced from 112 lbs. of Cannel-coal contained, after purification, the following quantities of nitrogen:—

Hours from commencement of distillation.	100 measures of purified gas contain measures of nitrogen.	
$\frac{1}{2}$ an hour...	20	Due chiefly to atmospheric air. Probably the time when ammonia was principally produced. Probably vapour of water was present in very small quantity, and cyanogen and related compounds were produced in increasing quantity.
1 hour	$4\frac{3}{4}$	
3 "	5	
5 "	15	
7 "	15	
9 "	15	
$10\frac{1}{2}$ "	20	
12 "	20	

Without assuming the absolute accuracy of these figures, we may regard them as valuable indicators, pointing, I think, in the direction I have ventured to conjecture.

A beautiful reaction furnishes experimental proof of the damage

done to gas by acids. Clean deal sawdust is well moistened with pure sulphuric acid, diluted with five or six volumes of water, so that the sawdust may not be discoloured, and gas is passed through it in a slow stream. With rich gases, which give the light of from 20 to 25 sperm candles for a consumption of five feet an hour, the sawdust instantly changes to a most beautiful pink colour, and the tint gradually deepens until the whole becomes of a dark mahogany. With poor gases, which give the light of from 10 to 12 candles, this coloration is exceedingly faint at first, and deepens very slowly. The differences of coloration are so considerable and constant, that I have no doubt of the possibility of thus determining the value of gas as an illuminant. By using a standard acid, the same kind of sawdust, a uniform volume of gas, and the same sized U-tubes, notation of time and depth of colour would give a close approximation to the illuminating value of the gas. At all events, the sources of error are not greater than those of photometry in the hands of all but the most experienced, and the process is quite as close an approximation to truth as an ultimate analysis of gas, containing, as it does, impurities which render skill and precaution useless. A comparison of the analysis of coal-gas given in 'Bunsen's Gasometry,' with the substances now known to exist in gas, will convince us that at present we cannot attach any value to such analyses.

To determine the substances in gas which produce this coloration, some of its chief illuminating constituents were prepared and passed separately through the acid sawdust.

Olefiant gas made in the usual manner, and carefully purified, reddens the acid sawdust. Ether vapour does not affect it, and therefore need not be removed from the gas for this experiment.

Propylene, produced by passing the vapour of fusel-oil through a red-hot combustion-tube filled with cast-iron nails, but kept at so low a temperature that a small portion of oil passed over without decomposition, reddened the acid sawdust.

Commercial benzole, with the exception of one specimen, reddened the acid sawdust.

I have not yet had leisure to prepare and test acetylene.

The coloration of fir-wood, moistened by hydrochloric acid, has been mentioned by Williams as characteristic of pyrrole.

To show that the colour was produced by illuminating matter

abstracted, some sawdust was treated with acid strong enough to char it slightly* ; and gas, which instantly reddened the clean sawdust and dilute acid, was passed first through the black and then through the clean acid sawdust. No colour was produced in the latter, though the flow of gas continued for an hour.

Hydrochloric may be substituted for sulphuric acid, so far as that gas colours sawdust moistened with it, but it is liable to a considerable disadvantage. If gas contain ammonia, the vapour of the acid unites with it in the tube before the gas comes into contact with the sawdust, and the result is a deposit of chloride of ammonium on the surface of the sawdust where the colour commences, which renders the observation less precise and easy. Olefiant gas likewise does not redden this acid sawdust, and therefore cannot be estimated by it.

Nitrogenized compounds in coal-gas present the greatest difficulty in the way of efficient purification, and the almost impossibility of obtaining them in a state fit for examination, renders their investigation laborious and unsatisfactory. Much nitrogen is contained in gas as cyanogen, which can be separated from the clay used in purification. Probably not much less exists as sulphocyanogen, which can be separated from the foul clay with ease, and the presence of further quantities in combination with sulphuretted hydrocarbons and tar can be demonstrated. The bodies formed by this combination of elements are, I believe, unknown at present.

By placing clay in a purifier through which crude gas passes from the condenser of a gas-works, and treating the saturated clay with spirit, a solution is obtained, of a brown colour, which has no effect upon litmus, turmeric or lead-paper, which decolorizes a solution of iodine, and from which nitrate of silver throws down a white or brownish white precipitate, and acetate of lead a white precipitate. The aqueous solution possesses the same properties, and, like the solution in spirit, is always neutral. Litmus paper, immersed in either of the solutions and exposed to the air, becomes quickly, strongly, and permanently reddened. Soluble sulphides have been tested for repeatedly with nitroprusside of sodium, as well as with acetate of lead, but have never been found ; yet a sulphur compound exists in solution which possesses the power of forming a sulphide with

* This acid was of the same strength as that used in some gas-works.

metallic mercury. The spirit solution, digested on mercury, with occasional shaking, produces the black sulphide of mercury, while the aqueous solution, similarly treated, produces the red sulphide. Insoluble sulphides, however, exist in the foul clay, and evolve sulphide of hydrogen on the addition of an acid. These insoluble sulphides are oxidized rapidly by exposure of the clay to atmospheric action.

A solution of clay in spirit was treated with an excess of powdered acetate of lead, and the white precipitate filtered off. The brown filtrate was supersaturated with ammonia and filtered. The clear brown filtrate, diluted with twelve times its bulk of water, became milky, and with much difficulty was obtained clear by filtration. Part of the spirit was then distilled off, to ascertain whether it would bring over a volatile sulphur compound, but the spirit was quite free from sulphur. The remaining fluid was then acidified with nitric acid, which caused brisk effervescence and a strong smell of hydrocyanic acid. Nitrate of silver was added as long as it continued to produce a precipitate; the precipitate, dried and heated, gave off cyanogen, which burnt with its characteristic flame. The clear filtrate, slowly evaporated to dryness, left a pale yellow crystalline mass, which did not change colour by several days' exposure to light. Part of this, burnt in a porcelain crucible, gave off nitrous fumes, and left a considerable residue blackened by oxide of silver. Water was added to this residue, and the oxide of silver filtered off, and an abundant precipitate of sulphate of baryta obtained, with a salt of baryta. The remainder of the yellow salt was redissolved in water, with a view to separate a granular portion which was mixed with the more perfectly crystalline salt, but an accident unfortunately spoilt the remainder, and rendered any further progress impossible.

Sulphocyanide of ammonium may be obtained in considerable quantity from an alcoholic solution of foul clay. Upon one occasion I obtained nearly an ounce, in a fair state of purity, from less than a quart bottle of foul clay; and so tenaciously does clay retain this compound, that from some clay which had been exposed to the full action of the weather in a field for two years, I obtained a considerable coloration with perchloride of iron. Sulphocyanide of ammonium may be obtained from gas which has been purified by oxide of iron, by passing the gas through spirit of wine and evaporating.

When common yellow brick-clay is used in the purification of coal-

gas, the solutions from it always contain salts of iron, but they never become of a blood-red colour until a mineral acid is added. When, however, the solutions are evaporated, and the deliquescent residue is exposed to the air, most, and sometimes all of the iron is peroxidized and yields the well-known reaction.

The nitrogen in tar may be shown from the spirit-solution of foul clay. The spirit, evaporated to dryness and allowed to stand, deposits tar and a mixture of deliquescent crystalline salts. They were allowed to deliquesce, the fluid was removed, and the residual tar well washed with water. Subsequently it was dissolved in hot spirit, precipitated by water, and well washed. When nothing more was removed by washing, the tar was heated, and evolved sulphide of hydrogen and ammonia. Contrary to every other compound in gas with which I have experimented, this tar gave off sulphide of hydrogen before ammonia. In other instances I have found the nitrogen compound evolved at a lower temperature than the sulphur one.

Mineral matter derived from the clay is found in all solutions; but as my object in this paper is to speak only of substances in gas, I purposely omit those united with them derived from the clay. For the same reason I make no mention of the value of the foul clay as a manure.

Sulphur compounds in gas purified so as not to affect basic acetate of lead, and their removal.

A recent Royal Commission on lighting picture galleries, has stated the large quantity of sulphur found in some London gas, and has intimated a doubt about the possibility of its removal. Dr. Letheby concludes, from seven years' examination of gas in London, that though quite free from sulphide of hydrogen, it contains, on an average, 200 grains of sulphur in 1000 cubic feet; and Dr. Frankland, in the new edition of 'Ure's Dictionary of Arts,' part iv. pp. 730, 731, writes, "It is probable that volatile organic compounds of sulphur are produced by the action of this element with carbon and hydrogen simultaneously, although we have as yet no positive evidence of their presence in illuminating gas. . . . When once generated with coal-gas, all attempts to remove these constituents have hitherto proved ineffectual, and there seems little ground for hope that any practicable process will be devised for their abstraction." I have now the honour to submit evidence of the existence of these sul-

phurized compounds, and also a practical process for their removal. My attention was specially drawn to this subject by a conversation with the manager of a London gas-works. He informed me that he not unfrequently filled his gas-holders with gas which would not affect acetate of lead, and that after the gas had been stored a few hours, it became so foul as to blacken lead-paper the instant it was applied. He sought an explanation of this phenomenon ; and as the water of his gas-holder tanks was clean, and there were no accidental sources of sulphide of hydrogen, I concluded that an organic compound containing sulphur and hydrogen had been broken up, and that the sulphide of hydrogen was thus produced. I learnt also, by other observations, that gas which went to the gas-holders free from ammonia, sometimes became ammoniacal if kept, and joining this fact with the former one, inferred that the compound which thus broke up contained nitrogen as well as sulphur and hydrogen. Subsequently I observed that the saturated clay taken from the purifiers of gas-works, contained a quantity of foul naphthalin. This led me to procure a quantity of (so called) naphthalin which had been taken from the mains of a London gas-works, and which therefore must have been deposited by purified gas. Some portions of this naphthalin were white, but others were slightly darkened by the presence of carbonaceous matter, and the whole was in *fine powder*, aggregated together by the process of deposition. The tendency to form exceedingly small crystals seems a constant characteristic of naphthalin which has been deposited in gas-pipes, for by no amount of care and trouble have I been able to obtain it in large crystals, though the solutions from which it has crystallized have been months in evaporating. With naphthalin from tar, on the contrary, I have obtained, from an ethereal solution, crystals an eighth of an inch thick, nearly half an inch broad, and more than half an inch in length. The supposed naphthalin from gas-pipes dissolves wholly in ether and hot alcohol, and crystallizes from the spirit on cooling as pure naphthalin does. The solutions are neutral to test-papers. Boiled with an alcoholic solution of potash it evolves no ammonia, and with hydrochloric acid no sulphide of hydrogen. Heated alone, it evolves first ammonia, and then sulphide of ammonium, mixed, I think, with a trace of bisulphide of carbon, and then distils. Several samples began to give off their ammonia at 388° Fahr., and sulphide

of hydrogen at 422° Fahr., leading to the hope that here was a compound of definite composition which would admit of correct analysis and perhaps of formulation ; but some more of the naphthalin, produced, like the other, from Newcastle coal, but at another gas-works, possessed such different physical properties as to convince me that very much more must be known of this substance before any reliable analyses can be published. The latter sample gave a neutral solution in spirit, like the other, but of a considerably browner colour. When heated alone it gave off ammonia with ebullition at 218° Fahr., and then became tranquil. When the temperature reached 375° Fahr., it began to evolve sulphide of hydrogen, which continued to increase in quantity up to 390° Fahr., when it nearly ceased, and quite ceased at 410° Fahr. The proportion of tar in this sample was much greater than I have seen it in any other. Subsequently I obtained some more naphthalin which had been deposited in the pipes of another London gas-works, and this, like the former, contained both nitrogen and sulphur, which were evolved upon distillation as sulphide of hydrogen and ammonia.

Having thus obtained one sulphurized hydrocarbon, and determined the temperature at which its sulphur and nitrogen could be obtained as easily removeable compounds, I was prepared to advance towards a better purification of gas with great probability of success. Another well-confirmed observation helped to guide me. Gas freed from every trace of sulphide of hydrogen always blackens lead-paper strongly when passed through clay ; and if it be subsequently passed through lime, it affects turmeric though quite free from ammonia when taken for experiment. This process may be repeated through a series of ten or twelve purifiers containing clay and lime placed alternately, the test-papers being less affected at each purifier, until at length they are not discoloured at all. This experiment has been made upon gas produced in various parts of England and Scotland from many kinds of coal, and I think the number of instances sufficient to justify the conclusion that *all* gas, as sold, contains the compound from which clay liberates sulphide of hydrogen. I have not yet been able to separate the compound upon which clay thus acts. I have, however, ascertained that the clay which has liberated sulphide of hydrogen from gas which did not affect test-papers when taken for experiment contains tar, which may be dis-

solved out by alcohol, and may be obtained alone by evaporating the solvent.

Although collateral matter has been carefully excluded from this paper, I cannot refrain from remarking that the property of clay here mentioned is in fact the announcement of a new property of soils, and one which will help to account for the formation of many natural metallic sulphides. I hope soon to have some investigations of this subject ready for publication.

To ascertain whether this property of breaking up a sulphurized compound in purified gas and removing tar was possessed by clay alone, or shared by other substances used in purification, some purified gas was passed through a considerable chemical excess of all the substances employed in purification, viz. lime, precipitated peroxide of iron, sulphate of iron, chloride of calcium, and dilute sulphuric acid, all but the lime being mixed with moist sawdust. Upon passing the gas next through a purifier filled with clay, it darkened lead-paper, and affected turmeric when it had passed a subsequent purifier filled with lime. This proves the power of clay to break up one or more sulphurized compounds which no other substance used in purification effects; and if this sulphur were not liberated from the impure naphthalin compound already mentioned, it seemed certain that gas which had been previously purified by clay might be much improved, if not rendered pure, by a removal of the sulphur of the naphthalin. There is strong experimental evidence that the compound from which clay liberates sulphide of hydrogen is not the sulphurized naphthalin one; for if hydrogen be passed through a vessel containing this substance, then through clay, and subsequently over lead-paper, no trace of sulphide of hydrogen is found, though the gas passing smells strongly of impure naphthalin. This gas and vapour burn with a lightless flame. Subsequently some naphthalin was heated to ebullition, and a current of hydrogen sent through it and then burnt. The flame was lightless as before. I mention this fact to remove the popular error that naphthalin, as it exists in coal-gas, is a good illuminant. Even Dr. Frankland thus regards it; and both in Clegg's book on coal-gas, and in the new edition of Ure's Dictionary, states that the hydrocarbons in gas are valuable in proportion to the carbon they contain, and that naphthalin is the most valuable as containing the largest proportion of carbon. The

above-mentioned experiments evince the contrary. On another occasion I determined the illuminating power of some gas, and then, without alteration of the quantity passing, sent the gas through a U-tube containing naphthalin from the London gas-mains. The character of the flame was changed from white to red, but the photometer indicated no difference in the light given. Two other persons conversant with photometry were present at this experiment and agreed in the result, though up to that time they had held the prevailing opinion as to the value of naphthalin in gas without testing the statements made upon the subject.

Another sulphur compound is said always to be present in coal-gas and to be irremovable, and which, like those I have hitherto spoken of, does not affect lead-paper, viz. bisulphide of carbon. To ascertain the presence of bisulphide of carbon, I pass gas through strong spirit of wine (methylated spirit answers perfectly) kept at about 160° Fahr. The gas and vapours pass out of the flask which contains the spirit up a long tube into an inverted flask, so that all which is condensed may run back into the spirit. It then passes into another flask for additional condensation, and thence forward to a gas-holder or burner. Bisulphide of carbon dissolved in spirit becomes precipitated as a white cloud which settles to the bottom of the vessel, when the spirit is copiously diluted with water. The white cloudy precipitate escapes slowly by single bubbles through the diluted spirit, and at length leaves a solution perfectly clear. The spirit through which gas has passed, and from which it has abstracted bisulphide of carbon, acts in precisely the same manner upon dilution, and no one who has seen the reaction once or twice can possibly mistake it. The study of other compounds led me to conclude that if this substance exist *as such*, and not merely *by its elements*, in gas, it could be removed almost as easily as the naphthalin compound could be purified, and that the same process could be made available to remove the sulphur of both. I thought that under certain conditions the affinity of hydrogen for sulphur would exceed that of carbon for sulphur, and therefore that I might obtain the sulphur of bisulphide of carbon as a sulphide of hydrogen, about the removal of which there is no difficulty. Experiment confirms the reasoning. When hydrogen mixed with vapour of bisulphide of carbon is passed through a tube filled with slaked lime or clay

which has been dried at 400° or 500° Fahr., and is kept between 400° and 600° Fahr. during the passage of the gas and vapour, not a trace of bisulphide of carbon passes from the tube, but sulphide of hydrogen does pass. The lime is darkened by a deposit of carbon, and a sublimate of sulphur is found in the exit-tube. A considerable excess of hydrogen should be used, or else a portion of the bisulphide of carbon vapour is carried over by the current and escapes decomposition. That this reaction is not the result of heat merely, but is a truly chemical one which the base under the influence of heat effects, and the remarkable fact that slaked lime when heated forms, but does not unite with, sulphide of hydrogen, receive illustration from the following experiments.

Hydrogen and vapour of sulphide of carbon were passed through—1st, cold slaked lime; 2nd, cold clay; 3rd, hot oxide of iron used at a gas-works in purification; 4th, hot broken bricks; 5th, hot broken glass, without in any instance producing sulphide of hydrogen. On the contrary, when passed through (1) hot lime and (2) hot clay, sulphide of hydrogen was formed and passed over immediately, and continued to pass as long as the current was kept up. The lime, when cooled out of contact with the air, gave no sulphide of hydrogen upon being supersaturated with dilute sulphuric acid, but clay when thus treated gave off much.

The hydrogen used was in all cases passed through lime and over lead-paper, to secure its being free from sulphide before use. On one occasion, when the clay had been imperfectly dried before heating, I observed much sulphurous acid instead of sulphide of hydrogen. I therefore passed hydrogen, bisulphide of carbon vapour, and steam over hot clay which had been properly dried. At first sulphide of hydrogen passed over alone, then mixed with sulphurous acid, which at length passed alone. Subsequently sulphide of hydrogen passed, and at length sulphurous acid ceased. As the one gas increased the other diminished, and throughout the experiment sulphide of carbon vapour passed undecomposed. It is shown by this experiment that hot clay in the presence of more water than forms a hydrate acts very differently from the same clay when dry, and the whole subject deserves a full investigation.

Action of sulphide of hydrogen upon clay and lime, cold and hot.

Well-washed sulphide of hydrogen passed into cold slaked lime (obtained from Buxton) in a tube, colours the lime green as soon as it comes into contact with it, and the progress of the gas along the tube corresponds with the coloration. Lead-paper is not affected until the lime becomes coloured close up to the exit.

The same gas, passed into a tube containing slaked lime kept about 600° Fahr. at the middle, but cool at both ends, acts differently. The cool lime at the inlet end becomes coloured; the hot lime in the middle remains white, and the cool lime at the exit end becomes coloured, and lead-paper is stained as soon as these two cool portions are saturated, while the middle portion remains unchanged in colour.

The same gas, passed into a tube containing hot lime only, causes no discoloration, but instantly blackens lead-paper placed at the exit end; and upon being conducted into a tube of cold lime, colours it as if it had just passed from the vessel in which it is produced.

The same gas was passed into a tube containing lime which had been thoroughly dried at 600° Fahr., and cooled out of contact with the air. No discoloration of the lime took place, but the gas passed unaffected by the lime, and blackened lead-paper. Water added to the lime gives it the power of decomposing the gas as if it had not been heated. The presence of more water than is necessary to form hydrate of lime (Ca O, HO), is thus shown to be required for the decomposition of sulphide of hydrogen by slaked lime.

Sulphide of hydrogen passed into a tube of cold clay is taken up in considerable quantity, and the clay becomes black from the formation of sulphide of iron. The blackening begins at the inlet end, and progresses with the passage of the gas towards the exit end of the tube.

The same gas, passed into clay, heated to 500° or 600° Fahr., gives the same reactions; but when the clay has been heated and well-dried, and cooled in the closed tube, it takes up a very small quantity of the gas.

Coal-gas, quite free from sulphide of hydrogen, when passed through hot lime, blackens lead-paper, showing that masked and hitherto irremovable compounds have been so altered as to be easily removeable. The lime does not take up sulphide of hydrogen, but

becomes gradually, yet very slowly, darkened by the deposition of tar and carbon from vapour of bisulphide of carbon. The reaction with previously dried slaked lime commences at 108° Fahr., and continues through the whole range of temperature up to redness. At a red heat the sulphur of the bisulphuret of carbon and other sulphur compounds unites with the lime and forms sulphide of calcium. Practically very high temperatures are useless, as the hydrocarbons of gas begin to be decomposed about the melting-point of lead, and to deposit their carbon upon the hot lime. Fortunately injurious temperatures are not required. I have frequently freed gas from every trace of sulphur, so that upon combustion no sulphurous acid was generated, by employing lime so heated as not to deposit any carbon, and removing the sulphuretted hydrogen evolved in the hot tube by ordinary hydrate of lime.

The same gas passed through hot clay gradually darkens the clay by forming sulphide of iron, and, when the blackness has reached the end of the tube containing the clay, lead-paper is blackened by the passing gas. The clay treated with an acid evolves sulphide of hydrogen. Carbonic acid is evolved in both cases. It is thus proved that bisulphide of carbon, in the presence of hydrogen passing over hot hydrate of lime, is decomposed, and that its sulphur becomes united to hydrogen. Coal-gas always contains a considerable quantity of hydrogen, so that, if it contain vapour of bisulphide of carbon, the process I have the honour to describe will effect its removal. The same process will break up the impure naphthalin compound and convert its sulphur into sulphide of hydrogen; and the employment of clay in the ordinary purifiers, before the gas passes through the hot ones, will so arrange the elements of certain other sulphur compounds as to enable the manufacturer to remove their sulphur as sulphide of hydrogen. Sulphocyanide of ammonium is decomposed by the heated lime, and its sulphur is liberated as sulphide of hydrogen. The only requisite for complete success was that no injury should be done to the light-giving materials of gas while removing the impurities. I have passed the principal illuminating constituents of coal-gas through the hot lime and clay, and find that they are not injured. The temperature which suffices for purification is not high enough for injury. The photometer shows that coal-gas is not injured.

The quantity of tar in gas as supplied to consumers, and the evil of its presence as a source of sulphur, are not considered as, I think, they deserve to be. It is exceedingly rare to find gas free from tar, and I never yet met with tar which did not contain both nitrogen and sulphur. Part of this tar is combined with ammonia in some manner, and may be obtained by passing gas through a bottle containing pebbles moistened with hydrochloric acid. Part is united to naphthalin, as I have already mentioned: part is united to benzole vapour, and part to other hydrocarbon vapours, such as paraffin, if two instances within my own knowledge be sufficient to justify a statement in reference to gas in general. In one instance I passed gas through a metal vessel filled with a number of wire-gauze diaphragms and kept below 32° Fahr. Some cakes of solid paraffin were found floating upon the water which had been placed in the vessel before commencing the experiment, and a mixture of tarry oils which had deposited the paraffin. In another instance, an old gas-holder was about to be replaced by a new one, and on the water of the tank in which the old gas-holder had worked, there was found upwards of a thousand gallons of a dark-coloured fluid. All but two carboys was sold to a tar distiller. These two carboys were left exposed to the air without corks for some time, and when the manager of the gas-works went to get me some of the fluid for examination, he found that the whole contents had evaporated. I had previously, however, obtained about half an ounce of the mixture. It contained paraffin, naphthalin, and the oils which accompany paraffin. Nearly a fifth of its weight of solid pitch was obtained by distilling off the hydrocarbons. A quantity of sulphide of hydrogen and ammonia were evolved during the distillation, and some of the most stinking compounds I ever met with produced from coal. From these two instances it is clear that some, or perhaps all, of the volatile hydrocarbons in gas possess the power of upholding tar with them in their vapours; and it is proved that this tar is no inconsiderable source of the sulphurous acid produced by the combustion of gas as at present purified. I have obtained tar containing sulphur from every specimen of commercial benzole I have examined; and as this will evaporate at common temperatures without leaving a residue, we are justified in the presumption that tar thus united to benzole exists in gas.

The best method of showing the tar in gas is to pass it through or over well-purified coal-oil, and subsequently through a good condensing arrangement. I have known colourless coal-oil become of a dark mahogany colour, and have separated sulphuretted hydrogen, ammonia, and solid pitch by distillation.

II. "On the Gyroscope." By ARTHUR HILL CURTIS, Esq.
Communicated by Professor BOOLE. Received Sept.
20, 1860.

(Abstract.)

The object of this paper is to deduce on strict mechanical principles all the known properties of the gyroscope. The only assumption made is that the velocity of rotation impressed on the instrument is very great compared with that which the attached weight would produce on it if acting alone for an instant in a direction perpendicular to the axis. The theorems which the author establishes are the following:—

THEOREM I.—The curves described by the extremity of the axis of the gyroscope are a system of spherical cycloids generated by the motion of a point on the spherical radius of a circle, which, constantly remaining on the same sphere, rolls without sliding on the circumference of another fixed circle situated on the same sphere. These cycloids may be either ordinary, curtate, or prolate—including the case when the system degenerates into a circle, in which case the generating point becomes the centre of the rolling circle. Their species depends on the direction of the initial velocity communicated to the axis, the direction in which the instrument is set rotating, and the position of the attached weight; when, for instance, no initial velocity is communicated to the axis, the cycloids will be ordinary *at first*, and would continue so if the gyroscope were a perfect instrument for illustrating the motion of a body round a fixed point; but the inertia of the rings on which it is mounted, and of the attached weight, as well as the resistance of the air, after a short period has elapsed, has the effect of imparting to the axis a certain velocity which modifies the curves described by it, and at last causes the

