PAPERS READ BEFORE THE CHEMICAL SOCIETY.

XXXVIII—*On the Gases enclosed in Coals from the South Wales Basin, and the Gases evolved by Blowers and by boring into the Coal itself.* PART I.

By J. W. THOMAS.

THE composition of the Gases enclosed by coal has attracted some considerable attention of late. Investigations have been conducted by Dr. Ernest von Meyer, in Professor Kolbe's laboratory at Leipzig, both upon English and upon German coals, from some of the principal coal basins, the results of which have been published in the *Journal für praktische Chemie* [2], v, 144—183; 407—427, and vi, 389—416, and an abstract of which will be found in the Chemical Society's Journal [2], x, 798 and 801, and xi, 483. The eight samples of English coal which were analysed were obtained from the Newcastle and Durham coal fields, but no information was given whether they were bituminous or anthracite. It appeared to me therefore of sufficient importance to examine the deposits of anthracite and of other coals from the Great South Wales Basin.

Meyer undertook his experiments of determining the quantity and percentage composition of the gases actually enclosed within the pores of the coals, with a view of throwing some additional light upon the natural processes which were at work in their formation, and upon the natural history of coal generally. With the view of extending these researches to the gases of the coals from the South Wales Basin, and also of obtaining information on the conditions attending preceding colliery explosions, I, at the suggestion of Mr. Valentin, took up this work, the results of which I now beg to submit to the Society.

It is obvious that the results obtainable in an investigation of this nature are largely dependent upon the methods employed. The analysis of gases has now become of comparatively easy and rapid execution, thanks to Frankland's gas apparatus, improved and modified by McLeod—an apparatus of which I cannot speak in too high terms of satisfaction. To those who have been in the habit of working by Bunsen's method some of the figures of the subjoined analyses will appear somewhat incredible, owing to the small excess of oxygen I frequently used in exploding marsh-gas. This, in fact, is possible only

with an apparatus in which the gases can be very considerably rarefied.

The gases enclosed in the eight samples of English coal analysed by Meyer were those of ordinary mine-gas, and consisted of carbonic anhydride, marsh-gas, oxygen, and nitrogen. In no single case did he meet with any hydrocarbon other than marsh-gas. In a few coals from German sources, however, Meyer observed also hydride of ethyl and olefiant gas. I have invariably looked for these gases whenever the figures of a preliminary analysis gave any indications of their presence, but have rarely met with more than traces in the coals which I examined. I also confined myself, for the present, to the coals from the South Wales Basin—bituminous, steam, and anthracite—which had never before been investigated, and with which a previous practical acquaintance had made me familiar. I made it a point to procure the samples in lumps, about 10" cube, and to submit them to analysis as speedily as possible.

In the classification of the numerous samples of coals I have adopted the three classes: *bituminous*, sometimes called "house coals;" *steam coal*, a class intermediate between bituminous and anthracite, a coal for which the South Wales Basin is famous; and lastly, *anthracite*.

The following table gives the names of the different samples of coal, the collieries and districts whence they are derived, and the depth from the surface:—

No. of Sample.	Seam.	Colliery.	Kind of coal.	District.	Depth from surface.
1	No. 1	{ Plymouth iron works	{ Bituminous	Merthyr	Level
2	No. 3		"	"	"
3	No. 3	Cwm Clydach	"	Rhondda	—
3a	Abergorki	Bute Merthyr	{ Semibitumi- nous Steam	"	Level
4	2 ft. 9 ins.	"	"	"	100 yards
5	Upper, 4 ft.	Navigation	"	Aberdare	400 "
6	" 4 ft.	Dunraven	"	Rhondda	206 "
7	" 4 ft.	Cyfartha	"	Merthyr	180 "
8	" 6 ft.	Bute Merthyr	"	Rhondda	140 "
9	" 6 ft.	Dunraven	"	"	225 "
10	" 9 ft.	Duffryn	"	Aberdare	—
11	Bettwys	—	Bituminous	Ogmore	140 "
12	Lantwit	—	"	"	—
13	—	{ Bonvilles Court	{ Anthracite	{ Pembroke- shire coal field	—
14	—	Watney's	"	{ Carmarthen- shire coal field	—

On looking carefully over Meyer's paper, and especially on trying to reconcile certain anomalies which occur in his analytical results, I was led to question the accuracy of his method of obtaining the gases from the coals. Meyer introduced small pieces of coal, amounting to from two to four hundred grams, into a glass flask which was immediately filled up with hot de-aërated water, and boiled as long as any appreciable quantities of gases were given off. The delivery-tube was likewise filled with boiled water and fitted by a caoutchouc plug into the mouth of the flask. The gases were collected over boiled water in a number of tubes, and submitted to analysis by Bunsen's method. To those who know the difficulty of removing the whole of the gases from water, even under diminished pressure, it will at once be apparent that the same difficulty would be encountered, if possible, on an increased scale, by endeavouring to collect in this manner the gases evolved from coal, not to speak of the danger and liability to loss from the solubility of the carbonic anhydride in the water, on transferring the mixed gases to the mercury-trough and the subsequent removal of the water from the tubes.

After various preliminary endeavours to devise a more accurate and at the same time more expeditious method of analysis, I fixed at last upon one which I found to answer well. It may be described briefly as follows:—

Slices of coal were sawn out of the middle of the large cubes, and a strip about $\frac{5}{8}$ " in thickness and 6" to 8" in length was next cut from the middle of this slice, the edges rounded off, so as to make it slide readily into a glass tube of the proper diameter.

The coal was brushed with a feather to remove any adhering dust, and speedily placed in the glass tube, one end of which had previously been drawn out into a long narrow neck so as to form a connection with the Sprengel mercurial pump. The other end was then sealed off below the blowpipe, at a sufficient distance from the coal to prevent any material rise in temperature. The usual water-joint connection was then made with the Sprengel pump, the air exhausted as quickly as possible, until almost a perfect vacuum had been obtained, and the last portion of the gases which was brought over collected and subjected to analysis. Many of the bituminous and steam coals of the South Wales coal field are of a porous nature, and far from hard or dense; and from their physical aspect it appeared probable that, on withdrawing the air from around the strips of coal and on the formation of a partial vacuum, a large portion of the gases enclosed in the coal would escape. This was not found to be the case, however, as very little gas was evolved from any of the coals which I had occasion to examine, even when almost a complete vacuum had been obtained, and the amount of gases so given off rarely exceeded 2 or 3 c.c. per

100 grams of coal. Some of the steam and bituminous coals, which were hard and laminated, as well as the still harder and denser anthracites, evolved only traces of gas, whilst the enclosed gases were rapidly given off as soon as the temperature was raised.

When the whole of the air had been removed, the tube containing the coal was immersed in a vessel of boiling water and kept at a temperature of 100° for about seven hours, or until the mercury pump ceased to bring over any appreciable quantity of gas. The gases thus evolved were collected in graduated tubes.

From 10 to 30 grams of coal were usually employed in each experiment, according to the nature of the coal and the quantity of gas evolved, a very small quantity of anthracite being sufficient to furnish an ample amount of gas for analysis, whilst highly bituminous coals gave off so little gas that 30 grams of coals were required to yield the necessary volume. Duplicate analyses were invariably made of the gases evolved from each sample of coal, and in cases where the results of the second experiment differed from the first, a further analysis was made.

The rapidity with which the occluded gases are evolved, under a vacuum, at 100° depends upon the hardness of the coal and the quantity of gas enclosed. By far the greater portion of the gases given off at that temperature is brought over by the pump during the first three hours.

Still the whole of the enclosed gases present in these coals is not withdrawn at 100° nor even at 200° , and there remains a considerable quantity still imprisoned in the pores of the coals after having been kept at that temperature for hours. In a few instances I proved this by heating the coal up to 300° , or close upon the point where decomposition begins to take place.

This fact appears to me of considerable importance, as it shows that Meyer can only have worked with a portion of the gases, viz., with that portion which is occluded from coal at the temperature of boiling water.

The following are the analytical results I obtained:—

SAMPLE NO. 1.—*Bituminous, from a Level above South Pit, Plymouth Iron Works.*

100 grams of coal evolved 55.9 c.c. of gas at 100° .

An analysis made of the last portion of gases exhausted in forming a vacuum at ordinary temperatures, gave—

$\text{CO}_2 = 2.01$ $\text{O} = 19.11$ $\text{N} = 78.88$.

Analysis of the Gas Evolved at 100°

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 16°.	Progress.
130·7 mm.	15·0	131·17	Volume employed.
83·1 mm.	15·0	83·40	Volume after absorption of CO ₂ .
82·2 mm.	15·5	82·35	Volume after absorption of O.
291·9 mm.	16·0	291·90	Volume plus O (no com- bustion).
387·1 mm.	16·0	387·10	Volume after H added.
244·2 mm.	16·0	244·20	Volume after explosion.
244·2 mm.	16·0	244·20	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	36·42
Oxygen	·80
Nitrogen	62·78
	<hr/> 100·00

SAMPLE No. 2.—*Bituminous, from South Pit, Plymouth Iron Works.*

This coal was probably exposed to atmospheric influences in the seam, previous to being cut.

100 grams of coal evolved 61·2 c.c. of gas at 100°.

An analysis made of the last portion of gases, withdrawn in forming a vacuum, at ordinary temperatures gave—

CO₂ = 0·31 O = 20·68 N = 79·01.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Temperature.	Progress.
124·6 mm.	12·9	Volume employed.
103·7 mm.	12·9	Volume after absorption of CO ₂ .
100·3 mm.	12·9	Volume after absorption of O.
291·8 mm.	12·9	Volume after addition of O (no explosion).
374·6 mm.	13·0	Volume after H added.
249·5 mm.	13·0	Volume after explosion.
349·0 mm.	13·0	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	16.77
Oxygen	2.72
Marsh-gas	.40
Nitrogen	80.11
	<hr/> 100.00

SAMPLE No. 3.—*Bituminous, from Cwm Clydach.* No. 3. *Rhondda.*

100 grams of coal evolved 55.1 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at ordinary temperatures, gave—

$\text{CO}_2 = 0.22$ $\text{O} = 20.59$ CH_4 trace. $\text{N} = 79.19$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 23.4°.	Progress.
142.5 mm.	23.4	142.5	Volume employed.
134.7 mm.	23.3	134.74	Volume after absorption of CO_2 .
133.2 mm.	23.2	133.29	Volume after absorption of O.
421.8 mm.	23.3	421.95	Volume after O added.
240.5 mm.	23.4	240.50	Volume after explosion.
149.8 mm.	23.7	149.64	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	5.44
Oxygen	1.05
Marsh-gas	63.76
Nitrogen	29.75
	<hr/> 100.00

The tube containing the coal, after disconnecting from the Sprengel pump, was left exposed to the atmosphere for eleven weeks and two days, at the expiration of which it was again connected with the pump and heated to 100° C. for seven hours.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$\text{CO}_2 = 0.45$ CH_4 trace $\text{O} = 20.60$ $\text{N} = 78.95$.

100 grams of coal evolved 33·2 c.c. of gas at 100° of the following composition :—

Observed pressure of gas (dry).	Temperature.	Progress.
73·0 mm.	16·8	Volume employed.
64·9 mm.	16·8	Volume after absorption of CO ₂ .
59·3 mm.	16·8	Volume after absorption of O.
191·5 mm.	16·8	Volume after O added (no explosion).
324·5 mm.	16·8	Volume after H added.
111·7 mm.	16·8	Volume after explosion.
104·9 mm.	16·8	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	11·10
Oxygen	7·67
Marsh-gas	9·31
Nitrogen	71·92
	<hr/> 100·00

SAMPLE NO. 3A.—*Semibituminous. Bute Merthyr Colliery, Rhondda District.*

This coal gave off its enclosed gases very readily.

100 grams of coal evolved 73·6 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

CO₂ = 2·12 O = 19·01 CH₄ = 0·85 N = 78·02.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 19°.	Progress.
97·5 mm.	18·8	97·57	Volume employed.
85·5 mm.	18·9	85·53	Volume after absorption of CO ₂ .
84·9 mm.	19·0	84·90	Volume after absorption of O.
431·0 mm.	19·0	431·00	Volume after O added.
289·8 mm.	19·0	289·8	Volume after explosion.
219·1 mm.	19·0	219·1	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	12·34
Oxygen	0·64
Marsh-gas	72·51
Nitrogen	14·51
	<hr/> 100·00

SAMPLE NO. 4.—*Steam, from Bute Merthyr Colliery; 2 feet 9 inch seam.*

100 grams of coal evolved 194·8 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at ordinary temperatures, gave—

$\text{CO}_2 = 1\cdot02$ $\text{O} = 19\cdot07$ $\text{CH}_4 = 0\cdot61$ $\text{N} = 79\cdot3$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 17·8°.	Progress.
120·9 mm.	17·8	120·9	Volume employed.
114·8 mm.	17·8	114·8	Volume after absorption of CO_2 .
114·4 mm.	17·8	114·4	Volume after absorption of O.
366·2 mm.	17·9	367·07	Volume after O added.
156·7 mm.	17·9	156·65	Volume after explosion.
51·1 mm.	17·9	51·10	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	5·04
Oxygen	0·33
Marsh-gas	87·30
Nitrogen	7·33
	<hr/> 100·00

SAMPLE NO. 5.—*Steam, Upper 4-feet Seam, Navigation Colliery.*

100 grams of coal evolved 250·1 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$\text{CO}_2 = 1\cdot17$ $\text{CH}_4 = 0\cdot86$ $\text{O} = 19\cdot41$ $\text{N} = 78\cdot56$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 21·8°.	Progress.
138·5 mm.	21·0	138·9	Volume employed.
120·2 mm.	21·0	120·55	Volume after absorption of CO ₂ .
119·6 mm.	21·2	119·86	Volume after absorption of O.
493·8 mm.	21·7	493·98	Volume after O added.
269·3 mm.	21·8	269·30	Volume after explosion.
155·9 mm.	21·8	155·90	Volume after absorption of CO ₂ .
			Composition in 100 parts.
Carbonic anhydride			13·21
Oxygen			0·49
Marsh-gas			81·64
Nitrogen			4·66
			<hr/> 100·00

SAMPLE NO. 6.—*Steam, Upper 4-feet Seam, Dunraven Colliery.*

100 grams of coal evolved 218·4 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

CO₂ = 0·66 CH₄ 2·23 O = 18·51 N = 78·60.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 13°.	Progress.
91·9 mm.	14·2	91·50	Volume employed.
86·7 mm.	13·7	86·48	Volume after absorption of CO ₂ .
86·1 mm.	13·1	86·07	Volume after absorption of O.
345·8 mm.	13·0	345·80	Volume after O added.
193·0 mm.	13·0	193·00	Volume after explosion.
115·6 mm.	13·0	115·60	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	5·46
Oxygen	·44
Marsh-gas	84·22
Nitrogen	9·88
	<hr/> 100·00

SAMPLE No. 7.—*Steam, Upper 4-feet Seam, Cyfartha.*

This coal had probably been exposed to atmospheric influences previous to being removed from the seam, and had been taken from the pit nine days before being analysed.

100 grams of coal evolved 147·4 c.c. of gas at 100°.

An analysis made of the last portions of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$\text{CO}_2 = 0\cdot49$ CH_4 trace $\text{O} = 20\cdot66$ $\text{N} = 78\cdot85$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Temperature.	Progress.
165·1 mm.	22·3	Volume employed.
133·9 mm.	22·3	Volume after absorption of CO_2 .
132·2 mm.	22·3	Volume after absorption of O .
508·3 mm.	22·3	Volume after O added.
295·5 mm.	22·3	Volume after explosion.
184·1 mm.	22·3	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	18·90
Oxygen	1·02
Marsh-gas	67·47
Nitrogen	12·61
	<hr/> 100·00

SAMPLE No. 8.—*Steam, 6-feet Seam, Bute Merthyr Colliery.*

This was, without exception, the hardest steam-coal which I have examined, and it approached very nearly to the anthracites in structure and appearance.

100 grams of coal evolved 375·4 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$$\text{CO}_2 = 0.51 \quad \text{CH}_4 = 0.98 \quad \text{O} = 20.01 \quad \text{N} = 78.50.$$

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 18.4°.	Progress.
117.8 mm.	18.4	117.8	Volume employed.
106.9 mm.	18.4	106.9	Volume after absorption of CO ₂ .
106.5 mm.	18.4	106.5	Volume after absorption of O.
436.6 mm.	18.8	436.0	Volume after O added.
233.4 mm.	19.0	232.9	Volume after explosion.
131.0 mm.	19.0	130.7	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	9.25
Oxygen	0.34
Marsh-gas	86.92
Nitrogen	3.49

100.00

This coal was broken into small pieces about the size of a walnut, and left exposed to the atmosphere for fourteen weeks. A portion was then taken and subjected to 100° C. for seven hours under a vacuum.

100 grams of coal evolved 112.3 c.c. of gas at 100°.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Temperature.	Progress.
151.5 mm.	17.2	Volume employed.
133.7 mm.	17.2	Volume after the absorption of CO ₂ .
129.7 mm.	17.2	Volume after absorption of O.
345.0 mm.	17.2	Volume after O added.
179.3 mm.	17.2	Volume after explosion.
96.3 mm.	17.2	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	11.75
Oxygen	2.64
Marsh-gas	54.78
Nitrogen	30.83

100.00

SAMPLE No. 9.—*Steam, 6-feet Seam, Dunraven Colliery.*

This coal was soft and porous. This accounts in some measure for the low percentage of marsh-gas.

100 grams of coal evolved 149·3 c.c. of gas at 100°.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$\text{CO}_2 = 0\cdot76$ $\text{O} = 17\cdot93$ $\text{CH}_4 = 3\cdot75$ $\text{N} = 77\cdot56$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
104·6 mm.	10·5	100·58	Volume employed.
92·9 mm.	11·0	89·16	Volume after absorption of CO_2 .
92·3 mm.	11·0	88·59	Volume after absorption of O.
291·2 mm.	11·6	278·83	Volume after O added.
137·2 mm.	12·0	131·17	Volume after explosion.
59·9 mm.	12·0	57·27	Volume after absorption of CO_2 .

Composition in
100 parts.

Carbonic anhydride	11·35
Oxygen	·56
Marsh-gas	73·47
Nitrogen	14·62

100·00

SAMPLE No. 10.—*Steam, 9-feet Seam, Duffryn Colliery.*

100 grams of coal evolved 215·4 c.c. of gas at 100°.

The last portion of air withdrawn in forming a vacuum at the ordinary temperature, was lost.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 22·3°.	Progress.
111·5 mm.	22·0	111·6	Volume employed.
105·3 mm.	22·3	105·3	Volume after absorption of CO_2 .
104·7 mm.	22·3	104·7	Volume after absorption of O.
361·3 mm.	22·3	361·3	Volume after O added.
177·1 mm.	22·3	177·1	Volume after explosion.
84·8 mm.	22·4	84·8	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	5·64
Oxygen	·54
Marsh-gas	82·70
Nitrogen	11·12
	<hr/> 100·00

SAMPLE No. 11.—*Bituminous, Bettwys Coal, Ogmores Valley.*

100 grams of coal evolved 24·0 c.c. of gas at 100°.

An analysis of the last portion of gases, withdrawn in forming vacuum, at the ordinary temperature, gave—

$\text{CO}_2 = 0\cdot22$ $\text{O} = 20\cdot66$ $\text{N} = 79\cdot12$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 22·7°.	Progress.
59·5 mm.	22·4	59·56	Volume employed.
46·3 mm.	22·4	46·36	Volume after absorption of CO_2 .
42·7 mm.	22·5	42·73	Volume after absorption of O.
149·3 mm.	22·7	149·30	Volume after O added (no explosion).
227·8 mm.	22·7	227·80	Volume after H added.
107·2 mm.	22·7	107·20	Volume after explosion.
105·6 mm.	22·7	105·60	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	22·16
Oxygen	6·09
Marsh-gas	2·68
Nitrogen	69·07
	<hr/> 100·00

SAMPLE No. 12.—*Bituminous, Lantwit.*

100 grams of coal evolved 39·7 c.c. of gas at 100°.

An analysis of the last portion of gases, withdrawn in forming a vacuum, at the ordinary temperature, gave—

$\text{CO}_2 = 0\cdot31$ $\text{O} = 20\cdot51$ $\text{CH}_4 = 0\cdot23$ $\text{N} = 78\cdot95$.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Temperature.	Progress.
168.5 mm.	22.0	Volume employed.
152.5 mm.	22.0	Volume after absorption of CO ₂ .
148.7 mm.	22.0	Volume after absorption of O.
424.5 mm.	22.0	Volume after O added.
316.9 mm.	22.0	Volume after explosion.
263.0 mm.	22.0	Volume after CO ₂ absorbed.

	Composition in 100 parts.
Carbonic anhydride	9.43
Oxygen	2.25
Marsh-gas	31.98
Nitrogen	56.34
	<hr/> 100.00

The tube containing the coal, after disconnecting from the Sprengel, was left exposed to the atmosphere for ten weeks, at the expiration of which it was again connected with the pump, exhausted, and heated to 100° C. for seven hours.

100 grams of coal evolved 31.2 c.c. of gas.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 16°.	Progress.
142.3 mm.	15.6	142.5	Volume employed.
115.8 mm.	15.6	115.96	Volume after absorption of CO ₂ .
104.5 mm.	15.6	104.65	Volume after absorption of O.
316.9 mm.	16.0	316.90	Volume after O added.
405.3 mm.	16.0	405.30	Volume after explosion.
239.2 mm.	16.0	239.20	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	18.62
Oxygen	7.94
Marsh-gas	7.86
Nitrogen	65.58
	<hr/> 100.00

SAMPLE No. 13.—*Anthracite, Bonville Court.*

100 grams of coal evolved 555·5 c.c. of gas at 100° C.

An analysis made of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$$O = 20\cdot89 \quad N = 79\cdot11.$$

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 11·7°.	Progress.
87·9 mm.	11·7	87·9	Volume employed.
85·6 mm.	11·7	85·6	Volume after absorption of CO ₂ .
85·6 mm.	11·7	85·6	Volume after absorption of O.
425·3 mm.	11·7	425·3	Volume after O added.
262·1 mm.	11·6	262·2	Volume after explosion.
180·4 mm.	11·6	180·34	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	2·62
Oxygen	none
Marsh-gas	93·13
Nitrogen	4·25
	<hr/> 100·00

SAMPLE No. 14.—*Anthracite, Watney's Llanelly.*

100 grams of coal evolved, when heated for seven hours at 100°, 600·6 c.c. of gas.

An analysis of the last portion of gases withdrawn in forming a vacuum at the ordinary temperature, gave—

$$O = 20\cdot79 \quad N = 79\cdot21.$$

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Temperature.	Progress.
64·5	13·3	Volume employed.
55·0	13·4	Volume after absorption of CO ₂ .
55·0	13·3	Volume after absorption of O.
279·5	13·3	Volume after O added.
171·5	13·3	Volume after explosion.
117·2	13·3	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Carbonic anhydride	14.72
Marsh-gas	84.18
Nitrogen	1.10
	<hr/> 100.00

The same portion of coal, after standing *in vacuo* at the ordinary temperature (14° C.) for nineteen hours evolved 56.6 c.c. of gas per 100 grams of coal; and on being further heated in a bath of paraffin at 200° C. for eight hours, it evolved 993.1 c.c. per 100 grams of coal.

Analysis of the Gas Evolved at 200° .

Observed pressure of gas (dry).	Temperature.	Progress.
94.3 mm.	13.3	Volume employed.
86.7 mm.	13.3	Volume after absorption of CO_2 .
351.2 mm.	13.4	Volume after O added.
178.2 mm.	13.4	Volume after explosion.
91.6 mm.	13.4	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride.....	8.06
Marsh-gas.....	91.83
Nitrogen	.11
	<hr/> 100.00

After again standing *in vacuo*, at the ordinary temperature (12° C.) for forty-one hours, 19.1 c.c. of gas per 100 grams of coal were evolved; and when further heated at 300° in a paraffin bath, 206.5 c.c. of gas per 100 grams of coal were given off.

Analysis of the Gas Evolved at 300° .

Observed pressure of gas (dry).	Temperature.	Progress.
98.2 mm.	8.5	Volume employed.
96.8 mm.	8.5	Volume after absorption of CO_2 .
442.8 mm.	8.6	Volume after O added.
249.9 mm.	8.6	Volume after explosion.
153.2 mm.	8.6	Volume after absorption of CO_2 .

	Composition in 100 parts.
Carbonic anhydride	1.43
Marsh-gas	98.47
Nitrogen	.10
	<hr/> 100.00

The total volume of gas evolved by this coal was 1875·9 c.c. per 100 grams.

These three experiments, then, show clearly that the whole of the gas present in the sample was not given off at 100° nor at 200°; but at 300° the evolution ceased for some hours; and from this it may be inferred that no decomposition took place at that temperature. This is likewise proved by glancing at the composition of the respective gas volumes.

SAMPLE No. 14.—9 grams of this coal, taken from the centre of a large lump which had been exposed to the atmosphere for four weeks, subsequently to taking the portion employed in the foregoing experiment, was introduced in small pieces into a narrow glass tube. One end of the tube was previously drawn out into a long neck to form a connection with the Sprengel, and a portion of the neck thickened and drawn out very fine for the purpose of hermetically sealing it under a vacuum. After introducing the coal into the tube, the wide end was sealed in the blowpipe flame, and the tube connected with the Sprengel, and exhausted.

The coal was heated at 100°, under a vacuum, for twenty-one hours, and remained at the ordinary temperature for another seventy hours.

At the end of this time 65·8 c.c. of gas was withdrawn, equal to 731·1 c.c. per 100 grams of coal.

The gas collected was transferred to a Bunsen eudiometer, and measured, and the tube containing the coal *in vacuo*, after having been hermetically sealed before the blowpipe, was passed up into the eudiometer, and pressed against the side to break off the point. It was left in contact with the gas for five days, after which it was filled with mercury to displace the gas, and then removed from the eudiometer. The remaining gas was then measured, and after allowing for the rise of temperature incidental upon introducing the tube into the eudiometer, &c., I found that no more than 5 c.c. of gas had become re-absorbed by the coal.

This experiment was undertaken with a view to ascertain whether the gases were held by virtue of some condensing power possessed by the coal, or merely imprisoned in its pores, and held fast mechanically.

A portion of the gases evolved by the 9 grams of coal during the first hour, heated at 100°, was analysed, and also a portion of the gas collected, after heating at 100° for three hours. The following are the results of the analyses:—

Gas Evolved during the first hour.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 11°.	Progress.
97.0 mm.	12.2	96.58	Volume employed.
82.6 mm.	11.6	82.42	Volume after absorption of CO ₂ .
52.7 mm.	11.9	82.43	Volume after absorption of O.
336.0 mm.	10.8	336.24	Volume after O added.
178.7 mm.	11.0	178.70	Volume after explosion.
99.8 mm.	11.0	99.80	Volume after absorption of CO ₂ .
			Composition in 100 parts.
Carbonic anhydride			14.60
Marsh-gas			81.34
Nitrogen			4.06
			<hr/> 100.00

Analysis of the Gas after the Coal was heated for three hours.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 13.7°.	Progress.
90.6 mm.	13.5	90.67	Volume employed.
78.0 mm.	13.7	78.00	Volume after absorption of CO ₂ .
333.1 mm.	13.5	333.34	Volume after O added.
183.9 mm.	13.7	183.90	Volume after explosion.
109.2 mm.	13.7	109.20	Volume after absorption of CO ₂ .
			Composition in 100 parts.
Carbonic anhydride			13.91
Marsh-gas			82.45
Nitrogen			3.64
			<hr/> 100.00

Having given full details of the various analyses, there remains for me now only to sum up briefly the deductions which in my opinion may be drawn from them.

The gases from the three classes of coal which were analysed differ, as might be expected, both in quality and even more so in quantity. The bituminous coals when on or near the surface contain little or no

marsh-gas, and the percentage of carbonic anhydride is usually very high. The quantity of gas which they yield is much smaller than that given off from either steam coal or anthracite. It would indeed be possible to arrive at a pretty safe conclusion as to the bituminous character of a coal, by analysing the enclosed gases, and taking into account the quantity. It will also become readily apparent that seams of bituminous coals can be and are worked all over South Wales with naked lights, as they contain little or no marsh-gas. And the few samples taken from deeper levels which contained a high percentage of the same still differ materially from the steam coal and anthracite, by giving off comparatively small quantities of gases only. The real difficulty of working these seams arises, in fact, not so much from the presence of marsh-gas as that from carbonic anhydride. On no occasion did I meet with any carbonic oxide, however, although I looked carefully for this poisonous gas.

Steam coals evolve a much larger quantity of gases than bituminous, and their composition also differs by showing invariably a very high percentage of marsh-gas—as much, in fact, as 87 per cent. The volume of gas depends in a great measure upon the hardness and porosity of the coals, and upon the time which has elapsed since they were removed from their respective seams or veins; this latter applies equally to all coals.

Hard compact steam coals, especially those showing laminated structure, evolve a quantity of gas approaching to that given off by anthracites.

Steam coal also gives off a considerable quantity of gas at 200°, after having been previously heated at 100° C. for some hours. The analytical data, together with those showing the composition of gases present in coal after exposure to the atmosphere for several months, were, however, unfortunately lost.

Anthracites yield by far the largest gas-volumes, *e.g.*, sample 14, of specific gravity 1.35, and giving on analysis 2.67 per cent. of hydrogen, yielded from 100 grams of coal as much as 600 c.c. of gas, when heated at 100° for seven hours. On heating it to 200° for eight hours, close upon 1,000 c.c. of gas were obtained, whilst at 300° a still further quantity was given off, the gas obtained amounting altogether to 1875.9 c.c. per 100 grams of coal.

The composition of the gases evolved from anthracite closely resembles that from steam coals. The only difference appears to be that the anthracites from the western part of the coal-basin occlude more marsh-gas and less carbonic anhydride (comp. sample 13), and that they are absolutely free from oxygen, while steam coals, as a rule, showed traces of oxygen.

Since, however, no oxygen could be found in any of the blower

gases, as I shall have opportunity to show in Part II of this paper, I am inclined to think that the small quantity of oxygen was derived from the air which diffused into the coal during the time of handling it.

It is worth observing, moreover, that the gases evolved from anthracite at 100°, 200°, and 300°, are analogous in composition, in so far as they consist of carbonic anhydride, marsh-gas, and nitrogen only; but that the percentage of the latter is reduced to a mere trace (in fact, within the analytical limits of error); also, that the percentage of carbonic anhydride decreases, leaving a gas-volume consisting almost entirely of marsh-gas.

Why the heavier gases should come off first in a partial vacuum—an observation which is entirely in contradiction to the law of diffusion—I am unable to explain; for when the coal was left in connection with the evolved gases at the ordinary temperature, no material re-absorption was observed. In fact, the coal has no power to re-condense the gases when once liberated.

The following table will show the quantities of gases evolved, as well as the percentage composition:—

No. of Sample.	Gas evolved by 100 grms. of Coal, at 100° under vac.	Composition of Gases.			
		Carbonic anhydride.	Oxygen.	Marsh-gas.	Nitrogen.
1	55·9 c.c.	36·42	0·80	—	62·78
2	61·2 c.c.	16·77	2·72	·40	80·11
3	55·1 c.c.	5·44	1·05	63·76	29·75
3a	73·6 c.c.	12·34	0·64	72·51	14·51
4	194·8 c.c.	5·04	0·33	87·30	7·33
5	250·1 c.c.	13·21	0·49	81·64	4·66
6	218·4 c.c.	5·46	0·44	84·22	9·88
7	147·4 c.c.	18·90	1·02	67·47	12·61
8	375·4 c.c.	9·25	0·34	86·92	3·49
9	149·3 c.c.	11·35	0·56	73·47	14·62
10	215·4 c.c.	5·64	0·54	82·70	11·12
11	24·0 c.c.	22·16	6·09	2·63	69·07
12	39·7 c.c.	9·43	2·25	31·98	56·34
13	555·5 c.c.	2·62	—	93·13	4·25
14	600·6 c.c.	14·72	—	84·18	1·10

The fact must not be lost sight of that the preceding conclusions refer only to anthracites, when examined in the laboratory: neither must it be taken for granted, because a coal contains a large volume of occluded gases, even when such gases consist mainly of marsh-gas, that the seam or vein from which it is derived is a fiery one, and one that requires great caution in working.

The very reverse is indeed the case. Now, although steam coal

yields less gas than anthracite, it must not be supposed for a moment that it is therefore safer to work the former. Steam coal, before being removed from the seam or vein, holds enclosed a much larger quantity of gas. Being less hard and more porous, the gas escapes from it in vastly increased quantities over that from anthracite. The volume of gas rushing out from the working face of most deep steam coals is so enormous, as to be almost incredible, whilst little gas escapes from a working face of anthracite coal. The great hardness and jet-like structure of the latter accounts in a great measure also for the large volume of gas which it holds enclosed, and it is probable that its formation must have taken place under such immense pressure that the gases generated during the transformation of the organic matter into anthracite were not able to make their escape.

I have been led also to examine the gases given off from the working face of coal and from blowers, and my anticipation that the composition of the occluded gases and of the mine-gases would stand in a definite and fixed relation was borne out by my experiments.

PART II.

Numerous analyses of the gases evolved from blowers, collected both in the mine as well as on the surface, have been made by Henry, Graham, Playfair, and other investigators; but, as far as I am aware, they confined themselves to the North of England coal fields.

In the *Records of the Museum of Economic Geology*, June, 1846, Lyon Playfair gave the results of many analyses, and clearly showed that carbonic anhydride is present in mine-gas. Previous to his investigations, the presence of this gas in blowers was open to doubt, as Graham did not detect it in the analyses which he submitted to the Chemical Society (*Memoirs of the Chemical Society*, vol. ii, p. 7). Playfair concludes that this was owing to the method employed by Graham in obtaining the gases, viz., collection over water, carbonic anhydride being soluble in that liquid.

The method which I adopted for collecting the blowers was somewhat similar to that by which Playfair obtained some of his samples. Others he collected over water. My method was as follows:—

The crack or rent in the rock from which the gases were evolved was carefully filled in with clay, to prevent the diffusion of atmospheric air, and a small hole was left in the centre, into which a glass funnel was introduced, and made air tight with clay.

Glass tubes which had previously been drawn out at each end into a small neck were connected with the funnel by means of india-rubber

tubing, and screw clamps were placed upon the india-rubber connections at both ends of the tubes.

When the blower was a strong one, it was only necessary to allow the gas to pass through the tubes for about ten minutes, in order to displace the air. But I found that in most cases it was impracticable to displace the whole of the air in this manner, as the gas found several outlets through the many cracks in the rock. I therefore applied suction by means of a double-acting syringe. When all the air had been displaced, the tubes were slightly warmed, and the clamps screwed tight; they were then taken without delay to the lamp station for the purpose of sealing the ends before a blowpipe flame.

Being desirous of comparing the blower gases with the gas evolved by the coal won in the gallery or heading in which the blower gas was collected, a hole was drilled into the solid face of the coal itself, and the gases collected in the manner mentioned. The same method was also used for collecting those blowers which in some instances were carried to the surface of the pits.

The following are the results of my analyses :

No. 1. Gases obtained from the top rock of the 6-foot seam, Dunraven Colliery, Treherbert, 225 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
92.0 mm.	11.0	88.30	Volume employed.
91.4 mm.	10.6	87.85	Volume after absorption of CO ₂ .
91.4 mm.	10.6	87.85	Volume after absorption of O.
340.0 mm.	10.8	326.56	Volume after O added.
160.7 mm.	11.2	154.11	Volume after explosion.
70.8 mm.	11.2	67.90	Volume after absorption of CO ₂ .

Composition in
100 parts.

Marsh-gas	97.65
Carbonic anhydride	.50
Nitrogen	1.85

100.00

No. 2. Gas obtained by boring into the coal, 6-foot seam, Dunraven Colliery, Treherbert, 225 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
102.5 mm.	15.2	96.80	Volume employed.
101.8 mm.	14.4	96.43	Volume after absorption of CO ₂ .
101.8 mm.	14.5	96.40	Volume after absorption of O.
389.6 mm.	14.4	369.10	Volume after O added.
191.0 mm.	14.7	180.70	Volume after explosion.
91.5 mm.	14.9	86.50	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	97·31
Carbonic anhydride	·38
Nitrogen	2·31
	<hr/> 100·00

No. 3. Gas obtained from the top rock of the 4-feet seam, Dunraven Colliery, Treherbert, 125 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 12°.	Progress.
104·4 mm.	11·8	104·47	Volume employed.
103·9 mm.	11·8	103·97	Volume after absorption of CO ₂ .
104·0 mm.	12·0	104·00	Volume after absorption of O.
360·8 mm.	12·3	360·44	Volume after O added.
158·8 mm.	12·0	158·80	Volume after explosion.
57·8 mm.	12·0	57·80	Volume after absorption of CO ₂ .
			Composition in 100 parts.
Marsh-gas			96·74
Carbonic anhydride			0·47
Nitrogen			2·79
			<hr/> 100·00

No. 4. Gas obtained from the 4-feet seam by boring into the coal, Dunraven Colliery, Treherbert, 125 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
44·9 mm.	10·6	43·16	Volume employed.
44·7 mm.	10·6	42·97	Volume after absorption of CO ₂ .
44·7 mm.	10·6	42·97	Volume after absorption of O.
180·8 mm.	11·2	173·40	Volume after O added.
94·4 mm.	11·5	90·43	Volume after explosion.
50·9 mm.	11·5	48·76	Volume after absorption of CO ₂ .
			Composition in 100 parts.
Marsh-gas			96·54
Carbonic anhydride			0·44
Nitrogen			3·02
			<hr/> 100·00

No. 5. Gas obtained from the 6-feet seam by boring into the coal, Fochriew Colliery, No. 2, Merthyr District, 395 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
87.0 mm.	10.6	83.63	Volume employed.
87.0 mm.	11.0	83.50	Volume after absorption of CO ₂ .
83.1 mm.	11.6	79.57	Volume after absorption of O.
358.0 mm.	12.2	342.00	Volume after O added.
227.0 mm.	12.5	216.61	Volume after explosion.
161.5 mm.	12.7	154.00	Volume after absorption of CO ₂ .

Composition in 100 parts.	
Marsh-gas	74.86
Carbonic anhydride	0.15
Air { Oxygen	4.69
{ Nitrogen	17.75
Nitrogen	2.55
<hr/>	
100.00	

No. 6. Gas obtained by boring into the coal, 9-feet seam. Fochriew Colliery, No. 2, Merthyr District, 454 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
89.3 mm.	14.1	84.70	Volume employed.
89.0 mm.	14.3	84.34	Volume after absorption of CO ₂ .
88.9 mm.	14.4	84.21	Volume after absorption of O.
375.0 mm.	15.0	354.40	Volume after O added.
200.4 mm.	15.0	189.40	Volume after explosion.
113.2 mm.	15.1	106.94	Volume after absorption of CO ₂ .

Composition in 100 parts.	
Marsh-gas	97.37
Carbonic anhydride	0.42
Nitrogen	2.21
<hr/>	
100.00	

No. 7. Gas obtained from the 4-feet seam by boring into the coal. South Pit, Plymouth Iron Works, Merthyr, 300 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
93.7 mm.	12.9	89.28	Volume employed.
93.1 mm.	13.1	88.64	Volume after absorption of CO ₂ .
93.1 mm.	13.0	88.67	Volume after absorption of O.
348.0 mm.	13.0	331.43	Volume after O added.
169.0 mm.	13.0	160.95	Volume after explosion.
79.6 mm.	13.0	75.81	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	95.42
Carbonic anhydride	0.60
Nitrogen	3.98
	<hr/> 100.00

No. 8. Gas obtained from the top rock of the 4-feet seam, South Pit, Plymouth Iron Works, Merthyr, 300 yards from the surface. Water oozed out, together with the gas. This accounts for the low percentage of CO_2 .

Observed pressure of gas (dry).	Temperature.	Progress.
97.6 mm.	13.0	Volume employed.
97.5 mm.	13.0	Volume after absorption of CO_2 .
97.5 mm.	13.0	Volume after absorption of O.
367.8 mm.	13.0	Volume after O added.
182.6 mm.	13.0	Volume after explosion.
90.0 mm.	13.0	Volume after absorption of CO_2 .

	Composition in 100 parts.
Marsh-gas	94.84
Carbonic anhydride	0.10
Nitrogen	5.06
	<hr/> 100.00

No. 9. Gas obtained from the top rock of the 6-feet seam, Forch-ammon Colliery, Aberdare District, 230 yards from the surface.

This blower contained the highest percentage of carbonic anhydride of any which I have examined, and, apparently, was derived from an unworked seam of coal some yards above, with which a quantity of slag or shale rich in CO_2 may have been combined. Or the gases evolved by the seam of coal may have passed through a vein of such a shale before reaching the gallery in which they were collected. No water accompanied the gas. Several analyses of this gas were made.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 11.2°.	Progress.
93.8 mm.	11.5	93.7	Volume employed.
89.7 mm.	11.2	89.7	Volume after absorption of CO_2 .
89.6 mm.	11.2	89.6	Volume after absorption of O.
357.1 mm.	11.2	357.1	Volume after O added.
179.0 mm.	11.2	179.0	Volume after explosion.
82.9 mm.	11.2	89.9	Volume after absorption of CO_2 .

	Composition in 100 parts.
Marsh-gas	95.05
Carbonic anhydride	4.26
Nitrogen	.69
	<hr/> 100.00

No. 10. This gas was obtained from a rent in the top rock of the 4-feet seam, Ferndale No. 2 Colliery, Rhondda District.

The rock was much broken, thus rendering it impossible to prevent atmospheric air from becoming mixed with the gas. The carbonic anhydride is very high in this sample.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 14°.	Progress.
91.9 mm.	13.3	92.13	Volume employed.
91.3 mm.	13.9	91.33	Volume after absorption of CO ₂ .
82.0 mm.	14.1	81.97	Volume after absorption of O.
334.0 mm.	14.0	334.00	Volume after O added.
246.6 mm.	14.0	246.6	Volume after explosion.
203.0 mm.	14.0	203.0	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	47.37
Air	48.60
Carbonic anhydride	0.90
Nitrogen	3.13
	<hr/> 100.00

No. 11. This gas was obtained from a heading connecting the upcast and downcast shafts, Bute Merthyr Colliery, Rhondda District, situated about 20 yards above the 2-feet 9-inch seam, and 80 yards from the surface.

This was a very strong blower, and there was no water issuing from the rock.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
95.6 mm.	14.7	90.5	Volume employed.
95.0 mm.	14.7	89.9	Volume after absorption of CO ₂ .
95.1 mm.	15.0	89.9	Volume after absorption of O.
390.3 mm.	15.0	368.9	Volume after O added.
207.5 mm.	15.0	196.1	Volume after explosion.
116.1 mm.	15.0	109.8	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	95.47
Carbonic anhydride	0.62
Nitrogen	3.91
	<hr/> 100.00

No. 12. Gas obtained on the floor of a hard heading between the 6-foot and 9-foot seams, Maesteg Merthyr Colliery, 140 yards from the surface.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
93.0 mm.	11.8	88.98	Volume employed.
91.1 mm.	11.6	87.23	Volume after absorption of CO ₂ .
91.1 mm.	11.6	87.23	Volume after absorption of O.
339.5 mm.	11.6	325.12	Volume after O added.
162.0 mm.	12.0	154.88	Volume after explosion.
73.4 mm.	12.6	70.02	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	95.51
Carbonic anhydride	1.96
Nitrogen	2.53
	<hr/> 100.00

No. 13. This gas was obtained from the lamp room, Llwynypia Colliery, Rhondda District, and is brought up to the surface for the purpose of lighting the engine-room, lamp-room, and the top of the down-cast shaft. I made several analyses of this gas, and invariably found that a small quantity of some hydrocarbon, probably hydride of ethyl, was present in addition to marsh-gas.

Observed pressure of gas (dry).	Tempe- rature.	Progress.
110.4 mm.	12.7	Volume employed.
109.6 mm.	12.7	Volume after absorption of CO ₂ .
109.6 mm.	12.7	Volume after absorption of O.
109.5 mm.	12.7	Volume after absorption with fuming sulphuric acid.
401.4 mm.	12.7	Volume after O added.
190.0 mm.	12.7	Volume after explosion.
83.4 mm.	12.7	Volume after absorption of CO ₂ .
291.7 mm.	12.7	Volume after H added.
53.2 mm.	12.7	Volume after explosion.

	Composition in 100 parts.
Marsh-gas	94.78
Hydride of ethyl	0.90
Carbonic anhydride	0.72
Nitrogen	3.60
	100.00

No. 14. This gas was collected from the side of Cwm Park Brook, where it escaped in large quantity. Ystrad Rhondda District.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 0°.	Progress.
88.0 mm.	11.0	84.5	Volume employed.
87.7 mm.	10.8	84.2	Volume after absorption of CO ₂ .
87.6 mm.	10.8	84.1	Volume after absorption of O.
336.8 mm.	12.1	321.9	Volume after O added.
168.0 mm.	12.1	160.6	Volume after explosion.
83.5 mm.	12.1	79.8	Volume after absorption of CO ₂ .

	Composition in 100 parts.
Marsh-gas	95.56
Oxygen	0.11
Carbonic anhydride	0.35
Nitrogen	3.98

100.00

The following Table gives a brief summary of the preceding analyses of blowers and gases from borings:—

No. of Sample.	Whether a blower, or obtained by boring into coal.	Composition of the gas.				
		Marsh- gas.	Hydride of ethyl.	Carbonic anhydride.	Oxygen.	Nitrogen.
1	Blower.	97.65	—	0.50	—	1.85
2	Boring.	97.31	—	0.38	—	2.31
3	Blower.	96.74	—	0.47	—	2.79
4	Boring.	96.54	—	0.44	—	3.02
5	Boring.	74.86	—	0.15	4.69	20.30
6	Boring.	97.37	—	0.42	—	2.21
7	Boring.	95.42	—	0.60	—	3.98
8	Blower.	94.84	—	0.10	—	5.06
9	Blower.	95.05	—	4.26	—	0.69
10	Blower.	47.37	—	0.90	10.15	41.58
11	Blower.	95.47	—	0.62	—	3.91
12	Blower.	95.51	—	1.96	—	2.53
13	Blower.	94.78	0.90	0.72	—	3.60
1	Blower.	95.56	—	0.35	0.11	3.98

On looking over these analytical data, and comparing the volume of carbonic anhydride absorbed after the combustion of the marsh-gas with the contraction in volume after explosion, it will become apparent that in some instances there were indications of traces of a hydrocarbon other than marsh-gas. The quantity of this hydrocarbon, which I have every reason to think is hydride of ethyl, is, however, so small that I have not taken it into account; and in making up the analysis it has been calculated as marsh-gas. The blowers showing these traces of other gases were invariably examined for olefiant gas; but in no instance was its presence detected.

Some time after collecting and analysing sample 13, I revisited the colliery for the purpose of forming some idea of the illuminating power of the gas, and I connected an ordinary fish-tail gas burner by means of an india-rubber tube to a pipe which conveyed the mine-gas. A very appreciable amount of light was obtained. In the same manner a Silber patent Argand burner was tried; but in this experiment no illuminating power was shown by the mine-gas; the flame resembled that of a Bunsen burner. The gas was next passed through a tube containing carded cotton, to remove any particles of coal-dust which may have been carried along; but although the flame was smaller, owing to the resistance offered by the cotton, it appeared to have an equal illuminating power. I may also mention that several cubic feet of the gas were passed through a solution of plumbic nitrate without giving any indication of sulphuretted hydrogen. The other blowers were also tested for this gas, but gave no evidence of its presence.

On examining the analyses of these blowers side by side with those from the North of England coal fields already referred to, the high percentage of marsh-gas and comparatively low percentage of nitrogen, strikes one most forcibly. It is also curious to observe the great similarity between the blower gases which I have examined.

On comparing, for instance, gas No. 3 obtained from the top rock of the seam, with gas No. 4 obtained by boring into the body of the coal, the percentage composition appears almost identical, showing that the blower must have been fed from the same seam. The gases No. 3 and No. 4, together with coal No. 6 (Part I), were procured not only from the same seam, but also within a few yards of each other. The gas No. 4 evolved by the *seam* of coal contained only 44 per cent. of carbonic anhydride, while the gas obtained by exhausting the portion of coal No. 6 taken out of the same seam, gave 5.46 per cent. of carbonic anhydride. The portion of coal referred to was cut from the middle of a large lump; and as no air had previously been in contact with it, the carbonic anhydride in the enclosed gases must have been present in the coal before being cut from the seam.

Now, since the gases enclosed in the steam-coals, which were left

exposed to the atmosphere, escaped somewhat in accordance with the law of diffusion, some idea may be formed from the above comparisons of the enormous volume of gas which is held enclosed in the coals of this class prior to their removal from the seam or vein.

Before concluding, I desire to express my gratitude to Dr. Frankland for his ever-ready and valuable advice.

In acknowledging my obligations to the colliery proprietors, I must admit my inability to express my full sense of the courtesy which I received at their hands, as well as the truly kind services rendered by their managers and sub-officers.