VIII.—*On the Gases enclosed in Cannel Coals and Jet.*

By J. W. THOMAS.

THE analyses of the gases enclosed in anthracite, bituminous, and steam coals, were given in a former paper (*Chem. Soc. J.* [2], xiii, 793), and reference made to the work which had been previously done in this direction. The gases enclosed in cannel,—another important class of coal used for the manufacture of coal-gas, &c.,—have not, as far as I am aware, been determined.

The method used for obtaining the enclosed gases was similar to that described in the paper referred to, with the exception that Florence flasks, having their necks drawn out and bent over, were substituted for glass tubes when Scotch cannel was employed,—a large quantity of coal being required to furnish the necessary volume of gas. These coals were broken in a mortar and passed through a sieve having 9 meshes to the inch, and the dust was removed by a sieve having 64 meshes to the inch.

The following table shows from whence the cannel coals and jet were obtained :—

No of Sample.	Description.	District.
No. 1	Wigan cannel $\frac{5}{8}$ seam, 350 yards deep.	Wigan Arley Mine, Lancashire coal field.
2	Wigan cannel $\frac{3}{4}$ seam, 600 yards deep.	Lancashire coal field.
3	Scotch cannel (Heywood cannel (Wilson-town)).	Lanark.
4	Scotch cannel (Lesmahago).	
5	Whitehill cannel shale, Lasswade.	Edinburgh.
6	Whitby jet (finest quality for ornaments).	Whitby.

Cannel coals are usually very hard and close-grained, fracturing conchoidal, without crumbling, and when placed in a vacuum do not evolve any appreciable quantity of gas. No. 1 was somewhat porous, and resembled, in appearance, the hardest steam coals of the South Wales Basin.

The following are the results I obtained :—

SAMPLE No. 1.—*Wigan Cannel from Wigan Arley Mine.*

100 grms. of coal evolved 421·3 c.c. of gas at 100°

The last portion of air exhausted in forming a vacuum contained 20·54 per cent. of oxygen.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 11°.	Progress.
91·7 mm.	11·3	91·60	Volume employed.
85·7 mm.	11·0	85·70	Volume after absorption of CO ₂ .
85·7 mm.	11·0	85·70	Volume after absorption of O.
342·5 mm.	11·0	342·50	Volume after adding O.
183·6 mm.	11·1	183·53	Volume after explosion.
101·1 mm.	11·5	100·92	Volume after absorption of CO ₂ .
347·9 mm.	11·9	346·76	Volume after adding H.
66·5 mm.	11·9	66·30	Volume after explosion.
			Composition in 100 parts.
Carbonic anhydride			6·44
Marsh-gas			80·69
Hydride of ethyl			4·75
Nitrogen			8·12
			<hr/> 100·00

SAMPLE No. 2.—*Wigan Cannel.*

100 grms. of coal evolved 350·6 c.c. of gas at 100°.

The last portion of air exhausted in forming a vacuum contained 20·77 per cent. of oxygen.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 11·6°.	Progress.
127·0 mm.	10·7	127·42	Volume employed.
115·6 mm.	11·0	115·85	Volume after absorption of CO ₂ .
115·7 mm.	11·2	115·90	Volume after absorption of O.
446·5 mm.	11·6	446·50	Volume after adding O.
223·5 mm.	11·8	223·34	Volume after explosion.
105·4 mm.	12·4	105·10	Volume after absorption of CO ₂ .
7·6 mm.	11·6	7·60	Volume after absorption of O.

Composition in 100 parts.	
Carbonic anhydride	9·05
Marsh-gas	77·19
Hydride of ethyl	7·80
Nitrogen	5·96
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100·00	

The tube containing the coal was heated for two days until apparently exhausted, the last portion of gas brought over was of the following composition:—

Analysis of last portion Evolved at 100° C.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 12·6°.	Progress.
118·4 mm.	12·6	118·40	Volume employed.
113·7 mm.	12·6	113·70	Volume after absorption of CO ₂ .
433·0 mm.	13·0	432·37	Volume after adding O.
197·6 mm.	13·0	197·30	Volume after explosion.
66·8 mm.	12·6	66·80	Volume after absorption of CO ₂ .
304·3 mm.	12·6	304·30	Volume after adding H.
110·9 mm.	12·6	110·90	Volume after explosion.

Composition in 100 parts.	
Carbonic anhydride	3·97
Marsh-gas	79·58
Hydride of ethyl	15·32
Nitrogen	1·13
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100·00	

The first portion of sample No. 2 gave off gas readily, about twice its volume being evolved in six hours. On the second day it was again heated for 10 hours—some of the higher hydrocarbons of the paraffin series were condensed in the connecting-tube of the Sprengel, and also brought over by the pump. On the third morning, a white crystalline substance was formed in the connecting-tube, which, together with the tubes in which the gas was collected, emitted the odour of the oils obtained from petroleum distilled at 100° . I was unable to obtain satisfactory results, owing to the presence of so much oily matters brought over by the Sprengel pump. A second portion of the coal was taken and connected with the Sprengel in the usual manner. The branch tube holding the water-joint was made of extra length, and of such a form as to admit of its being surrounded with freezing mixture. The gas brought over was thus obtained more free from vapour of the higher hydrocarbons.

This coal was again heated to 200° , when a further quantity of gas was evolved equal to 276.2 c.c. per 100 grms. of coal. In spite of the cooling effect of the freezing mixture, some oily matters and vapour were brought over by the pump, and the results of the analysis were not sufficiently concordant to enable one to calculate the percentage of the hydrocarbons present. It was interesting, however, to observe the deposition of oily matters in the neck of the flask in which the coal was placed, as well as along a considerable length of the connecting-tube. This coal appears to hold in a condensed form the whole of the paraffins from C_4H_{10} upwards, together with the gases CO_2 , N, CH_4 , C_2H_6 , and probably C_3H_8 .

A portion of this coal was maintained for eight hours under a partial vacuum at 50° , and the gas evolved smelt strongly like crude petroleum, and the surface of the water (from the coal) in the connecting-tube (which was immersed in freezing mixture) was covered with oily matter, which disappeared shortly after the apparatus was disconnected.

SAMPLE NO. 3.—*Scotch Cannel, Haywood Colliery, Wilsontown.*

100 grms. of coal evolved 16.8 c.c. at 100° .

The last portion of air exhausted in forming a vacuum contained 20.86 per cent. of oxygen.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 15·0°.	Progress.
134·4 mm.	13·4	135·20	Volume employed.
62·0 mm.	13·8	62·27	Volume after absorption of CO ₂ .
62·1 mm.	13·8	62·37	Volume after absorption of O.
244·0 mm.	15·0	244·00	Volume after adding O.
337·8 mm.	15·0	337·80	Volume after adding H.
195·3 mm.	14·0	196·00	Volume after explosion.
61·8 mm.	14·2	61·98	Volume after absorption of O.

	Composition in 100 parts.
Carbonic anhydride	53·94
Nitrogen	46·06
Traces of Hydrocarbons	
	<hr/> 100·00

SAMPLE No. 4.—*Iesmahago Cannel.*

100 grms. of coal evolved 55·7 c.c. of gas at 100°.

The last portion of gas exhausted in forming a vacuum contained 20·99 per cent. of oxygen.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 13°.	Progress.
436·2 mm.	13·0	436·2	Volume employed.
67·4 mm.	13·0	67·4	Volume after absorption of CO ₂ .
67·3 mm.	13·0	67·3	Volume after absorption of O.
67·2 mm.	13·0	67·2	Volume after absorption with ammonio-cuprous chloride.
66·0 mm.	14·0	65·75	Volume after absorption with fuming sulphuric acid.
205·3 mm.	12·2	205·90	Volume after adding oxygen.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 13°.	Progress.
319·2 mm.	12·6	319·66	Volume after adding H.
141·4 mm.	12·8	141·50	Volume after explosion.
134·8 mm.	13·0	134·80	Volume after absorption of CO ₂ .
322·0 mm.	13·0	322·0	Volume after adding H.
107·4 mm.	13·0	107·4	Volume after explosion.

	Composition in 100 parts.
Carbonic anhydride	84·55
Nitrogen	14·54
Gases and vapour of the C _n H _{2n+2} series agreeing with C ₃ H ₈	0·91
	<hr/> 100·00

SAMPLE No. 5.—*Cannel Shale, Lasswade, Edinburgh.*

100 grms. of the shale evolved 15·7 c.c. of gas.

The last portion of air exhausted in forming a vacuum contained 20·85 per cent. of oxygen.

Analysis of the Gas Evolved at 100°.

The absence of oxygen was proved by previous analyses.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 15°.	Progress.
312·9 mm.	14·9	313·0	Volume employed.
97·8 mm.	15·0	97·8	Volume after absorption of CO ₂ .
256·8 mm.	14·6	257·17	Volume after adding O.
407·6 mm.	15·0	407·60	Volume after adding H.
163·4 mm.	15·0	163·40	Volume after explosion.
146·3 mm.	15·2	146·20	Volume after absorption of CO ₂ .
389·4 mm.	15·6	388·55	Volume after adding H.
218·9 mm.	15·8	218·26	Volume after explosion.

	Composition in 100 parts.
Carbonic anhydride	68·75
Gases of the C _n H _{2n+2} series agree- ing with C ₂ H ₆ , C ₃ H ₈	2·67
Nitrogen	28·58
	<hr/> 100·00

SAMPLE No. 6.—*Whitby Jet (finest quality).*

100 grms. of jet evolved 30·2 c.c. of gas at 100°.

Analysis of the Gas Evolved at 100°.

Observed pressure of gas (dry).	Tempe- rature.	Corrected vol. at 13°.	Progress.
55·2 mm.	12·8	55·24	Volume employed.
49·2 mm.	13·0	49·2	Volume after absorption of CO ₂ .
454·5 mm.	12·8	454·83	Volume after adding O.
282·6 mm.	13·0	282·6	Volume after explosion.
88·6 mm.	13·0	88·6	Volume after absorption of CO ₂ .
387·4 mm.	13·0	387·4	Volume after adding H.
125·2 mm.	13·0	125·2	Volume after explosion.

Composition in
100 parts.

Carbonic anhydride	10·93
Quartane or ethyl	86·90
Nitrogen	2·17

100·00

The contraction of volume after explosion, carbonic acid absorbed, and oxygen consumed when compared with the volume (sample 6), correspond nearly with C₄H₁₀, including probably a little vapour of other hydrocarbons higher in the series. Absolute alcohol absorbs more than three-fourths of the entire volume of gas withdrawn from jet, and gives it up again on the addition of water.

The following table gives the quantity of gases evolved as well as their composition:—

Composition of Gases.

No. of Sample.	Gas evolved by 100 grms. of coal at 100° under a vacuum.	Carbonic anhydride.	Marsh- gas.	Hydride of ethyl.	Quartane or ethyl.	Nitrogen.
1	421·3 c.c.	6·44	80·69	4·75	—	8·12
2	350·6 c.c.	9·05	77·19	7·80	—	5·96
3	16·8 c.c.	53·94	—	—	—	46·06
4	55·7 c.c.	84·55	—	—	{ C ₃ H ₈ 0·91 }	14·54
5	55·7 c.c.	68·75	—	2·67	—	28·58
6	30·2 c.c.	10·93	—	—	86·90	2·17

The coals examined by Meyer from the Newcastle and Durham coal-fields (abstract of paper, published in the *Journal für praktische Chemie* [2], v, 144--183; 407--427, and vi, 389--416 will be found in the *Chem. Soc. J.* [2], x, 798 and 801, and xi, 483), did not contain any hydrocarbon other than marsh-gas. The bituminous, anthracite, and steam coals, already referred to at the commencement of this paper, also contained only CO_2 , CH_4 , O and N as occluded gas.

It will be seen, however, that the canal coals differ considerably from those mentioned, inasmuch as they enclose hydride of ethyl, and most probably C_3H_8 , and all the paraffin series. I am unable to determine the presence or absence of C_3H_8 in a mixture containing CH_4 and C_2H_6 , as

I have, therefore, calculated the volume of explosive gas as CH_4 and C_2H_6 .

The whole of the canal coals and jet contain the gases of the paraffin series and oily matters, which appear to belong to the same. Wigan canals, with regard to the gases which they hold enclosed, occupy a position intermediate with steam and Scotch canal; and Scotch canal occupies a position intermediate with bituminous house coals and Wigan canal. Thus, in the Wigan canals, there is a large volume of gas, consisting for the most part of marsh-gas, with a low percentage of carbonic acid and nitrogen, and, *in these respects*, closely allied to the steam coals. The Scotch canals, on the other hand, contain but little gas, which consists almost entirely of carbonic anhydride and nitrogen, similar to the bituminous class of house coals. Scotch canal contains a small quantity of the higher hydrocarbon gases. Owing to the high percentage of carbonic anhydride present, it became possible to employ a large and concentrated volume for the determination of the combustible gases.

In the analysis of sample 4, the respective volumes of the contraction after explosion, carbonic anhydride formed, and oxygen consumed, when compared with the volume, agree nearly with hydride of propyl; it is possible, therefore, that CH_4 , C_2H_6 , C_4H_{10} may be present also. In sample No. 5, C_2H_6 and C_3H_8 agree nearly with the respective volumes above mentioned.

The gases from all the canal coals have been treated with fuming sulphuric acid and ammonio-cuprous chloride. Some of them showed indications of C_nH_{2n} gases, but it is probable that the loss in volume was due to the absorption of the vapour of the higher hydrocarbons, because, when the whole volume of combustible gas was exploded, the CO_2 formed, O consumed, and contraction due to explosion, did not agree with the calculated volume.

Negative results were obtained with ammonio-cuprous chloride, showing the absence of carbonic oxide.

Absolute alcohol absorbed more or less gas in all instances, but the total volume of combustible gas was insufficient to obtain decided results with the Scotch cannels. The gases obtained from sample No. 5, after absorption with absolute alcohol, and exploding with oxygen by the aid of hydrogen, yielded only 1 per cent. of combustible gas, and the hydride of ethyl in canal No. 2 was considerably lessened after absorption with alcohol.

Jet differs from the harder cannels by occluding only a small percentage of CO_2 and N, and also by containing a large percentage of $\text{C}_n\text{H}_{2n+2}$ gas. The tube in which the gases were brought over by the pump contained one- or two-tenths of a c.c. of oily matter emitting the odour of paraffin.

It is necessary when working with any coal, or carbonaceous material whatever, for the purpose of obtaining its enclosed gases, to first ascertain by experiment the volume which is evolved at the required temperature. In this manner, a portion of the substance can be taken which shall yield the quantity of gas necessary for analysis, and shall not be too large to be collected in one tube; and the coal should be exhausted before using any of the gas for analysis, unless it be required to ascertain the deportment of the gases under a vacuum.

In conclusion, I would express my thanks to those gentlemen who favoured me with the coals and jet.