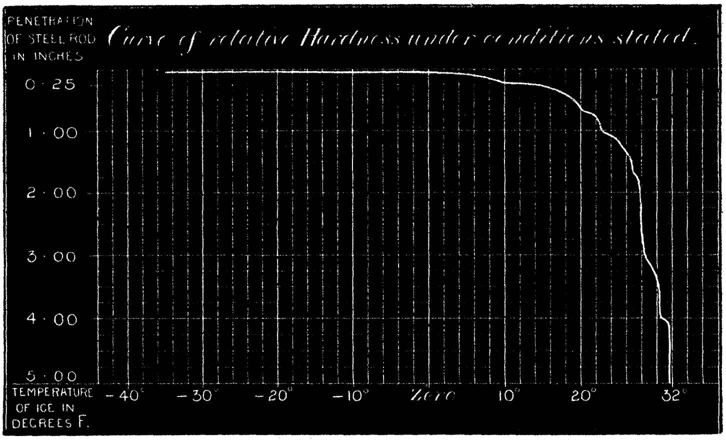
Table III.—Relative Hardness or Penetrability of Ice at various Temperatures.



The steel rod penetrated at −35° F. 0·043 in., and at zero F. 0·094 in.

results are given in Table III. These are the average of very many observations. The ice appeared practically to maintain its almost impenetrable hardness from −35° F. until about +10° to 20° F., after which its power of resistance to the penetration of the steel rod rapidly decreased with the increase of temperature. It will also be noticed that the relative contraction and dilatation of the ice between the extremes of low temperature employed was considerable. The whole of the experiments were many times repeated to ensure accuracy, and it may be observed that above 20 tons of snow and above 7 tons of salts for freezing mixtures, &c., were consumed in conducting the varied experiments of the investigation.

XIII. "On the Gaseous Constituents of Meteorites." By GERRARD ANSDELL, F.C.S., and Prof. JAMES DEWAR, F.R.S.

Received June 10, 1886.

The nature of the occluded gases which are present to a greater or less extent in all meteorites, whether belonging to the iron, stony, or carbonaceous classes, has engaged the attention of but few chemists. It is, nevertheless, an especially interesting and important subject, owing to the uncertainty which still exists as to the origin of these celestial bodies.

Graham ("Proc. Roy. Soc.," vol. 15 (1867), p. 502, was the first who made any experiments in this direction, when he determined the gases occluded in the Lenarto meteoric iron, which yielded 2·85 times its volume of gas, 86 per cent. of which was hydrogen, and 4·5 per

cent. carbonic oxide. He was followed in 1872 by Wöhler ("Pogg. Ann.," vol. 146, p. 297) and Berthelot ("Compt. rend.," vol. 74, pp. 48, 119), who estimated approximately the gases contained in the Greenland Ovifak iron. These gases consisted of about equal parts of carbonic acid and carbonic oxide; the celestial origin of this iron is, however, very doubtful.

In the same year (1872) the American chemist, Mallet ("Proc. Roy. Soc.," vol. 20, p. 365), made a very complete determination of the gases occluded by the Augusta Co., Virginia, meteoric iron, which, however, differed very considerably from Graham's results. He obtained an amount of gas equal to 3·17 times the volume of the iron, made up of 35·83 per cent. of hydrogen, 38·33 per cent. carbonic oxide, 9·75 per cent. of carbonic acid, and 16·09 per cent. of nitrogen.

Wright and Lawrence Smith followed Mallet, and our present knowledge of this interesting subject is principally due to these American chemists. They have taken advantage of the numerous meteoric masses which have fallen from time to time throughout America, and which can easily be obtained in sufficient quantity for complete and accurate observations on their gaseous constituents.

Wright contributed several papers to the "American Journal" in 1875 and 1876, and, according to his analyses, the total volume of gas occluded and the composition of the same differs considerably in the two principal classes of meteorites. He found the total volume of gas extracted was much greater in the case of the stony meteorites than in the iron ones, the principal characteristics of these gases being, that in the former the carbonic acid greatly predominated, accompanied by a comparatively small amount of carbonic oxide and hydrogen, whereas in the latter the carbonic acid never exceeded 20 per cent., the carbonic oxide being, as a rule, considerably more than this, and the hydrogen sometimes reaching as high as 80 per cent.

It is impossible, however, to arrive at anything more than general conclusions as to the total amount of gas given off by any special meteorite, or its composition, for, as shown by Wright and confirmed by ourselves, both the total quantity and composition of the gases vary very considerably according to the temperature at which they are drawn off.

Wright found a notable quantity of marsh-gas in all the stony meteorites which he examined, though not a trace in any of the iron ones; this seemed to be a distinctive difference between the two classes of meteorites, but subsequently Dr. Flight, of the British Museum ("Phil. Trans.," vol. 173 (1882), p. 885), found marsh-gas in a specimen of the Cranbourne siderite, so that it is evident certain of the iron meteorites also contain this gas.

Lawrence Smith ("Amer. Journ.," 1876) confined himself principally to an examination of the graphite nodules which are frequently

found imbedded in the iron meteorites, and to the nature of the carbon in the so-called carbonaceous meteorites. He extracted the organic or hydrocarbon-like bodies by means of ether, but did not determine the gases given off on heating. Previous to this, Roscoe ("Pro. Phil. Soc. Man.," 1862) had obtained the same hydrocarbon-like body by exhausting the Alais meteorite with ether, but the quantity he had to work upon was so small that he could not make a very complete examination.

These are some of the principal points that have been made out with regard to the gases occluded by meteorites. The results, however, are so comparatively few, that we thought it worth while to take the opportunity which presented itself, of having several good specimens of meteorites at our disposal, to confirm these results, and, if possible, add something to our present knowledge of the subject.

The investigation may be divided into five parts, having the following objects in view: firstly, the confirmation of previous results by the examination of some well-known meteorite; secondly, the analysis of several whole meteoric stones, whose interior had never been exposed to the effects of the atmosphere, by reason of the characteristic coating of glaze; thirdly, the examination of a celestial graphite nodule, taken from the interior of an iron meteorite; fourthly, the comparison of some meteorite of the carbonaceous class with the above; and, fifthly, the examination of different terrestrial graphites.

The method employed for the abstraction of the gases was exactly the same in every case, so that a short description will suffice for all. The temperature was kept as nearly as possible the same in every experiment, but no doubt differences of many degrees occurred in some of the experiments, which was unavoidable in using an ordinary combustion furnace.

The meteorite or graphite, as the case might be, was broken up into a coarse powder, introduced into a convenient length of combustion tubing, and connected up with a Sprengel pump, a small bulb-tube immersed in a freezing mixture intervening, so as to retain any moisture or condensable volatile products that might come off. The tube was first thoroughly exhausted and then heated in an ordinary gas combustion furnace to a low red heat. The gases, during the heating, were gradually drawn off by the Sprengel, and when the tube had remained for several minutes at a low red heat it was completely exhausted. The total quantity of gas collected was in every case used for the analysis.

The "Dhurmsala" specimen was an ordinary fragment of a much larger original mass, but in the case of the Pultusk and Mocs meteorites, we were fortunate in obtaining complete stones, weighing respectively 57 and 103 grams, having the characteristic black glaze on their surfaces.

Such a large quantity of water was condensed in the bulb tube in heating the Dhurmsala meteorite, it being the first one examined, that it was thought it might be principally due to the great absorptive power of these porous bodies, and that therefore the moisture might have been condensed in the pores of the meteorite from the surrounding air. The Pultusk and Mocs specimens appeared to be especially adapted for ascertaining whether this was the case, as the complete covering of black glaze would probably prevent the moisture from penetrating to the interior of the stones. The fragments of these stones were therefore transferred as quickly as possible to the combustion tube after they had been broken up. Notwithstanding these precautions, fully as much water was condensed from them as from the Dhurmsala specimen, which seems to suggest that the water is really combined in some form in the stone and not obtained directly from the surrounding atmosphere, although it must be admitted that the glaze on both the stones was not of a very glossy character, and did not have the appearance of being absolutely impervious to moisture.

The pumice-stone was examined merely with a view to comparing the gases occluded by a porous body of volcanic origin with those contained in meteorites. The sample taken was a fresh piece of stone, which had not been dried or purified in any way.

It is evident that it differs considerably from the meteoric stones, the total occluded gas being very small, only about half its volume, the carbonic acid at the same time being much less with a proportionate increase in the carbonic oxide.

The general method of analysis was as follows, and the accuracy of the results was confirmed by varying in some cases the method of separating the gases. The carbonic acid was first removed from the mixture by caustic potash, the carbonic oxide being then absorbed by subchloride of copper, and the remainder of the gases exploded with excess of oxygen. The carbonic acid formed was again removed by caustic potash, and the excess of oxygen by alkaline pyrogallate, the residue being taken as nitrogen. The relative quantities of marsh-gas and hydrogen were calculated from the total diminution after explosion, and the amount of carbonic acid formed :—

	Sp. gr.	Occluded gases in vols. of the meteorite.	Percentage composition.				
			CO_2.	CO.	H.	CH_4.	N.
Dhurmsala....	3·175	2·51	63·15	1·31	28·48	3·9	1·31
Pultusk	3·718	3·54	66·12	5·40	18·14	7·65	2·69
Mocs	3·67	1·94	64·50	3·90	22·94	4·41	3·67
Pumice-stone..	2·50	0·55	39·50	18·50	25·4	—	16·60

It will be seen that the above numbers are quite confirmatory of Wright's results, the carbonic acid in the three meteorites examined being by far the largest constituent, while marsh-gas in considerable quantity was found in all. The percentage of this latter gas is somewhat higher than that found by Wright in the stony meteorites he examined, but this is probably due to the fact that a rather higher temperature was employed by us to drive off the gases. This supposition seems to be confirmed on considering the analysis of the Pultusk meteorite, which is the only one examined both by Wright and ourselves; for whereas his abstracted gas only reached 1·75 times the volume of the stone, the total quantity of gas obtained by us was twice as much or equal to 3·54 times its volume.

It is therefore unquestionable that marsh-gas is given off on heating these meteoric stones, but whether it exists as such occluded in the material, or whether it is formed by some chemical decomposition of some organic constituent of the mass is by no means clear.

Wright came to the conclusion "that the marsh-gas really existed as such in the stony meteorites, as the temperature at which it was driven off would be too low for its formation," at the same time he thinks it quite possible that "at very much higher temperatures, in the reaction by which the carbonic acid is broken up by the iron, a portion of the carbon might combine with the hydrogen present to form marsh-gas."

We shall return to this question of the formation of marsh-gas, after we have described the experiments in the various forms of graphite.

Knowing the great absorptive power for gases possessed by porous bodies generally, it was thought advisable to determine directly what this absorptive power was in the case of these stony meteorites, which are of such an eminently porous nature.

For this purpose the powdered Dhurmsala meteorite, from which the gases had been removed, was left in moist air under a bell glass, for different periods of time as tabulated below, the gases being drawn off at a low red heat after each period:—

	Occluded gas in vols. of the meteorite.	CO_2.	CO.	H.	N.
After 24 hours........	0·61	54·0	—	42·4	3·6
After 6 days more	2·47	47·0	5·0	47·0	1·0
After 8 days more	0·63	96·1	2·0	1·5	—

The absorption of water and gases evidently went on tolerably rapidly for the first seven days, but after the second heating of the meteorite, its porosity seems to have been affected in some way, for after a further period of eight days, we find it taking up only about a fourth of the quantity of gas which it had absorbed in the previous six days.

The actual amount of water given off after this exposure to a moist atmosphere was considerably less than what was obtained in the original heating of the meteorite, and from this we infer that the water is chemically combined in the stone. It would be difficult to explain, otherwise than by chemical combination, the power by which the water is retained by these meteorites, as it is not given off until a very high temperature is reached. In any case it is clear that the hydrogen must come from the action of water on the iron nickel alloy, or finely disseminated carbon. Greville Williams has pointed out that the large amount of hydrogen obtained from heating finely divided zinc-dust is not due to free hydrogen, but to the action of the zinc on the hydrated oxide of zinc.

We now pass on to the consideration of the various graphites examined. The celestial graphite was a perfect oblong nodule weighing 30 grams, which had been taken from the interior of a mass of the Toluca meteoric iron. It had a uniform dull-black colour, except at one end where there was a slight incrustation of sulphide of iron. Its fracture showed a uniform dull black, compact mass; it was easily pounded up in a porcelain mortar, and formed a fine granular powder without any lustre.

On extracting the gases from this specimen a considerable quantity of marsh-gas was obtained, so that it appeared to us most important to compare it with some samples of terrestrial graphites, more especially as the occluded gases had, to our knowledge, never before been determined in these bodies.

For this purpose four samples of native graphites were obtained. The Cumberland graphite was a magnificent specimen of the original Borrodale, and had been in a private cabinet for over fifteen years. It had the characteristic dense homogeneous structure, and brilliant external lustre of the graphites coming from this district. The Siberian example was from the Alexandref Mine; its structure was columnar and striated, with little external lustre; it was rather more easily broken up than the Borrodale, but formed the same dull black powder. The specimen from Ceylon was of the type usual to that island; highly lustrous and flaky, breaking up very easily, and forming small shining plates when ground up. The last sample, which was from the same cabinet as the others, but whose origin was unfortunately unknown, had a dull external surface, was exceedingly porous, and much more brittle than any of the previous ones, grinding up very easily into a dull black powder. It had more the appearance of the celestial graphites, which was heightened by having slight incrustations of sulphide of iron in its surface. Its low specific gravity also shows it to be some exceptional variety.

It seemed to us most important in connexion with this subject to examine some matrix with which the graphites are usually found

associated. These rocks are very variable, but consist principally of a kind of decomposed trap or gneiss. We succeeded in obtaining a good specimen of semi-decomposed gneiss from Canada with a considerable quantity of graphite disseminated throughout the mass, and also several samples of Ceylon graphite imbedded in its matrix, which in this case consisted of felspar and quartz.

The results, as tabulated below, confirm Wright's analyses of several trap rocks, in which he found principally carbonic acid and hydrogen. The small quantity of marsh-gas no doubt comes from the disseminated graphite, but the presence of the hydrogen is more difficult to explain and requires further investigation.

	Sp. gr.	Occluded gases in vols. of the graphite.	CO_2.	CO.	H.	CH_4.	N.
Celestial graphite	2·26	7·25	91·81	—	2·50	5·40	0·1
Borrodale ,,	2·86	2·60	36·40	7·77	22·2	26·11	6·66
Siberian ,,	2·05	2·55	57·41	6·16	10·25	20·83	4·16
Ceylon ,,	2·25	0·22	66·60	14·80	7·40	3·70	4·50
Unknown ,,	1·64	7·26	50·79	3·16	2·50	39·53	3·49
Gneiss	2 45	5·32	82·38	2·38	13·61	0·47	1·20
Felspar	2·59	1·27	94·72	0·81	2·21	0·61	1·40

On comparing these samples of graphite, it will be seen that the Borrodale and the Siberian give off about the same total volume of gas, that the celestial and the unknown graphites closely approximate each other in this respect, yielding more than double the volume of the others, and that the Ceylon sample stands alone in yielding a very minute quantity. All the terrestrial samples, except that from Ceylon, are alike in giving off a very considerable quantity of marsh-gas, though they differ somewhat in the actual quantity, and it is evident that, although the celestial graphite contains a considerable amount, it is very much less than that yielded by the terrestrial samples.

A few tentative experiments were made to ascertain the absorbing power for gases of this celestial graphite. For this purpose dry carbonic acid, marsh-gas, and hydrogen were respectively drawn through the tube containing the previously exhausted graphite for twelve hours in the cold, the gases being pumped out at a low red heat after each treatment with the dry gas. After the carbonic acid treatment the volume of gas collected was only 1·1 times that of the graphite, containing 98·4 per cent. of carbonic acid; after the marsh-gas the volume of the gas was only 0·9 that of the graphite, containing 94·1 per cent. carbonic acid; and after the hydrogen the volume of the gas

collected was only 0·17 times that of the graphite, containing 95·0 per cent. of carbonic acid. It is therefore evident that the large quantity of gas occluded in celestial graphites cannot be explained by any special absorptive power of this variety of carbon. In view of the large and varying percentages of marsh-gas in the gaseous products of all these graphites, it appeared to us of especial interest to ascertain whether the quantity of marsh-gas extracted coincided in any way with the hydrogen obtained by their combustion. We therefore submitted all the samples to ultimate analysis, with the following results:—

	Percentage composition.		
	Hydrogen.	Carbon.	Ash.
Celestial graphite	0·11	76·10	23·50
Borrodale ,, ...	0·11	94·76	4·85
Siberian ,, ...	0·17	79·07	20·00
Ceylon ,, ...	0·017	90·90	9·08
Unknown ,, ...	0·246	78·51	21·26

These analyses do not seem to point to any very definite conclusion as to the origin of the marsh-gas. The unknown graphite, which contains the largest percentage of marsh-gas, certainly comes out far the highest in hydrogen, and the hydrogen in the Ceylon graphite also bears a certain relation to the small quantity of marsh-gas it contains, but the first three samples are very similar to each other in the amount of hydrogen they contain.

In order to get some further insight into the origin of this marsh-gas in the celestial graphite, about 2 grams of the original nodule were very finely ground up and digested for several hours with strong nitric acid. After being thoroughly washed from every trace of nitric acid and dried at 110° C., it was again submitted to analysis, with the result that the amount of hydrogen remained exactly the same as before, proving that it existed in the form of some very stable compound in the graphite.

To clear up this matter still further, about 10 grams of the original nodule were digested with pure ether in the way described by Lawrence Smith for extracting the hydrocarbon-like bodies. It was allowed to stand for twenty-four hours with excess of ether, and then filtered, and washed with more ether. The graphite thus treated was dried at 110° C., and the gases extracted from it.

For the purpose of comparing one of the terrestrial graphites with the above in regard to its behaviour with ether, the specimen of unknown origin was selected, as yielding the largest quantity of marsh-gas. The residue, after digestion with ether, was dried, and the gases pumped out as before.

It will be seen that by this treatment with ether the volume of gas

given off by the celestial graphite, and also the marsh-gas, have been reduced to rather more than one-half, while with regard to the unknown graphite, although the total volume of gas remains about the same (probably due to a rather higher temperature being employed), the marsh-gas has also been reduced to rather less than one-third the original amount, and the hydrogen has correspondingly increased.

	Occluded gases in vols. of the graphite.	CO_2.	CO.	H.	CH_4.	N.
Celestial graphite before treatment with ether...........	7·25	91·81	—	2·50	5·40	0·1
Celestial graphite after treatment with ether...........	3·50	81·50	10·63	1·41	2·12	0·74
Unknown graphite before treatment with ether...........	7·26	50·79	3·16	2·50	39·53	3·49
Unknown graphite after treatment with ether...........	7·15	64·86	5·67	14·37	12·96	2·00

These experiments prove that either the ether did not dissolve out all the actual carbonaceous compounds present, or that the marsh-gas was subsequently formed during the heating of the graphite.

As Dr. De La Rue had kindly placed at our disposal a splendid specimen of the Orgueil meteorite, we took the opportunity of comparing the gases occluded by this typical specimen of the carbonaceous class with those obtained from the stony meteorites and the graphites. This meteorite has been so thoroughly examined by Clöez and Pisani (" Compt. rend.," vol. 59 (1864), pp. 37, 132) with regard to its chemical inorganic constituents, that nothing need be said as to its general composition. We therefore confined ourselves to the gases given off on heating which had not previously been determined.

During the heating of the meteorite a large quantity of water, on which floated numerous small pieces of sulphur, collected in the bulb tube immersed in the freezing mixture. This water was strongly acid, and indeed smelt strongly of sulphurous acid. On evaporating it to dryness with a drop of hydrochloric acid, abundance of ammoniacal salts were found in the residue. In the cool anterior part of the combustion-tube a considerable sublimate had collected, which proved to be principally sulphate of ammonium with traces of sulphides and sulphites, and a large quantity of free sulphur. A very large quantity of gas was given off, having the following composition:—

	Sp. gr.	Occluded gases in vols. of the meteorite.	Percentage composition.				
			CO_2.	CO.	CH_4.	N.	SO_2.
Orgueil meteorite	2·567	57·87	12·77	1·96	1·50	0·56	83·00

Sulphurous acid is evidently the main constituent of the gases given off; but if we eliminate this gas, which has been formed from the decomposition of the sulphate of iron, we find the meteorite yields 9·8 times its volume of gas, having very much the same composition as that from some of the stony meteorites, viz.:—

CO_2, 76·05; CO, 11·67; CH_4, 8·93; N, 3·33.

Clöez found the organic matter in this meteorite to be composed of carbon 63·45, hydrogen 5·98, oxygen 30·57, which is nearly in the proportions of a terrestrial humus substance. We know such substances break up by the action of heat into gases of the nature found above, at the same time, however, a quantity of the carbonic acid undoubtedly comes from the presence of the carbonates of magnesium and iron. The operation by which terrestrial carbon has been changed into graphite is by no means clear. As a rule the transition of one kind of carbon into another necessitates the action of a very high temperature. If, therefore, a really high temperature is in all cases necessary, it is difficult to explain how compounds of carbon came to resist decomposition, and should come to be found associated with all natural graphites.

We may assume that the graphite resulted from the action of water, gases and other agents, on the carbides of the metals, and that during the chemical interactions which took place, a portion of the carbon became transformed into organic compounds.

In either case we are led to the conclusion that the method of formation of the meteoric and terrestrial graphites was similar, and it is perfectly possible they may after all have come from a common source.

We purpose continuing this investigation, and in order to acquire further information, it is our intention to examine the gases given off from meteorites at definite temperatures, and especially the gases from such as can be found coated with an impervious glaze, and to examine more particularly into the presence of water in such bodies, and the source of the nitrogen found in the same.

Note.

Since the above analyses of different graphites were made, we have examined a sample of the artificial graphite which results from the action of oxidising agents in the cyanogen compounds present in crude caustic soda. The following analysis shows that this artificial

variety of graphite is characterised by giving a very large yield of marsh-gas.

CO_2	45·42
CO	39·88
CH_4	4·43
H	8·31
N	2·00

Occluded gases in volumes of the graphite=53·13.

XIV. "Preliminary Communication on the Structure and Presence in Sphenodon and other Lizards of the Median Eye, described by von Graaf in *Anguis fragilis*." By W. Baldwin Spencer, B.A., Demonstrator of Comparative Anatomy in University of Oxford, Fellow of Lincoln College. Communicated by Prof. H. N. Moseley, F.R.S. Received June 10, 1886.

In 1872 Leydig* described a structure in *Lacerta agilis*, *L. muralis*, *L. vivipara*, and *Anguis fragilis*, to which he gave the name of "frontal organ."

In the embryo, owing to its being deeply pigmented, it forms a prominent feature on the roof of the original forebrain in connexion with the pineal gland; in the adult it lies immediately beneath the skin, and, according to him and subsequent observers, completely separated from the brain.

In *Anguis fragilis* the organ is seen microscopically to consist of long cells like those of a cylindrical epithelium, which are so arranged that together they form a shallow pit with a circular outline. The edge of the pit is directed downwards, and has a thick black girdle of pigment. It corresponds in position to that occupied by the parietal foramen in the adult.

Leydig regarded our knowledge of the organ as insufficient to allow of any statement being made with regard to its function.

Rabl-Rückhard,† in 1882, describing the development of the pineal gland in the trout, pointed out the resemblance between its development as a hollow outgrowth of the brain and that of the optic vesicles.

Granted such secondary developments from the epiblast and mesoblast as combine to produce the eye, and which are absent in the case of the pineal gland, though the distal extremity of the latter lies in a

* "Die in Deutschland lebenden Arten der Saurier," p. 72, taf. 12.

† "Zur Deutung und Entwickelung des Gehirns der Knochenfische." Arch. für Anat. u. Phys., Jahrg. 1882, p. 111.