

## THE HYDROGEN OF COAL.

BY FRANK F. GROUT.

Received June 13, 1907.

Last summer, in making some calculations of the composition of coals, for the Illinois Geological Survey, working under the direction of Prof. Parr, the writer found some remarkably uniform figures for hydrogen in all coals (except anthracite and cannel<sup>1</sup>) and reported the same. Nothing seems to have been done with the suggestion. Some further results have been obtained since my connection with the survey has ended, and they may be of interest in connection with the recent article by Prof. Parr.<sup>2</sup> The facts are mentioned in *Economic Geology*, Vol. 2, page 231, in connection with a proposed classification of coals.

In the great number of coal analyses which have recently been published,<sup>3</sup> the per cent. of hydrogen in the hydrocarbon is extremely uniform. Using just such coals as those from which Prof. Parr constructs his scheme and curve, and using "pure coal" as a basis of calculation,—*i. e.*, considering the sum of carbon, oxygen, and hydrogen equal to 100 per cent.,—hydrogen is found to range only from 4.50 per cent. to 6.24 per cent. The average of some two hundred samples is 5.64 per cent., and the average error 0.30 per cent. of the pure coal. In a single coal basin, the figures are much closer. The twenty samples of Illinois coal tested, average 5.67 per cent., with an average error of 0.22 per cent.

These figures are based on a knowledge of the ultimate analyses. But if it is desired to estimate the ultimate analyses from the proximate, a different "pure coal" must be used. The proximate analysis gives us fixed carbon and volatile matter as a "pure coal" basis. This gave almost equally good figures. Using the first twenty analyses of Bull. 290, U. S. G. S., the hydrogen of the ash- and water-free coal is 5.38 per cent.; the maximum error is 0.51 per cent.; the average error, only 0.16 per cent. Now, with a carbon estimation, we have the basis of our ultimate analyses. Several instruments have recently come into the market, for a close carbon estimation, without regard to other elements present. So this work is simplified. Sulphur is usually determined, but nitrogen is still to be accounted for. This may be set down as arbitrarily as the hydrogen, but not as accurately—1.48 per cent. of pure coal. The variation noted is from 1.00 per cent. to 1.83 per cent. Now, if we subtract from the pure coal the sum of carbon and sulphur (determined) and hydrogen and nitrogen (estimated), the difference represents oxygen. The total errors which accumulate on the oxygen by these assumptions is about 1.00 per cent., as a maximum. Still, the value of

<sup>1</sup> These are easily distinguished by the scheme outlined in *Economic Geology*, 2, 225.

<sup>2</sup> This Journal, 29, 582.

<sup>3</sup> U. S. Geol. Survey, Bull. 261, 590, etc.

such an estimated ultimate analysis is in some doubt; only, in the matter of hydrogen, it is surprisingly accurate. In comparison with other methods of determining hydrogen, the *arbitrary figure* certainly has the advantage of simplicity.

Prof. Parr offers his calculation<sup>1</sup> not as more accurate than that based on ultimate analyses, but if correctly understood as often giving a figure from which a close fuel value can be calculated by such formulae as Dulong's. And further, in his own words, it may "indicate other properties depending on the structure and composition of the coal." The only points emphasized are the calculation of ultimate analyses and fuel value.

The difficulty of getting a figure for hydrogen seems as great as that for determining fuel value, even if the hydrogen is calculated from the carbon percentage. One of the simplest methods of estimating carbon, is by means of the sodium peroxide combustion. But that same combustion gives the fuel value, in a simple, handy instrument, the Parr calorimeter. So what reason is there to carry the process along to a carbon estimation and complex calculation of hydrogen, only to get fuel values? These fuel values are more simply obtained by reading the thermometer of the calorimeter at one stage in the carbon estimation.

Again, assuming that one has been given the carbon estimation and not the fuel value, what method is best to use to calculate it? Prof. Parr's curve gives better results than any calculation from the proximate analysis alone. It requires a knowledge of total carbon and when this is available, another way to get the result would be to use the estimated ultimate analysis, as suggested above. If one-eighth oxygen is subtracted from hydrogen, available hydrogen is left. By the arbitrary figures given above, hydrogen seems to vary to a maximum error of 0.51 per cent., and oxygen to 1.00 per cent. Hence, available hydrogen may be in error by 0.72 per cent. The actual maximum difference between the results of this method and ultimate analysis in the coals tested was 0.44 per cent. Prof. Parr's curve gave a maximum of 0.60 per cent. The average error of this arbitrary method, from ultimate analysis, is 0.14 per cent. That for his curve is 0.20 per cent.

In calculating fuel values, it is to be noted that recent results indicate a higher value than is found by Dulong's formula and the ultimate analysis. In terms of hydrogen this would mean that as an average, 0.17 per cent. less hydrogen is found in the analysis than is required to give the fuel value actually found. By adding this amount, 0.17 per cent., to figures calculated above, one may get figures for available hydrogen, which will give good fuel values. The average error in terms of hydrogen is 0.15 per cent.; the maximum, 0.50 per cent. This seems better than any suggested calculation, and should be of practical application, especially in restricted fields. The following is a summary of the

<sup>1</sup> Loc. cit., p. 586.

average errors resulting from the use of an arbitrary figure (like 5.38 per cent. as representing hydrogen in pure coal) in calculation of available hydrogen, and fuel value, compared with other methods.

H indicated by calories — H of ultimate analysis = 0.18 per cent.

H by Prof. Parr's curve — H of ultimate analysis = 0.20 "

H by Prof. Parr's curve — H indicated by calories = 0.17 "

H from arbitrary figure — H of ultimate analysis = 0.15 "

H from arbitrary figure<sup>1</sup> — H indicated by calories = 0.15 "

<sup>1</sup> Corrected 0.17 per cent., as explained in the preceding paragraph.

It is noticeable that the averages from an arbitrary simple figure are a little better than any of the more complicated ones from a curve. In view of the uniformity of these results, it is quite remarkable that the several curves and calculations that Prof. Parr has devised, did not lead even farther from the actual figures.

### Summary.

In all bituminous coal, and black and brown lignite, the proximate analysis and estimation of total carbon are sufficient data for a calculation of an ultimate analysis, in which no error seems to be above 1.00 per cent., and the average, much less. The high errors are in nitrogen and oxygen, where they are of slight consequence.

The hydrogen of ash-and water-free coal is 5.38 per cent., with an average error of only about 0.16 per cent. In a limited coal field, the maximum error is undoubtedly often less than 0.51 per cent. When an arbitrary figure like this gives such close results, the uselessness of any further calculation of hydrogen is apparent.

If it is possible to obtain the carbon percentage and proximate analysis more easily than to get the fuel value, a fairly close fuel value may be calculated by Dulong's formula, and the estimated ultimate analysis suggested above. Inasmuch as recent careful work indicates that Dulong's formula and the ultimate analysis give slightly low results, it is suggested that 0.17 per cent. be added to the per cent. of available hydrogen in the ash- and water-free coal, before applying the formula. A similar correction should be applied to the estimated ultimate analysis. Then, aside from a complete ultimate analysis, this estimated ultimate analysis gives the best foundation known for calculating fuel values. But the value of such calculation seems to be confined to cases where the carbon estimation is found easier than the calorimetric work.

GEOLOGICAL LABORATORY,  
UNIVERSITY OF MINNESOTA.

## THE FORMATION OF VOLATILE SULPHUR COMPOUNDS IN MEAT AND THEIR INFLUENCE ON THE DETECTION OF ADDED SULPHITES.

BY A. L. WINTON AND E. MONROE BAILEY.

Received August 12, 1907.

Sulphites are commonly detected in meat products by distillation with phosphoric acid into dilute bromine water and precipitation of the sul-