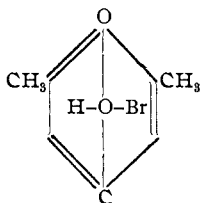
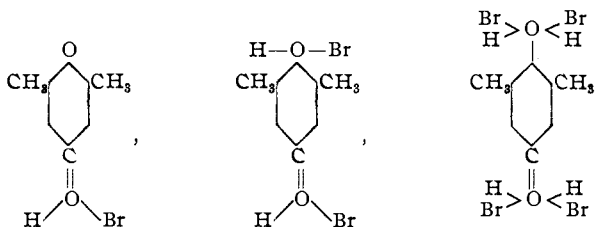


We have seen that hydrobromic acid unites with dimethylpyrone to give three stable compounds containing one, two and four molecules of acid. Since hydrobromic acid does not polymerize even when liquefied, any theory to explain the linking of the acid in the simplest compound should apply equally well to the others. We may regard these additive compounds as pyrone with "acid of crystallization," or we may ascribe formulas to them in which oxygen has a higher valency than two.

If we accept Collie's representation of the constitution of dimethylpyronehydrobromide,



it is difficult to give a satisfactory explanation of the formation of the other salts, unless we admit the possibility of the linking between the two oxygen atoms being broken at such a low temperature. But if we regard the dimethylpyrone itself as a substance with two divalent oxygen atoms we may represent the three salts as



the first containing one, the second two tetravalent, and the third three hexavalent oxygen atoms.

In the most complex salt the oxygen is supposed to function as a hexad, and this may be objected to as unusual and unnecessary. Yet the same arguments advanced for the tetravalency of oxygen apply equally strongly to its hexavalency here; and the position of this element in the sixth column of the periodic table permits the view that its valency may vary as does that of sulphur, selenium and tellurium.

ELEMENTARY ANALYSIS BY MEANS OF A CALORIMETRIC BOMB.

BY HAROLD L. HIGGINS AND ALICE JOHNSON.

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Since the complete oxidation of organic material, with the quantitative conversion of carbon to carbon dioxide, and of hydrogen to water, presents the greatest difficulty in elementary organic analysis, it is not surprising

that particular attention has been paid to making use of the ideal conditions of oxidation obtained inside of a calorimetric bomb. Burning substances in oxygen at a pressure of 25 atmospheres results, usually, in complete oxidation with minor products of combustion, particularly the oxidation of a small amount of nitrogen to nitric acid.

One chief objection to the use of the bomb for ordinary elementary analysis has been the fact that about 1 gram of substance is required,¹ and in many instances, particularly in the field of organic chemistry where frequently but a small amount of material may be available, this precludes the use of the method. On the other hand, in many researches where both the heat of combustion and an elementary analysis are desired, the bomb can be used to great advantage.

In metabolism experiments, either with men or with animals, where it is desired to determine not only the energy balance but likewise the carbon and hydrogen balance, elementary analysis by the bomb is of especial value. Under these conditions, it is necessary to determine both the heat of combustion of the food, feces, and urine, and the amount of carbon and hydrogen in these products; and the simultaneous determinations allow a great saving in time. Usually the substances to be dealt with are in sufficient quantities to permit of large samples, and of duplicate combustions. With coal and other fuels, simultaneous determinations of heat and elementary analyses may also be made where the percentages of carbon and hydrogen present in the coal are desired in addition to the energy value as represented by the heat of combustion.

The Determination of Carbon.—The most common method of determining carbon by the calorimetric bomb has been to collect, in potassium hydroxide or soda lime, all the carbon dioxide formed during the combustion of the substance and to weigh the amount collected. Berthelot,² and later Hempel,³ determined carbon in this way, using a one-valve bomb. The last traces of carbon dioxide were removed by suction, the gas being swept out several times and the bomb refilled with dry air. The method is simplified, however, by using a bomb with two valves, as shown by Kröker⁴ and Fries,⁵ the bomb being eventually freed of carbon dioxide by passing air through it.

Zuntz and Frenzel⁶ in 1897 suggested a method for making carbon determinations with the bomb, wherein they found the total weight or

¹ Hempel obviated this objection by the use of a small autoclave similar to the bomb, whereby smaller amounts of substance could be burned more satisfactorily, *Ber.*, 30, 202 (1897). See also Langbein, *Chem.-Zig.*, 38, 1055 (1909).

² Berthelot, *Compt. rend.*, 114, 317 (1892), and 129, 1002 (1899).

³ Hempel, *Loc. cit.*

⁴ Kröker, *Z. Ver. Rubenzucker-Industrie*, 46, Heft 482. *Ber.*, 30, 606 (1897).

⁵ Fries, *THIS JOURNAL*, 31, 272 (1909).

⁶ Zuntz and Frenzel, *Ber.*, 30, 380 (1897).

volume of the gases resulting from the combustion and by analyzing these gases, they were able to calculate the total amount of carbon dioxide present. Following this suggestion we have, under the direction of Professor Benedict, developed a method which seems to offer excellent opportunities for routine carbon analyses, which are sufficiently accurate for the most exact physiological experimenting. According to this method, we first weigh the gas at the end of the combustion and then determine the carbon dioxide in a sample by means of a Haldane gas analysis apparatus.¹ Knowing the weight of the gas, the percentage of carbon dioxide, and the amount of nitrogen present, we can calculate the amount of carbon dioxide present by the use of a formula obtained from the following equations:

$$(1) \quad x + y = c - a.$$

$$(2) \quad (x/1.43 + y/1.966 + a/1.26) b/100 = y/1.966.$$

In these equations, a equals weight of nitrogen gas; b , per cent. carbon dioxide in gas; c , weight of gas; x , weight of oxygen; and y , weight of carbon dioxide. The gas in each instance is that in the bomb at the end of the combustion. Solving for y , we obtain:

$$y = (c + 0.137a)/(0.2727 + 72.73/b) = \text{weight of carbon dioxide,}$$

or

$$\text{the weight of carbon}^2 = 3y/11 = (c + 0.137a)/(1 + 266.67/b)$$

Thus, having the total weight of carbon in the bomb, the percentage of carbon in the substance is readily obtained, after applying corrections for the carbon in the kindler, in the igniting thread, and in the oxygen used.

The Determination of Hydrogen.—Berthelot³ suggested that the bomb may be used in determining hydrogen by driving out all of the water as vapor and absorbing and weighing it in a dehydrating agent, such as concentrated sulphuric acid or calcium chloride. He immersed the bomb in a water bath and exhausted and admitted air alternately. Kröcker,⁴ with a two-valve bomb, was able to simplify this process, but the method has the following decided disadvantages: (1) The presence of nitric acid (as well as sulphuric acid, when the substance burned contains sulphur) makes it difficult to expel all of the water and nothing else, and furthermore, these acids tend to attack the valves of the bomb; (2) the heating of the bomb in the bath also increases the liability to injure the enamel lining; (3) it is very difficult to get the interior of the bomb perfectly dry at the beginning of the combustion, as is necessary when this method is used; (4) the operation is very time-consuming.

¹ Haldane, *J. Physiol.*, 22, 465 (1897).

² 0.137 represents (molecular weight oxygen/molecular weight nitrogen) — 1; 266.67 represents 100 molecular weight oxygen/atomic weight carbon.

³ Berthelot, *loc. cit.*

⁴ Kröcker, *loc. cit.*

Langbein¹ determined the water formed by placing a drying glass containing phosphorus pentoxide within the bomb, expelled most of the nitric acid by passing air through the bomb in a bath at 100°, and determined the sulphuric acid by titration. Hempel,² using a small autoclave similar to the bomb, drove out only a part of the water, and collected it in a calcium chloride tube. The remainder was weighed in the autoclave itself, the water representing the difference in weight of the autoclave when empty as compared with its weight after the combustion gases had been swept out, corrections being applied for nitric acid, for ash, and for the water formed from the kindler. We have applied Hempel's method to the bomb, modifying it somewhat to assist in making the determination more rapid and better adapted to routine work. The method of calculation of the water formed is easily understood from the following equation:

Weight of water formed = $d - e + f$, in which:

d = Weight of bomb after combustion, when it contains combustion gases at 1 atmosphere pressure, — weight of gas in the bomb — weight of nitric acid formed — weight of ash.

e = Weight of bomb before charging with oxygen — weight of air it contains — weight of pellet — weight of ignition thread — weight of kindler (if used).

f = Weight of water leaving the bomb on releasing the pressure.

The percentage of hydrogen is then easily calculated, corrections being necessary for the hydrogen in the ignition thread, in the oxygen (if any is present), in the nitric acid, and in the kindler.

Description of Apparatus Used.

Calorimetric Bomb.—In this research we have employed a Kröcker bomb, such as has been used by Jaeger and von Steinwehr,³ and Fischer and Wrede.⁴ The bomb is lined with enamel (although platinum may be substituted) and has a platinum-lined cover, and two valves with platinum-iridium points, one for the admission of oxygen and the other through which compressed air may be admitted to completely drive out the combustion gases if desired. The method of analysis here described is applicable, however, to a one-valve bomb. Instead of igniting the sample by iron wire, we use platinum wire, a cotton thread extending from this platinum wire to the substance to be burned; to ignite the sample, the current is passed through the platinum wire, raising it to incandescence and igniting the thread which, in turn, ignites the substance. A platinum cup is furnished with each bomb, but we find that the platinum deteriorates rapidly and we have therefore substituted nickel capsules,⁵ a nickel wire support serves to hold the capsule in place.

¹ Langbein, *Z. öffentl. Chem.*, 76 (1897).

² Hempel, *loc. cit.*

³ Jaeger and von Steinwehr, *Ber. phys. Ges.*, 5, 353 (1903).

⁴ Fischer and Wrede, *Sitzber. K. Preuss. Akad. Wiss.*, 5, 129 (1908).

⁵ See Atwater and Snell, *THIS JOURNAL*, 25, 659 (1903).

Compressed Oxygen.—In all of the more recent experiments we have used Linde oxygen made from liquid air, which is free from carbon dioxide and combustible gases. Analyses made of this gas showed but 6 milligrams of carbon dioxide in 100 grams of oxygen, and we were unable to find an appreciable amount of hydrogen or hydrocarbons.

Balance.—For weighing the bomb in our analyses, we make use of a balance¹ on which one is able to weigh accurately a load of 10 kilograms to 0.01 gram.

Gas Analysis Apparatus.—For our gas analyses, we use the Haldane apparatus, with which analyses of carbon dioxide and oxygen can be made with an accuracy of 1 part in 500. As a compensating burette is used, variations in pressure and temperature of the outer air are without effect. For the finer adjustment of the level of the mercury, a screw pinchcock of special construction is so applied that after closing all communication with the leveling tube, a slight motion of the screw so alters the pressure on the rubber tube as to allow a very accurate adjustment of the mercury in the burette.

Method of Manipulation.

In a determination, the bomb is first cleaned. The substance to be burned is then weighed—with the capsule, if ash is present—and put into the bomb, the ignition adjusted, and the cover screwed on. The valve is opened and then closed to make sure that the interior is at atmospheric pressure and the bomb and contents are weighed to 0.01 gram. The bomb is next charged with oxygen to 20 or 25 atmospheres and again accurately weighed. The combustion follows, the bomb being placed in a calorimeter, if a determination of the heat of combustion of the material is also desired. After the combustion, the bomb is carefully dried until it weighs exactly the same as it did before the combustion, so that the weighings taken after the combustion may be upon the same basis as those before.

The gas is released from the bomb, passing through a weighed U-tube containing sulphuric acid, then through the top of two T-tubes connected to two Haldane gas samplers previously filled with mercury, and finally bubbles through water. When the combustion gases have seemingly displaced the air previously in the system, the two gas samplers are filled with the gas by displacement of mercury, the mercury in the sample being lowered by means of a leveling bulb connected to the lower end of the sampler; then the gas in the sampler is put under pressure of mercury by closing the upper stopcock, and raising the leveling bulb on the outside. When the gas in the bomb reaches atmospheric pressure, the bomb is closed and weighed. It is then opened, the ash, if any, is weighed, and

¹ The balance, with glass case, was furnished through the Bausch & Lomb Optical Co., at a duty-free price of about \$40.00.

the rinsings are titrated for nitric acid. In determining the amount of nitric acid, we use the method of Stohmann, titrating with a solution of sodium carbonate of 0.003706 gram per cc.; 1 cc. of this solution is equivalent to 0.004406 gram of nitric acid, the heat of formation of which is 1 calorie. A table can readily be prepared showing the respective weights of nitric acid, hydrogen and nitrogen which the various volumes of sodium carbonate solution represent. With the analysis of the gas samples for carbon dioxide, all the data necessary for the determination of carbon and hydrogen are at hand.

The gas samples, being under pressure, need not be analyzed immediately but may be kept a week or longer, and a number of analyses made at the same time. The value of keeping the samples under pressure lies in the fact that if a slight leak occurs, some of the gas inside may escape, but none from without can enter the sampler. If, however, the gas samples have been kept for some time, they should be tested to find out if they are still under pressure, and if not, they should be discarded. When the analyses of the two samples show a marked difference, the one having the larger percentage of carbon dioxide is taken, as it is assumed that the other has air mixed with it; if the agreement of results is good, an average is taken.

In addition to collecting the sample over mercury, we have allowed the gas from the bomb to flow directly through the gas sampler and eventually displace all the air. To facilitate this displacement, the direction of the flow of gas is reversed during the operation. Duplicate analyses of gas from the same combustion show no differences in the two methods of sampling.

Calculation of Results.—From the data thus obtained, the computation follows. The formula used for computing the weight of carbon is:

$$\text{Weight of carbon} = (c + 0.137a)/(1 + 266.67/b).$$

The three factors, c , a , and b , are derived from the data previously obtained. c (the weight of gas in the bomb at the end of combustion) equals the weight of the bomb immediately after the combustion, less the weight of the bomb after all but 1 atmosphere of the combustion gas has been released, plus the weight of this atmosphere of gas (calculated from the table described later), less the weight of water passed out of the bomb and collected in the sulphuric acid U-tube.

The weight of nitrogen gas in the bomb at the end of the combustion, a , is found by adding the weights of nitrogen in the atmosphere of air in the bomb before the bomb is charged with oxygen, in the oxygen supplied, and in the substance burned, and from this total, subtracting the weight of the nitrogen oxidized to nitric acid. The weight of nitrogen in the air of the bomb before charging is constant for every bomb and is easily calculated from the volume. The weight of the oxygen added to the bomb

is equal to the difference between the weights of the bomb before and after charging; the weight of nitrogen in this oxygen is obtained by multiplying the weight of oxygen by the percentage weight of nitrogen it contains.¹ The weight of nitrogen in the sample burned is calculated from a Kjeldahl analysis of the substance; if no Kjeldahl analysis has been made, an estimation of the quantity of nitrogen with an accuracy of 0.10 gram, may suffice, as an error less than this will not affect the percentage of carbon by more than 0.15 per cent.

The percentage of carbon dioxide by volume, *b*, is found with the Haldane apparatus. After the total amount of carbon in the oxygen, in the thread used for ignition, and in the kindler (such as naphthalene or benzoic acid) has been subtracted from the weight of carbon thus found, the percentage of carbon is obtained by dividing the weight of carbon by the weight of the substance. Assuming the cotton thread (0.006 gram) used for ignition is pure cellulose, the carbon in the thread is calculated.

In calculating the percentage of hydrogen, use is made of the following formula:

$$\text{Weight of water formed} = d - e + f.$$

d represents essentially the weight of the bomb proper and the water it contains, and is found by subtracting from the weight of the bomb at the end of a combustion (with the pressure released and but one atmosphere of combustion gases left behind) the combined weights of the nitric acid, of the ash present and of the atmosphere of combustion gases. This latter factor involves a knowledge of the volume of air space within the bomb and the composition of the gas. The volume of the air space in the bomb is a constant and is found by weighing the bomb full of water. The percentage of carbon dioxide is already known, and the percentage of nitrogen (6 to 7 per cent. when no nitrogen is present in the substance) is found to be sufficiently constant to make an analysis for nitrogen unnecessary. A table has been prepared showing the weights of gas occupying this space for the varying percentages of carbon dioxide and nitrogen. When the substance contains considerable nitrogen, the gas may be analyzed for nitrogen on the Haldane apparatus, or it is much simpler and sufficiently accurate to approximate the percentage of nitrogen;² this is accomplished by the proportion

$$x : 7 = a : 0.44.$$

In this proportion 7 equals the percentage of nitrogen gas usually obtained when no nitrogen is in the sample, *a* equals the weight of nitrogen

¹ The percentage of nitrogen by volume is usually supplied by the manufacturer.

² With a two-valve bomb, one may sweep the combustion gas from the bomb with air and thus be able to deal with the weight of the bomb full of atmospheric air, instead of combustion gases. This would require more time and also a careful measurement of the water leaving the bomb.

gas present (a in the formula for determining carbon), and 0.44 equals the weight of nitrogen gas usually present, when no nitrogen is in the substance. The possible error in the percentage of hydrogen from using this formula is very small, an error of 3 per cent. in total nitrogen leading to an error of only about 0.0001 gram of hydrogen. The following table has been calculated for a bomb containing 275 cc. Intermediate values are easily found by interpolation.

It may be noted that this table is also used in the carbon determination in calculating the weight of gas in the bomb at the end of a combustion.

Per cent. CO ₂ .	Per cent. O ₂ .	Per cent. N ₂ .	Wt. 1 liter of gas. Grams.	Wt. of 275 cc. Gram.
12	81	7	1.482	0.4076
14	79	7	1.493	0.4106
16	77	7	1.504	0.4136
18	75	7	1.515	0.4166
20	73	7	1.525	0.4194
12	78	10	1.477	0.4062
14	76	10	1.488	0.4092
16	74	10	1.499	0.4122
18	72	10	1.510	0.4153
20	70	10	1.520	0.4180
12	75	13	1.472	0.4048
16	71	13	1.494	0.4108
20	67	13	1.515	0.4166
12	72	16	1.467	0.4034
16	68	16	1.489	0.4095
20	64	16	1.510	0.4153
12	68	20	1.460	0.4015
16	64	20	1.482	0.4075
12	64	24	1.454	0.3999
16	60	24	1.475	0.4056
..	21	79	1.296	0.3564

e represents the weight of the empty bomb. This is found by subtracting from the weight of the bomb at the beginning of the experiment before charging with oxygen (1) the weight of air which it contains (see table), (2) the weight of the substance burned, and (3) the weight of the ignition thread and kindler.

f is the weight of the water leaving the bomb on releasing the pressure and collected in the sulphuric acid U-tube and has been found to be very constant (0.017 gram). Owing to the small variation in this weight, we have decided that we may safely discard the U-tube and assume the weight of water leaving the bomb to be 0.017 gram.

One-ninth of the weight of water thus found plus the weight of hydrogen in the nitric acid formed, minus the hydrogen in the ignition thread and in the kindler, gives the weight of hydrogen in the substance.

Specimen combustion.
(Nitrogen-free material.)

<i>Cane sugar.</i>	Weight taken = 1.3117 grams
Weight of ignition thread.....	0.006 gram
Weight of bomb before charging with oxygen.....	2613.30 grams
Weight of bomb after adding oxygen.....	2621.62 grams
Weight of oxygen.....	8.32 grams
Weight of bomb after combustion gases are passed out.....	2612.82 grams
Gas analysis = 17.01 per cent. CO ₂	Nitric acid = 0.034 gram
Weight of water leaving bomb on release of pressure.....	0.017 gram
Weight of gas in bomb at end of combustion with pressure released	0.415 gram

(from table).

Weight of air in bomb at start of combustion, 0.356 gram (from table).

Percentage of carbon. Weight of carbon = $(c + 0.137a)/(1 + 266.67/b)$.

2621.62	8.32	
-2612.82	× 1.6 per cent. (percentage of nitrogen in oxygen by weight).	

8.80	0.1331	
+0.415	+0.2737 nitrogen in air in bomb.	

9.215	0.4068	
-0.017	-0.007 nitrogen in nitric acid.	

$$9.198 = c \quad 0.400 = a \quad 17.01 = b$$

Substituting in this equation:

Weight of carbon = $[9.198 + (0.137)(0.400)]/[1 + 266.67/17.01] = 9.253/16.677 = 0.5548$ gram.

0.5548	
-0.0027 carbon in thread. (No carbon in the oxygen used.)	

0.5521 carbon in sugar.

$0.5521 \div 1.3117 = 42.09$ per cent. carbon.

Percentage of hydrogen. Weight of water = $d - e + f$.

2612.82	2613.30	
-0.415	-0.356	
2612.405	2612.944	
-0.034	-1.312	0.017 = f
2612.371 = d	2611.632	
	-0.006	
	2611.626 = e	

Substituting, weight of water = $2612.371 - 2611.626 + 0.017 = 0.762$ gram.

$0.762/9 = 0.0847$ gram = weight of hydrogen.

0.0847	
+0.0005 hydrogen in nitric acid.	

0.0852	
-0.0004 hydrogen in ignition thread.	

0.0848 gram hydrogen in sugar.

$0.0848 \div 1.3117 = 6.47$ per cent. hydrogen.

Specimen combustion.
(Nitrogenous material.)

Urea. Weight taken = 1.9202 grams

Kindled by 0.0583 gram of benzoic acid.

Weight of ignition thread.....	0.006 gram
Weight of bomb before charging with oxygen.....	2613.22 grams
Weight of bomb after adding oxygen.....	2620.87 grams
Weight of oxygen.....	7.65 grams
Weight of bomb after combustion gases are passed out.....	2612.50 grams
Gas analysis = 14.135 per cent. CO ₂ .	Nitric acid = 0.050 gram
Weight of water leaving bomb on release of pressure.....	0.017 gram
Weight of gas in bomb at end of combustion with pressure released	0.404 gram

(from table).

Weight of air in bomb at end of combustion 0.356 gram (from table).

Percentage of carbon. Weight of carbon = $(c + 0.137 a)/(1 + 266.67/b)$.

Gas in bomb contains approximately 21 per cent. nitrogen for:

x : 7 per cent. = 1.29 : 0.44	x = 20½ per cent.
2620.87	7.65
—2612.50	× 1.71 per cent. (per cent. nitrogen in oxygen).

8.37	0.1308 nitrogen in oxygen	
+ 0.404	0.2737 nitrogen in air	14.135 = b
8.774	0.8967 nitrogen in urea	

—0.017	1.301
8.757 grams = c	—0.011

1.29 grams = a

Substituting in this equation:

$$\text{Weight of carbon} = [8.757 + (0.137)(1.29)]/[1 + 266.67/14.135] = 8.934/19.866 = 0.4497 \text{ gram.}$$

Carbon in thread.....	0.0027	0.4497
Carbon in benzoic acid kindler...	0.401	—0.0663
Carbon in oxygen used.....	0.0235	0.3834 gram carbon in urea
		0.0663 gram

$$0.3834 \div 1.9202 = 19.97 \text{ per cent. carbon.}$$

Percentage of hydrogen.

Weight of water = d — e + f

2612.50	2613.22
—0.404	—0.356
2612.096	2612.864
—0.050	—1.920
2612.046 = d	2610.944
	—0.058
	2610.886
	—0.006
	2610.880 = e

0.017 = f

Substituting, weight of water = $2612.046 - 2610.880 + 0.017 = 1.183$ grams

$1.183/9 = 0.1314$ gram of hydrogen.

0.1314 $+ 0.0008$ hydrogen in nitric acid <hr style="width: 100%;"/> 0.1322 $- 0.0033$ <hr style="width: 100%;"/> 0.1289	0.0004 hydrogen in ignition thread 0.0029 hydrogen in benzoic acid <hr style="width: 100%;"/> 0.0033 0.1289 gram hydrogen in urea $0.1289 \div 1.9202 = 6.71$ per cent. hydrogen
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In a carbon determination, the greatest liability to error rests with the gas analysis. An error of one-third of 1 per cent. in gas analysis should make a similar error of one-third of 1 per cent. in the result. Under the most adverse conditions, one should not make an error of greater than ± 0.5 per cent. in these analyses and in the sampling. As the formula involves two weighings of the bomb, allowing each weighing is inaccurate to ± 0.01 gram, a maximum error of ± 0.02 gram is possible which would ordinarily be about ± 0.2 per cent. in the total carbon. Errors from other sources would be so small as to be practically negligible, so that the total maximum error possible is ± 0.7 per cent.

The hydrogen determination is liable to a slightly larger percentage error. Two weighings of the bomb being necessary, an error of 0.02 gram of water is possible, involving from 1 per cent. to 5 per cent. error in the hydrogen according to the amount of hydrogen in the substance. All the other data used in calculating the water are sufficiently accurate to involve an error of not more than 1 per cent. One or two features in the analysis for hydrogen require attention: the presence of hydrogen, or hydrocarbons, in the oxygen used will cause the formation of water in the bomb; if an oxygen cylinder contains even as small an amount as 0.02 per cent. of hydrogen by weight, as much as 0.0144 gram of water will be formed when using about 8 grams of oxygen in a combustion, thus introducing an appreciable error. We have tested several cylinders of Linde oxygen and failed to find hydrogen in any of them. Another seemingly apparent difficulty would be the action of oxygen and nitric acid upon the lead gaskets of the bomb. The lead when oxidized would increase in weight and this increase would be measured as water. Practically, it has been found by experiments that the lead gasket, although superficially oxidized, does not appreciably increase in weight; experiments with an aluminium gasket give results parallel to those with the lead, although with the aluminium gasket there is no apparent oxidation during combustion. It is seen that the liability of error in the hydrogen determination varies from 2 to 6 per cent., according to the amount of hydrogen present.

The following determinations give some idea of the fluctuations of the

results of this method for determining carbon and hydrogen simultaneously.

		Per cent. C.	Per cent. H.
Sugar	Theory.....	42.11	6.43
	I.....	42.06	6.46
	II.....	42.28	6.42
	III.....	42.23	6.57
Benzoic acid	Theory.....	68.85	4.92
	I.....	68.97	5.00
	II.....	68.77	5.11
Urea	Theory.....	20.00	6.67
	I.....	19.85	6.77
	II.....	19.96	6.71
Hippuric acid	Theory.....	60.34	5.03
	I.....	60.31	4.93

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THE COMPOSITION OF SOME BENGALI FOOD MATERIALS.

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The importance of a knowledge of the dietetic habits of various nationalities was frequently emphasized by the late Professor W. O. Atwater. In connection with an extensive investigation into the food and diet of different classes of people in America, which was instituted by him and carried out under his direction, considerable material was collected regarding the dietetic habits of other nationalities, especially those of the Chinese and Japanese.¹ These data show that many popular impressions regarding the diet of people in foreign countries are erroneous. Particularly is this true with regard to the relative proportions of animal and vegetable food and with regard to the amount of protein ingested.

While considerable information has been gathered concerning the food and diet of Europeans and Americans, with the exception of the publications previously referred to, but a small amount of data is available regarding the dietetic habits of the swarming population of Asiatic countries. Of especial interest, therefore, is an investigation of the highest scientific accuracy as to the food and diet of various classes of people in India, which has been undertaken within the last few years by Captain D. McCay, of the Calcutta Medical College. Captain McCay first studied

¹ Blasdale, "A Description of Some Chinese Vegetable Food Materials and Their Nutritive and Economic Value," U. S. Dept. Agr., Office Exp. Sta., *Bull.* 68 (1899). Jaffa, "Nutrition Investigations among Fruitarians and Chinese at the California Agricultural Experiment Station, 1899-1901," U. S. Dept. Agr., Office Exp. Sta., *Bull.* 107 (1901). Jaffa, "Further Investigations among Fruitarians at the California Agricultural Experiment Station," U. S. Dept. Agr., Office Exp. Sta., *Bull.* 132 (1903). Oshima, "A Digest of Japanese Investigations on the Nutrition of Man," U. S. Dept. Agr., Office Exp. Sta., *Bull.* 159 (1905).