CAVENDISH AND HIS DISCOVERIES.

A LECTURE Delivered in the Hulme Town Hall, Manchester, on Wednesday, November 24, 1875.

BY PROFESSOR THORPE, F.R.S.E.

WHEN I had the honour to appear here on a former occasion I gave you some account of the life and labours of a famous Yorkshire philosopher, Joseph Priestley, one of the most illustrious of that remarkable band of learned men which did so much to make the reign of George the Third what Lord Brougham was wont to declare it to be—the Augustan age of modern history.

To-night I shall venture to offer you a brief notice of the character and work of another and equally illustrious member of that band—Henry Cavendish. These two men had, however, little in common beyond their zeal for science; indeed, it is scarcely possible to conceive of a stronger contrast than that which their personal histories afford. Priestley, the son of a poor cloth-dresser, was ardent, impulsive, ingenuous—fond of the strife of words, never so happy, indeed, as when, Ishmael-like, his hand was against everybody and everybody's hand was against him; a man withal "in whom the elements were kindly mixed," and of whom it might be truly said that nothing which related to man was foreign to his sympathies. Cavendish, a scion of a great house, was cold, retiring, reticent, passively selfish, a confirmed misogynist, a hater of noise and bustle; and of whom it was said that he probably uttered fewer words in the course of his four-score years than any man who ever lived so long—not even excepting the monks of La Trappe. Priestley delighted in literary composition; his pen was ever busy; he published more than a hundred works on subjects of the most extraordinary diversity, turning them off with an ease and rapidity which even the most prolific of lady novelists might envy. Cavendish, although he wrote much, printed fewer pages than Priestley did works; his morbid shyness, and his horror of popularity, compelling him to keep back his scientific memoirs even when he had prepared them for publication.

But that you may the better frame for yourselves some conception of the manner of man Cavendish was, let me attempt to sketch for you a scene in which he might have played a part. That there is nothing opposed to truth in it you may readily determine for yourselves, if what I say to-night may so far interest you in Cavendish as to lead you to read his life as written by Dr. Wilson or by Lord Brougham. Imagine, then, you are in the London of 90 years ago: it is night, and you are standing before an old-fashioned house in what is now a very unfashionable square. It is evident from the lights in the windows and the bustle before the door that there is a dinner party or some similar meeting in the house. A couple of chairmen have deposited a portly gentleman, with a large frill, on the step, and two or three lumbering vehicles, having set down their charges, are rattling away over the rough stones into the obscurity of the dimly-lighted street. My knowledge of London 90 years ago is so vague that I must ask you to complete the picture for yourselves by throwing in any other accessories which may occur to you as giving it a strong 18th century flavour, such as a few link-boys, a solitary watchman, an oil lamp or two, and a plentiful sprinkling of puddles and mud. You are informed that the house belongs to Sir Joseph Banks, who is the President of the Royal Society of London, and that the occasion is one of his weekly conversaziones. The portly visitor, with the large frill, makes his way upstairs, to the evident embarrassment of a thin, middle-aged gentleman in an old-fashioned Court dress of faded violet and a knocker-tailed periwig, who is moving uneasily about on the landing, manifestly afraid to face the assembly. The approach of the gentleman on the stairs, however, drives him into the room. He shuffles quickly from place to place, his manner is awkward; his face betrays a nervous irritation of mind, and he appears annoyed if looked at. It is the Honourable Mr. Cavendish. Finding himself close to a group, evidently, from the appearance which their faces wear, speaking of a deeply-important matter, he draws near to listen. They are talking of a rumour of some grave disaster which has befallen my Lord Cornwallis and his troops, who it would seem have been circumvented in some unexpected manner by the machinations of that arch-rebel Washington. Mr. Cavendish is scarcely interested, and he moves aside to catch something concerning it may be some fresh eccentricity of poor Lord George Gordon, or perhaps some account of the troubles of the unhappy Mr. Watt, the engineer, who, it is being said, is fighting tooth and nail to defend his just rights from a set of unprincipled rogues who pirate his inventions. Neither of these matters are sufficiently moving to detain him. But his manner quickly alters, for he overhears the mention of the name of Mr. Herschel. Mr. Herschel is a musician at Bath, who employs his leisure in constructing big telescopes, with one of which he has just discovered a new planet. Mr. Cavendish is greatly interested; he listens with marked attention; he is even about to put a question, and begins in a nervous hesitating manner, and in a thin shrill voice, when his eye catches that of a stranger; he is instantly silent, and retires in great haste, for he has a horror of a strange face. The portly gentleman with the large frill espies him, and comes up with a foreign gentleman, who is formally introduced to Mr. Cavendish. Mr. Cavendish is assured by the portly gentleman that his foreign friend is particularly desirous to make the acquaintance of a philosopher so profound and so universally celebrated—all of which is confirmed by the foreign gentleman, who adds that it was, indeed, his chief reason for coming to London, that he might see and converse with one of the greatest ornaments of Britain, and one of the most illustrious philosophers of that or any other age. Mr. Cavendish is speechless; he is overwhelmed with confusion, until seeing an opening in the crowd he darts through it with all possible speed, and, reaching his carriage, is driven home. His house is precisely such as you would expect from one of his habits and disposition; it is made up of laboratories and workshops, and very little is set apart for personal comfort. The principal laboratory is in what the builder intended to be the drawing-room; in an adjoining chamber is a forge; and the upper apartments are turned into an astronomical observatory. Mr. Cavendish rarely did violence to his love of solitude by asking any one to his house. If a friend chanced to dine with him he was invariably treated to a leg of mutton, and nothing else. We are told that on one occasion, three or four guests being expected, he was asked what was to be got for dinner. He replied with the customary formula, "A leg of mutton." "But," said the servant, "that will not be enough for five." "Then get two legs," was his answer. During the latter part of his life Mr. Cavendish was immensely rich. At the time of his death he was said to be worth a million and a quarter, and was the largest holder of Bank Stock in England. But he who was thus the most wealthy of learned men, and the most learned of wealthy men,* seemed quite indifferent to his riches. There is a well-known story of Cavendish threatening to remove his money out of the hands of his bankers if, as he said, they continued to plague him about it. The portrait which I throw upon the screen will give you some idea of Mr. Cavendish's personal appearance. The history of that picture is remarkable. Cavendish, as you may suppose, could never be induced to sit for his portrait; but the artist, who was bent upon having it, managed to get near his subject unobserved, and first sketching the three-cornered hat, and then the great-coat, he patiently watched his opportunity and inserted the profile between them.

The life of such a man is, as you may well imagine, nearly devoid of incident. There is but little more of his personal history to tell, except that he was the son of Lord Charles Cavendish, that he was born at Nice in 1731, and that he died in London in 1810. He died as he had lived, voluntarily severing every tie of human sympathy. When he found himself near his end, he called his servant to his bedside and said, "Mind what I say—I am going to die. When I am dead, but not till then, go to Lord George Cavendish and tell him—Go!" The dying man wished to be left alone, and the servant, who hesitated to leave him, was ordered from the room. In half-an-hour he returned to find that his master had quietly passed into

> "That undiscovered country, from whose bourn
> No traveller returns."

There is nothing lovable in such a character; on the other hand there is nothing in it that is despicable. This passionless man, whose moral character seemed almost a blank, had a marvellously clear intelligence, and a range of mental vision second to none of his age. In extent of acquirements, and in profundity of learning, he was unsurpassed by any of his contemporaries. His published work, although of the highest order, gives a very incomplete idea of his powers. He left behind him a mass of papers which indicate that he was far in advance of the science of his time. His memoirs on heat and electricity contain the germs

---

* Le plus riche de tous les savans et le plus savant de tous les riches.—BIOT.

of discoveries, if not actual discoveries, which are commonly associated with the names of subsequent investigators. He was an accomplished practical astronomer and a profound mathematician. His knowledge of the calculus and the manner in which he handled it have been described as masterly.

Science is indebted to a learned Scotch professor of the last century—Dr. Black—for the discovery of certain fundamental laws of heat; and the elucidation of these laws seems to have been the subject of Cavendish's earliest inquiries. One of the problems he set himself to solve, in the course of these investigations, was whether our mercurial thermometer was an accurate and uniform measurer of temperature, to the extent of showing whether the temperature of a mixture of hot and cold water is the mean of the temperatures of the hot and cold water before mixing. Having found that such was the case, Cavendish proceeded to determine the effect of mixing dissimilar liquids at different temperatures. "One would naturally imagine," he says, "that if cold mercury, or any other substance, is added to hot water, the heat of the mixture would be the same as if an equal quantity of water of the same degree of heat had been added, or, in other words, that all bodies heat and cool each other when mixed together equally in proportion to their weights."

He then shows by experiment that such is not the case. He mixed quicksilver and water together at different temperatures, and found that if it required 1lb. of water at a known temperature to cool a certain weight of hot water through a certain number of degrees, it would require 30lb. of quicksilver to cool the same weight of hot water through the same interval of temperature. He made trials with various metals, with sulphur, glass, charcoal, and many other bodies, and he concludes "that the true explanation of these phenomena seems to be that it requires a greater quantity of heat to raise the heat of some bodies a given number of degrees by the thermometer than it does to raise other bodies the same number of degrees."

We have here the first clear enunciation of a very important fact; if Cavendish had communicated his discovery to the world when he made it, namely, in 1764, he would have had priority over those who are generally styled the discoverers of the fact of specific heat. I regret that the time will not allow me to attempt to show you the full significance of this fact, for it exerts a very great influence in nature. I wish, however, to give you a clear conception of the fact itself, namely, that two bodies, say a piece of lead and a piece of zinc, may possess the same temperature and yet contain very different quantities of heat; and, to bring it home to you, I will try and illustrate it to you by an experiment. I am about to drop these metallic balls upon this cake of wax, which is so placed that you can see its image on the screen. One of the bullets is of lead, the other is of zinc, and both will be heated to the same temperature. But you will notice that, although, as I tell you, they both possess the same temperature, they yet contain very different amounts of heat. This will be evident to you from the different amounts they give out on cooling down to the temperature of the air. The zinc bullet you see is able to melt its way through the cake whilst the leaden bullet merely buries itself a little way in the wax. [Experiment.]

Cavendish did much to improve the mercurial thermometer. He pointed out several sources of error in the methods of making and using it. He was the first to insist on the necessity of correcting its indications when the whole of the mercury is not within the space of which the temperature is to be ascertained, and the first to draw up special directions to ensure uniformity in the mode of graduating it. He also accurately determined the temperature at which quicksilver freezes, and found it to be 39 degrees below the point at which water is ordinarily turned into ice. But it would require an entire evening to indicate the value of what Cavendish did on this subject of heat. That it occupied much of his attention is obvious from the number and character of his experiments, and the excellence of his numerical results. It is evident, too, that he thought deeply on the nature of heat. He rejected the doctrine that it was material, rather holding, as he tells us, "Sir Isaac Newton's opinion, that heat consists in the internal motions of the particles of bodies;" the theory in fact which is now, I should suppose, universally current. And it is worthy of remark that one of the greatest living expositors of this theory is the director of the finest physical laboratory in the world—a laboratory erected at Cambridge to the memory of Cavendish by his descendant, the present Duke of Devonshire.

Cavendish was a natural philosopher in the widest sense of the term, for he occupied himself in turn with every branch of physical science known in his time. But it is to his discoveries in chemistry that his fame is chiefly due; and here again we may trace the influence of Black in directing the current of his early inquiries. Chemists, up to the middle of the last century, had no clear conception of the existence of a variety of gaseous substances perfectly distinct from another. They were inclined to believe that all the different varieties of gas they met with were merely modifications of one and the same substance. Their distinctive characters were supposed to arise from their being "tainted," or "infected with fumes, vapours, or sulphurous spirits." The publication of a celebrated essay by Black on "*Magnesia Alba*," marked an epoch in the history of chemistry by demonstrating the existence of at least one uniform body totally distinct from the air we breathe. Black showed that the difference between chalk and quicklime was due to the presence of a gas in the chalk which was not in the quicklime. Quicklime, indeed, had the property of fixing this air and of thus being converted into chalk. Black named this air, which was so capable of entering into the composition of bodies, "fixed air;" now-a-days we call it carbon dioxide, a name which denotes its composition, of which Black was ignorant. Black did very little towards investigating this gas in the free state. The first full account of its properties was given by Cavendish in 1766. Cavendish prepared the fixed air with which he experimented by dissolving marble, which is, chemically speaking, the same thing as chalk, in spirits of salt or hydrochloric acid. This vessel, the reflection of which you see on the screen, contains some chalk. If I pour over it a few drops of solution of spirits of salt, or hydrochloric acid, you will see that gas is disengaged. There you see the bubbles making their way through the liquid! Cavendish found that this gas dissolved in its own bulk of water at common temperatures, and that cold water dissolves more of it than hot water; indeed, he says, "water heated to the boiling-point is so far from absorbing the air that it parts with what it had already absorded." Lime and alkalies, especially if dissolved in water, rapidly absorb the gas, but it may be collected and preserved over quicksilver for any length of time; indeed chemists owe the idea of using quicksilver to collect and preserve certain gases which are absorbed by water to Mr. Cavendish. This long tube is filled with fixed air or carbon dioxide. You see it is fitted with a cork and stopcock. I will quickly introduce into it a solution of soda. If I shake it for a moment or two, and open the end of the tube beneath the surface of this water, you will observe that the water will be forcibly driven into the tube in the form of a fountain, to replace the carbon dioxide which has been absorbed by the soda. [Experiment.] Although you are blessed here in Manchester with one of the best water supplies in the kingdom, you doubtless have heard of such things as "hard" waters; you may even know that some of these hard waters are made "soft" by boiling, and that this particular kind of hard water deposits a crust or "fur" in the tea-kettle and a "cake" in the steam-boiler. Now this "fur" is mainly composed of chalk, kept in solution in the water by the fixed air dissolved therein. When the water is boiled the fixed air is expelled, as Cavendish tells us, and accordingly the chalk is deposited. This explanation of the origin of the "fur" was first given by Cavendish. Possibly some of you may know that such hard waters are frequently softened on the large scale by adding lime to them. The lime combines with the fixed air (the agent, you bear in mind, which keeps the chalk in solution), and accordingly the chalk is deposited, together with that formed by the union of the fixed air with the added lime. The fact that water could be thus deprived of its dissolved chalk was pointed out by Cavendish. When the carbon dioxide is allowed gradually to escape from the solution the carbonate of lime is deposited in beautiful crystals, the shapes of which are often exceedingly curious and beautiful; indeed, there is no substance which has such a diversity of crystalline forms as this carbonate of lime. Here on the screen you have a representation of certain of these forms.

In various parts of the world, particularly in districts where limestone abounds, there are large caves, or grottoes, from the roofs of which depend long icicle-shaped masses of carbonate of lime termed *stalactites*. If you notice one of these masses you will observe that occasionally a drop of water falls from the end of it to the floor, or rather upon a similar mass of carbonate of lime on the floor, exactly underneath that which hangs from the roof. The lower mass which appears to stretch up towards the upper one is termed a *stalagmite*. Occasionally the two masses do meet one another and unite to form a continuous column. The origin of these masses—these stalactites and stalagmites—will readily occur to you: the rain-water percolating through the rock above the cave contains carbonic acid in solution, by which it dissolves the carbonate of lime in the rock. As it drips from the roof it gives up a portion of its carbonic acid to the air in the cavern, and accordingly a portion of the carbonate of lime is deposited; the next drop runs over the mass so deposited, and by giving out another portion of dissolved carbonic acid deposits another portion of carbonate of lime on the first deposition; and so the process goes on, each portion of water from the roof running down the icicle of carbonate of lime which is formed, and continually adding to its length. But the drops fall off to the floor long before they have given up the whole of their carbonic acid, and accordingly long before they have yielded up all the lime which they held in solution. Accordingly the escape of the carbonic acid goes on from the water after it has fallen on the floor and so you get this second deposit of carbonate of lime—this stalagmite—formed underneath the stalactite.

Cavendish also shewed that fixed air was considerably heavier than common air by weighing a bladder filled first with the one gas and then with the other. The fixed air he found to be one-and-a-half times heavier than the common air, a fact which I can illustrate to you by pouring the gas out of this bottle into the glass vessel on this pair of scales. You see the glass vessel appears now to weigh more, the air within having been displaced by the heavier carbon dioxide. [Experiment.] This gas will not support combustion. If I pour it over this ignited benzine you see the flame is at once extinguished. [Experiment.]

The old chemists, who in days gone by greatly busied themselves to discover a more direct method of turning things into gold than is practised by their successors in the chemical arts, have left us some marvellous stories concerning the behaviour of a gas which seems to be evolved from certain metals when they are brought into contact with acids, such as oil of vitriol, or muriatic acid. The exact nature of this gas remained unknown until Cavendish investigated its properties. This gas, which we now call hydrogen, is highly inflammable, and Cavendish showed that, like many other inflammable bodies, it cannot burn without the assistance of common air. When mixed with rather more than double its volume of air, it explodes violently on the approach of a light. [Experiment.] Cavendish also weighed this gas by the same method which he had employed to weigh the fixed air, and he found it to be eleven times lighter than common air. Cavendish, however, under-estimated the lightness of this gas; in reality it is about fourteen and a half times lighter than air. If then we can pour the heavy fixed air downwards, we may expect to be able to pour the light hydrogen upwards. I will allow the hydrogen from this bottle to flow into the large glass vessel, which, you see, is counterpoised on this balance. As the lighter hydrogen rises and displaces the air the vessel will appear to weigh less. [Experiment.] I may show you another experiment, which has the advantage of illustrating at once all the properties of hydrogen to which I have referred namely, its inflammability, its lightness, and the fact that it forms an explosive mixture with air. This bottomless jar is filled with hydrogen. When I apply a flame to the bent tube, the light hydrogen which is rushing up through it will ignite; but as the hydrogen makes its escape, air enters at the bottom; and this air, mixing with the remaining hydrogen, forms, as you will hear, an explosive mixture. [Explosion.]

When giving you an account of Priestley's work, I described to you his method of analysing the air. It was based on the fact that when the gas known as *nitric oxide* comes into contact with air, the oxygen in the air combines with the nitric oxide to form a product soluble in water. If the mixture of gases is made in a tube standing over water, the diminution in volume, consequent on the removal of the oxygen, is a measure of the amount of that gas in the air. As the quality of the air was supposed to depend upon the diminution of volume which it suffered by being mixed with nitric oxide, the instruments designed to make the tests, were termed *eudiometers*, from two Greek words denoting a 'measure of goodness.' Without going into details I may say that this method of analysis is liable to an objection from the cause first worked out by our illustrious townsman, John Dalton, that the same volume of oxygen can combine with different volumes of the nitric oxide. This fact was indeed known to Cavendish, and he made a great number of experiments in order to ascertain the best method of mixing the gases so as to obtain constant results.

By means of the apparatus he devised he was enabled to show that the composition of the atmosphere is sensibly constant. He tells us that "during the last half of the year 1781 I tried the air of near sixty different days * * * but found no difference that I could be sure of, though the wind and weather on those days were very various, some of them being very fair and clear, others very wet, and others very foggy." This conclusion is in harmony with the results of later experimenters. The atmosphere has practically the same composition all the world over, and all the year round. Cavendish gives us the numerical results of his experiments, and from these it appears that, when expressed in the manner we now adopt, the mean composition of the air is in 100 parts by measure :—

O—20·8
N—79·2

The most refined methods of analysis of modern times have shown that the mean numbers are

O—20·9
N—79·1

A result, you see, almost identical with that deduced from Cavendish's observations, and one which illustrates in a very striking manner the extreme care and accuracy with which he worked.

Cavendish next proceeded to determine the cause of the diminution in volume which common air suffers by the action of burning bodies upon it.

Among the many experiments which he made in order to elucidate this matter there is one which is especially remarkable, as it led him to his greatest discovery, that of the composition of water—a discovery which will make the name of Cavendish for ever memorable. Dr. Priestley relates in one of his volumes of "Experiments and Observations on Air," that when a mixture of common air and inflammable air is exploded by the electric spark in a glass vessel, "the inside of the glass, though clear and dry before, immediately became dewy." "As this experiment," says Cavendish, "seemed likely to throw great light on the subject I had in view, I thought it well worth examining more closely." Cavendish repeated this experiment in his characteristically careful manner. The inflammable air and common air were mixed in varying but known proportions, and the diminution in volume which attended the explosion in each case was accurately noted, and the amount of oxygen remaining in the air was determined by the eudiometer. Cavendish found that the greatest diminution of volume occured when two volumes of hydrogen were mixed with five volumes of air.

He tells us that when this mixture is exploded, "almost all the inflammable air and about one-fifth part of the common air lose their elasticity, and are condensed into the dew which lines the glass." Cavendish continues : "The better to examine the nature of this dew 500,000 grain measures of inflammable air were burnt with about two and a half times that quantity of common air, and the burnt air made to pass through a glass cylinder 8ft. long and $\frac{3}{4}$in. in diameter, in order to deposit the dew. The two airs were conveyed slowly into this cylinder by separate copper pipes, passing through a brass plate which stopped up the end of the cylinder; and as neither inflammable air nor common air can burn by themselves, there was no danger of the flame spreading into the magazines from which they were conveyed. * * * * By this means upwards of 135 grains of water were condensed in the cylinder, which had no taste nor smell, and which left no sensible sediment when evaporated to dryness; in short it seemed pure water." * * * By the experiments with the globe it appeared that when inflammable air and common air are exploded in a proper proportion, almost all the inflammable air and near one-fifth of the common air lose their elasticity, and are condensed into dew. And by this experiment it appears that this dew is plain water, and consequently that almost all the inflammable air and about one-fifth of the common air are turned into pure water."—

Cavendish then repeated the experiment with pure oxygen, or "dephlogisticated air," as this gas was then termed. I will give you the result in his own words, for the account has a great historical interest: "I took a glass globe holding 8,800 grain measures, furnished with a brass cock, and an apparatus for firing air by electricity. This globe was exhausted by an air-pump, and then filled with a mixture of inflammable and dephlogisticated air by shutting the cock, fastening a bent glass tube to its mouth, and letting up the end of it into a glass jar, inverted in water, and containing a mixture of 19,500 grain measures of dephlogisticated air, and 37,000 of inflammable; so that on opening the cock some of this mixed air rushed through the bent tube and filled the globe. The cock was then shut, and the included air fired by electricity, by which means almost all of it lost its elasticity. The cock was then again opened, so as to let in more of the same air, to supply the place of that destroyed by the explosion, which was again fired, and the operation continued till almost the whole of the mixture was let into the globe and exploded. By this means, though the globe held not more than the sixth part of the mixture, almost the whole of it was exploded in it, without any fresh exhaustion of the globe." Cavendish, however, found that in many of his trials the condensed water was sensibly acid to the taste, and by saturation with alkali, and evaporation, it yielded nitre. The search for the cause of the formation of this acid led Cavendish to another discovery, namely, that of the composition of nitric acid, an acid which is probably familiar to you under its old name of spirits of nitre or aquafortis. He showed that the formation of this acid was not an essential part of the process of the union of the oxygen and hydrogen, but that it was due to the presence of impurities in the gases used. Whenever the amount of oxygen was larger than could combine with all the hydrogen in the mixture, a portion of that oxygen united with the nitrogen of the common air present to form this nitric acid. I may show you an experiment in illustration of the method employed by Cavendish to effect the union of the oxygen and hydrogen. This thin glass globe is filled with a mixture of two volumes of hydrogen and one volume of oxygen. I have here an arrangement by means of which I can pass an electrical spark in this mixture. Before passing the spark I will place this wire gauze cylinder over the globe to protect us from the results of the explosion. Now I pass the spark and the glass is immediately shattered by the violence of the explosion—that is by the energy of the union of the oxygen and hydrogen. [Experiment.]

Such, then, were the experiments which led to the discovery, firstly, of the compound nature of water; secondly, of the character of its constituents; and thirdly, of the proportions in which these constituents are combined together. It would be impossible to over estimate the value of this discovery: it marks one of the grandest epochs in the history of chemistry. Who could have predicted that this most familiar of all liquids was composed of two colourless invisible gases—the one the inflammable hydrogen, the lightest substance known—the other, oxygen, the life-sustaining principle in the air we breathe—nay, the element which has been styled "the chemical centre in the scheme of nature." Nevertheless, it is easy to show that such is the case. By applying that very agent which, in the hands of Cavendish, caused the two gases to combine, I am now undoing the combination. I am passing a current of electricity through the water contained in this vessel, and you notice that gases are being evolved from the two wires. [Experiment.] By a modification of the experiment which Mr. Heywood has arranged for me I can show you that more gas is being generated at the one wire than at the other; there is, in fact, twice as much of the one gas formed as of the other. The gas formed in larger quantity is hydrogen:

the other is oxygen. Water is therefore made up of one volume oxygen combined with two volumes of hydrogen.

Nearly every important discovery has to pass through two ordeals—it is first impugned as not true, and then as not new; and this grand discovery which I have ascribed to Cavendish formed no exception to this rule. Not many years ago there was a great controversy concerning the question—Who was the discoverer of the composition of water? I am not now going to rake up the matter, for it is gradually being forgotten; and I think that every chemist now allows that the claims of Cavendish have been incontestably proved. The fact is the time was ripe for this discovery. Everybody familiar with the chemical work of the latter half of the last century will admit that the labours of a dozen of Cavendish's contemporaries were tending more or less directly to the same goal, and had Cavendish proved unequal to his opportunities his grandest discovery would not have been long delayed. It has been said that the discovery of law is regulated by law, and the history of the discovery of the composition of water affords a most striking exemplification of the truth of this remark.

The time will scarcely allow me to tell you more of what Cavendish did; but, if I am not trespassing too much on your patience, I should like just to mention another great work of his, since any account of Cavendish's labours would be very incomplete without some reference to it. An ancestor of Cavendish's was one of the first to sail round the earth. Cavendish himself was one of the first to attempt to weigh it. Cavendish, in fact, undertook to determine how much heavier the earth is than a sphere of water of equal size. There, represented on the screen, is the apparatus which he employed. It consisted of a long light wooden rod suspended horizontally by a thin wire. At the ends of the rod are leaden balls about two inches in diameter, and near these could be brought the two large spherical masses of metal which you see in the figure. By the mutual attraction of the balls, big and little, the long rod was caused to move slightly. The amount of the deviation, and the force necessary to produce it, being known, together with the weights of the balls, and the distances from their centres, the attraction of a sphere of water of the same diameter as the earth upon the ball on its surface can be calculated, from which can also be calculated the relation of the earth's density to that of water. From his experiments, Cavendish concluded that the earth is about five and a-half times heavier than water, a result which the subsequent labours of Mr. Baily, made with extraordinary care and patience, have shown to be very near the truth. It deserves to be mentioned, however, that Newton, with that marvellous insight which now-a-days seems to us nothing less than divination, had predicted that the earth would be found to be between five and six times heavier than water.

One more remark and I have done. A celebrated living French chemist, whose patriotism we admire scarcely less than his genius, has declared that "Chemistry is a French Science, its founder was Lavoisier of immortal memory." The merit of Lavoisier is undoubtedly great, and we still feel the influence which he exerted on the development of chemistry. It is accounted the chief glory of Lavoisier that he first clearly pointed out that the principles of gravitation lie at the basis of chemistry; that chemistry is in fact a science of quantitative relations. But let us take a retrospect of Cavendish's labours. He fixed the weight of the earth; he established the proportions of the constituents of the air; he occupied himself with the quantitative study of the laws of heat; and lastly, he demonstrated the nature of water and determined its volumetric composition. Earth, air, fire, and water—each and all came within the range of his observations. Now, I ask you, what is the most striking peculiarity of this work? Is it not its thoroughly quantitative character? Weighing, measuring, calculating; such, indeed, was the essential nature of Cavendish's work. If, then, the claim of anyone to be styled the founder of chemistry as a science, rests upon his recognition of the fact that it is a science of quantitative relations, may we not also, and with equal truth, say that "Chemistry is an English Science—its founder was Cavendish of immortal memory?"