THURSDAY, OCTOBER 26, 1882

SCIENTIFIC WORTHIES

XX.—JAMES PRESCOTT JOULE

JAMES PRESCOTT JOULE was born at Salford on Christmas-Eve of the year 1818. His father and his grandfather before him were brewers, and the business, in due course, descended to Mr. Joule and his elder brother, and by them was carried on with success till it was sold in 1854. Mr. Joule's grandfather came from Elton, in Derbyshire, settled near Manchester, where he founded the business, and died at the age of fifty-four in 1799. His father, one of a numerous family, married a daughter of John Prescott of Wigan. They had five children, of whom James Prescott Joule was the second, and of whom three were sons—Benjamin, the eldest, James, and John, and two daughters—Alice and Mary. Mr. Joule's mother died in 1836 at the age of forty-eight; and his father, who was an invalid for many years before his death, died at the age of seventy-four in the year 1858.

Young Joule was a delicate child, and was not sent to school. His early education was commenced by his mother's half-sister, and was carried on at his father's house, Broomhill, Pendlebury, by tutors, till he was about fifteen years of age. At fifteen he commenced working in the brewery, which, as his father's health declined, fell entirely into the hands of his brother Benjamin and himself.

Mr. Joule obtained his first instruction in physical science from Dalton, to whom his father sent the two brothers to learn chemistry. Dalton, one of the most distinguished chemists of any age or country, was then president of the Manchester Literary and Philosophical Society, and lived and received pupils in the rooms of the Society's House. Many of his most important memoirs were communicated to the Society, whose *Transactions* are likewise enriched by a large number of communications from his distinguished pupil. Dalton's instruction to the two young men commenced with arithmetic, algebra, and geometry. He then taught them natural philosophy out of Cavallo's text-book, and afterwards, but only for a short time before his health gave way in 1837, chemistry from his own "New System of Chemical Philosophy." "Profound, patient, intuitive," his teaching must have had great influence on his pupils. We find Mr. Joule early at work on the molecular constitution of gases, following in the footsteps of his illustrious master, whose own investigations on the constitution of mixed gases, and on the behaviour of vapours and gases under heat, were among the most important of his day, and whose brilliant discovery of the Atomic Theory revolutionised the science of Chemistry and placed him at the head of the philosophical chemists of Europe.

Under Dalton, Mr. Joule first became acquainted with physical apparatus; and the interest excited in his mind very soon began to produce fruit. Almost immediately he commenced experimenting on his own account. Obtaining a room in his father's house for the purpose, he began by constructing a cylinder electric machine in a very primitive way. A glass tube served for the cylinder; a poker hung up by silk threads, as in the very oldest forms of electric machine, was the prime conductor; and for a Leyden jar he went back to the old historical jar of Cunæus, and used a bottle half filled with water, standing in an outer vessel, which contained water also.

Enlarging his stock of apparatus, chiefly by the work of his own hands, he soon entered the ranks as an investigator, and original papers followed each other in quick succession. The Royal Society List now contains the titles of ninety-seven papers due to Joule, exclusive of over twenty very important papers detailing researches undertaken by him, conjointly with Thomson, with Lyon Playfair, and with Scoresby.

Mr. Joule's first investigations were in the field of magnetism. In 1838, at the age of nineteen, he constructed an electro-magnetic engine, which he described in Sturgeon's "Annals of Electricity" for January of that year. In the same year and in the three years following he constructed other electro-magnetic machines and electro-magnets of novel forms; and experimenting with the new apparatus, he obtained results of great importance in the theory of electro-magnetism. In 1840 he discovered, and determined the value of the limit to the magnetisation communicable to soft iron by the electric current; showing for the case of an electro-magnet supporting weight, that when the exciting current is made stronger and stronger, the sustaining power tends to a certain definite limit, which, according to his estimate, amounts to about 140 lbs. per square inch of either of the attracting surfaces. He investigated the relative values of solid iron cores for the electro-magnetic machine as compared with bundles of iron wire; and, applying the principles which he had discovered, he proceeded to the construction of electro-magnets of much greater lifting power than any previously made, while he studied also the methods of modifying the distribution of the force in the magnetic field.

In commencing these investigations he was met at the very outset, as he tells us, with "the difficulty, if not impossibility, of understanding experiments and comparing them with one another which arises in general from incomplete descriptions of apparatus, and from the arbitrary and vague numbers which are used to characterise electric currents. Such a practice," he says, "might be tolerated in the infancy of science; but in its present state of advancement greater precision and propriety are imperatively demanded. I have therefore determined," he continues, "for my own part to abandon my old quantity numbers, and to express my results on the basis of a unit which shall be at once scientific and convenient."

The discovery by Faraday of the law of electro-chemical equivalents had induced him to propose the voltameter as a measurer of electric currents; but the system proposed had not been used in the researches of any electrician, not excepting those of Faraday himself. Joule, realising for the first time the importance of having a system of electric measurement which would make experimental results obtained at different times and under various circumstances comparable among themselves, and perceiving at the same time the advantages of a system of electric measurement, dependent on, or at any rate comparable with the chemical action producing the electric current, adopted as unit quantity of electricity, the quantity required to decompose nine grains of water, 9 being the atomic weight of water, according to the chemical nomenclature then in use.

He had already made and described very important improvements in the construction of galvanometers, and he graduated his tangent galvanometer to correspond with the system of electric measurement he had adopted. The electric currents used in his experiments were thenceforth measured on the new system; and the numbers given in Joule's papers from 1840 downwards are easily reducible to the modern absolute system of electric measurements, in the construction and general introduction of which he himself took so prominent a part. It was in 1840, also, that after experimenting on improvements in voltaic apparatus, he turned his attention to "the heat evolved by metallic conductors of electricity, and in the cells of a battery during electrolysis." In this paper and those following it in 1841 and 1842, he laid the foundation of a new province in physical science—electric and chemical thermodynamics—then totally unknown, but now wonderfully familiar even to the roughest common-sense practical electrician. With regard to the heat evolved by a metallic conductor carrying an electric current, he established what was already supposed to be the law, namely, that "the quantity of heat evolved by it [in a given time] is always proportional to the resistance which it presents, whatever may be the length, thickness, shape, or kind of the metallic conductor," while he obtained the law, then unknown, that the heat evolved is proportional to the *square* of the quantity of electricity passing in a given time. Corresponding laws were established for the heat evolved by the current passing in the electrolytic cell, and likewise for the heat developed in the cells of the battery itself.

In the year 1840 he was already speculating on the transformation of chemical energy into heat. In the paper last referred to and in a short abstract in the *Proceedings* of the Royal Society, December, 1840, he points out that the heat generated in a wire conveying a current of electricity is a part of the heat of chemical combination of the materials used in the voltaic cell, and that the remainder, not the whole heat of combination, is evolved within the cell in which the chemical action takes place. In papers given in 1841 and 1842, he pushes his investigations farther, and shows that the sum of the heat produced in all parts of the circuit during voltaic action is proportional to the chemical action that goes on in the voltaic pile, and again, that the quantities of heat which are evolved by the combustion of equivalents of bodies are proportional to the intensities of their affinities for oxygen. Having proceeded thus far, he carried on the same train of reasoning and experiment till he was able to announce, in January, 1843, that the magneto-electric machine enables us to *convert mechanical power into heat.* Most of his spare time in the early part of the year 1843 was devoted to making experiments necessary for the discovery of the laws of the development of heat by magneto-electricity, and for the definite determination of the mechanical value of heat.

At the meeting of the British Association at Cork, on August 21, 1843, he read his paper "On the Calorific Effects of Magneto-Electricity, and on the Mechanical Value of Heat." The paper gives an account of an admirable series of experiments, proving that *heat* is *generated* (not merely *transferred* from some source) by the magneto-electric machine. The investigation was pushed on for the purpose of finding whether a *constant ratio exists between the heat generated and the mechanical power* used in its production. As the result of one set of magneto-electric experiments he finds 838 foot lbs. to be the mechanical equivalent of the quantity of heat capable of increasing the temperature of one pound of water by one degree of Fahrenheit's scale. The paper is dated Broomhill, July, 1843, but a postscript dated August, 1843, contains the following sentences:—"We shall be obliged to admit that Count Rumford was right in attributing the heat evolved by boring cannon to friction, and not (in any considerable degree) to any change in the capacity of the metal. I have lately proved experimentally that *heat is evolved by the passage of water through narrow tubes.* My apparatus consisted of a piston perforated by a number of small holes, working in a cylindrical glass jar containing about 7 lbs. of water. I thus obtained one degree of heat per lb. of water from a mechanical force capable of raising about 770 lbs. to the height of one foot, a result which will be allowed to be very strongly confirmatory of our previous deductions. I shall lose no time in repeating and extending these experiments, being satisfied that the grand agents of nature are, by the Creator's fiat, *indestructible*, and that wherever mechanical force is expended, an exact equivalent of heat is *always* obtained."

This was the first determination of the dynamical equivalent of heat. Other naturalists and experimenters about the same time were attempting to compare the quantity of heat produced under certain circumstances with the quantity of work expended in producing it; and results and deductions (some of them very remarkable) were given by Séguin (1839), Mayer (1842), Colding (1843), founded partly on experiment, and partly on a kind of metaphysical reasoning. It was Joule, however, who first definitely proposed the problem of determining the relation between heat produced and work done in any mechanical action, and solved the problem directly.

It is not to be supposed that Joule's discovery and the results of his investigation met with immediate attention or with ready acquiescence. The problem occupied him almost continuously for many years; and in 1878 he gives in the *Philosophical Transactions* the results of a fresh determination according to which the quantity of work required to be expended in order to raise the temperature of one pound of water weighed in vacuum from 60° to 61° Fah., is 772·55 foot lbs. of work at the sea-level, and in the latitude of Greenwich. His results of 1849 and 1878 agree in a striking manner with those obtained by Hirn and with those derived from an elaborate series of experiments carried out by Prof. Rowland at the expense of the Government of the United States.

His experiments subsequent to 1843 on the dynamical equivalent of heat must be mentioned briefly. In that year his father removed from Pendlebury to Oak Field, Whalley Range on the south side of Manchester, and built for his son a convenient laboratory near to the house. It was at this time that he felt the pressing need of accurate thermometers; and whilst Regnault was doing the same thing in France Mr. Joule produced, with the assistance of Mr. Dancer, instrument maker, of Manchester, the first English thermometers possessing such accuracy as the mercury-in-glass thermometer is capable of. Some of them were forwarded to Prof. Graham and to Prof. Lyon Playfair; and the production of these instruments was in itself a most important contribution to scientific equipment.

As the direct experiment of friction of a fluid is dependent on no hypothesis, and appears to be wholly unexceptionable, it was used by Mr. Joule repeatedly in modified forms. The stirring of mercury, of oil, and of water with a paddle, which was turned by a falling weight, was compared, and solid friction, the friction of iron on iron under mercury, was tried; but the simple stirring of water seemed preferable to any, and was employed in all his later determinations.

In 1847 Mr. Joule was married to Amelia, daughter of Mr. John Grimes, Comptroller of Customs, Liverpool. His wife died early (1854), leaving him one son and one daughter.

The meeting of the British Association at Oxford in this year, proved an interesting and important one. Here Joule read a fresh paper "On the Mechanical Equivalent of Heat." Of this meeting Sir William Thomson writes as follows to the author of this notice:—

"I made Joule's acquaintance at the Oxford meeting, and it quickly ripened into a life-long friendship.

"I heard his paper read in the section, and felt strongly impelled at first to rise and say that it must be wrong because the true mechanical value of heat given, suppose in warm water, must, for small differences of temperature, be proportional to the square of its quantity. I knew from Carnot that this *must* be true (and it *is* true; only now I call it 'motivity,' to avoid clashing with Joule's 'mechanical value.') But as I listened on and on, I saw that (though Carnot had vitally important truth, not to be abandoned) Joule had certainly a great truth and a great discovery, and a most important measurement to bring forward. So instead of rising with my objection to the meeting I waited till it was over, and said my say to Joule himself, at the end of the meeting. This made my first introduction to him. After that I had a long talk over the whole matter at one of the *conversaziones* of the Association, and we became fast friends from thenceforward. However, he did not tell me he was to be married in a week or so; but about a fortnight later I was walking down from Chamounix to commence the tour of Mont Blanc, and whom should I meet walking up but Joule, with a long thermometer in his hand, and a carriage with a lady in it not far off. He told me he had been married since we had parted at Oxford! and he was going to try for elevation of temperature in waterfalls. We trysted to meet a few days later at Martigny, and look at the Cascade de Sallanches, to see if it might answer. We found it too much broken into spray. His young wife, as long as she lived, took complete interest in his scientific work, and both she and he showed me the greatest kindness during my visits to them in Manchester, for our experiments on the thermal effects of fluid in motion, which we commenced a few years later."

"Joule's paper at the Oxford meeting made a great sensation. Faraday was there and was much struck with it, but did not enter fully into the new views. It was many years after that before any of the scientific chiefs began to give their adhesion. It was not long after, when Stokes told me he was inclined to be a Joulite."

"Miller, or Graham, or both, were for years quite incredulous as to Joule's results, because they all depended on fractions of a degree of temperature—sometimes very small fractions—his boldness in making such large conclusions from such very small observational effects, is almost as noteworthy and admirable as his skill in extorting accuracy from them. I remember distinctly at the Royal Society, I think it was either Graham or Miller, saying simply he did not believe Joule, because he had nothing but hundredths of a degree to prove his case by."

The friendship formed between Joule and Thomson in 1847 grew rapidly. A voluminous correspondence was kept up between them, and several important researches were undertaken by the two friends in common. Their first joint research was on the thermal effects experienced by air rushing through small apertures. The results of this investigation give for the first time an experimental basis for the hypothesis assumed without proof by Mayer as the foundation for an estimate of the numerical relation between quantities of heat and mechanical work, and they show that for permanent gases the hypothesis is very approximately true. Subsequently Joule and Thomson undertook more comprehensive investigations on the thermal effects of fluids in motion, and on the heat acquired by bodies moving rapidly through the air. They found the heat generated by a body moving at one mile per second through the air sufficient to account for its ignition. The phenomena of "shooting stars" were explained by Mr. Joule in 1847 by the heat developed by bodies rushing into our atmosphere.

It is impossible within the limits to which this sketch is necessarily confined, to speak in detail of the many researches undertaken by Mr. Joule on various physical subjects. Even of the most interesting of these a very brief notice must suffice for the present.

Molecular physics, as I have already remarked, early claimed his attention. Various papers on electrolysis of liquids, and on the constitution of gases, have been the result. A very interesting paper on "Heat and the Constitution of Elastic Fluids" was read before the Manchester Literary and Philosophical Society in 1848. In it he developed Daniel Bernoulli's explanation of air pressure by the impact of the molecules of the gas on the sides of the vessel which contains it, and from very simple considerations he calculated the average velocity of the particles requisite to produce ordinary atmospheric pressure at different temperatures. The average velocity of the particles of hydrogen at 32° F. he found to be 6055 feet per second, the velocities at various temperatures being proportional to the square roots of the numbers which express those temperatures on the absolute thermodynamic scale.

His contribution to the theory of the velocity of sound in air was likewise of great importance, and is distinguished alike for the acuteness of his explanations of the existing causes of error in the work of previous experimenters, and for the accuracy, so far as was required for the purpose in hand, of his own experiments. His determination of the specific heat of air, pressure constant, and the specific heat of air, volume constant, furnished the data necessary for making Laplace's theoretical velocity agree with the velocity of sound experimentally determined. On the other hand, he was able to account for most puzzling discrepancies which appeared in attempted direct determinations of the differences between the two specific heats by careful experimenters. He pointed out that in experiments in which air was allowed to rush violently or *explode* into a vacuum, there was a source of loss of energy that no one had taken account of, namely, in the sound produced by the explosion. Hence in the most careful experiments where the vacuum was made as perfect as possible, and the explosion correspondingly the more violent, the results were actually the worst. With his explanations the theory of the subject was rendered quite complete.

Space fails, or I should mention in detail Mr. Joule's experiments on magnetism and electro-magnets, referred to at the commencement of this sketch. He discovered the now celebrated change of dimensions produced by the magnetisation of soft iron by the current. The peculiar noise which accompanies the magnetisation of an iron bar by the current, sometimes called the "magnetic tick," was thus explained.

Mr. Joule's improvements in galvanometers have already been incidentally mentioned, and the construction by him of accurate thermometers has been referred to. It should never be forgotten that *he first* used small enough needles in tangent galvanometers to practically annul error from want of uniformity of the magnetic field. Of other improvements and additions to philosophical instruments may be mentioned a thermometer, unaffected by radiation, for measuring the temperature of the atmosphere, an improved barometer, a mercurial vacuum pump, one of the very first of the species which is now doing such valuable work not only in scientific laboratories, but in the manufacture of incandescent electric lamps, and an apparatus for determining the earth's horizontal magnetic force in absolute measure.

Here this imperfect sketch must close. My limits are already passed. Mr. Joule has never been in any sense a public man; and, of those who know his name as that of the discoverer who has given the experimental basis for the grandest generalisation in the whole of physical science, very few have ever seen his face. Of his private character this is scarcely the place to speak. Mr. Joule is still amongst us. May he long be spared to work for that cause to which he has given his life with heart-whole devotion that has never been excelled.

In June, 1878, he received a letter from the Earl of Beaconsfield announcing to him that Her Majesty the Queen had been pleased to grant him a pension of 200*l.* per annum. This recognition of his labours by his country was a subject of much gratification to Mr. Joule.

Mr. Joule received the Gold Royal Medal of the Royal Society in 1852, the Copley Gold Medal of the Royal Society in 1870, and the Albert Medal of the Society of Arts from the hands of the Prince of Wales in 1880.

J. T. BOTTOMLEY

COAL-TAR

A Treatise on the Distillation of Coal-Tar and Ammoniacal Liquor, and the Separation from them of Valuable Products. By George Lunge, Ph.D., F.C.S., Professor of Technical Chemistry in the Federal Polytechnic School, Zurich. (London: Van Voorst, 1882.)

A couple of centuries have just elapsed since the first English patent was granted to Becker and Serle for "a new way of makeing pitch and tarre out of pit coale, never before found out or used by any other"; and in 1742 a second patent was obtained by M. and T. Betton for the manufacture of "an oyle extracted from a flinty rock for the cure of rheumatick, and scorbutick, and other cases." Whether we have here a foreshadowing of the antiseptic method of treatment is impossible to say, but that there was virtue of another sort in coal-tar was fully recognised by the Earl of Dundonald, the father of brave Lord Cochrane, who, towards the close of the last century, set up tar ovens on a pretty extensive scale in Ayrshire.

What we know as the coal-tar manufacture is however practically an industry of the present generation: it is not even contemporaneous with that of the making of coal-gas, for during the earlier years of that manufacture the tar was counted as the most noxious of bye products to be got rid of by being burnt under the retorts or by being turned into the nearest stream. We have changed all that however, and to-day the tar is among those substances which, as Dr. Siemens pointed out the other day at Southampton, make the products of the destructive distillation of coal so much more valuable than the coa itself.

England is the great tar-producing country of the world; at the present time about half a million tons o tar are produced annually throughout Europe, of which we make about three-fifths. The distillation of coal-tar as a starting-point in the manufacture of colouring matters has indeed become one of our most important chemical industries. We however do not make these colouring matters although we are the principal users of them. Although Faraday first discovered benzene, and Mansfield gave his life in showing us how to isolate that substance on the large scale, and although Perkin led the way by the discovery of aniline purple, the first coal-tar colour; nevertheless the manufacture of the so-called coal-tar dyes has mainly centred itself in Germany. We send to the Germans the crude material, and they return to us the finished products. At the same time we also supply many of the chemicals necessary to transmute the baser substances into the costly dyes. In fact in this matter we are as mere hewers of wood and drawers of water; a circumstance which doubtless has not escaped the attention of the Royal Commissioners who are to report on the technical education of this country. We have not far to seek in tracing the cause of this: it is simply owing to the extraordinary development of chemical research in Germany arising largely from the attitude of the German universities towards scientific inquiry.

We have to thank Prof. Lunge for what is in reality the only monograph on this subject of tar distilling either in our own or in any continental language. Probably no one more fitted, both from practical experience and scien-