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SCIENTIFIC WORTHIES

XVII.—Robert Wilhelm Bunsen

THE value of a life devoted to original scientific work is measured by the new paths and new fields which such work opens out. In this respect the labours of Robert Wilhelm Bunsen stand second to those of no chemist of his time. Outwardly the existence of such a man, attached, as Bunsen has been from the first, exclusively to his science, seems to glide silently on without causes for excitement or stirring incident. His inward life however is on the contrary full of interests and of incidents of even a striking and exciting kind. The discovery of a fact which overthrows or remodels our ideas on a whole branch of science; the experimental proof of a general law hitherto unrecognised; the employment of a new and happy combination of known facts to effect an invention of general applicability and utility; these are the peaceful victories of the man of science which may well be thought to outweigh the high-sounding achievements of the more public professions.

Prof. Bunsen is eminently a soldier of science, his devotion to his flag has been unwavering and life-long, and his whole existence has been a noble struggle for the mastery of nature's secrets. Born on March 31, 1811, at Göttingen, where his father was Professor of Theology, Bunsen graduated in that ancient University before he had passed through his teens, and published an inaugural dissertation, "Enumeratio ac descriptio hygrometorum." Soon afterwards, at the age of twenty-two, he became a privat-docent at the university of his native town, thus entering the career of a teacher, which he has consistently followed with conspicuous success for close on half a century. In 1836 Bunsen became Professor of Chemistry at the Polytechnic School in Cassel; in 1838 he was appointed to the Chair of Chemistry in the University of Marburg, where he remained for thirteen years; afterwards he was for a short time at Breslau, whence he removed to Heidelberg, of which renowned University he has been one of the chief ornaments and attractions for the last thirty years.

Bunsen's first scientific investigation was one which attracted general attention, and the results of which are of permanent importance. In conjunction with Berthold, a colleague at Göttingen, he showed that moist freshly precipitated ferric hydroxide acts as a certain antidote in cases of poisoning by arsenic, provided that it is exhibited in sufficient quantity and early enough in the history of the case. The explanation of this action is the formation of an insoluble ferrous arsenite; 100 parts of the dry hydroxide carry down from five to six parts of arsenic. So well known and valued is this antidote in Germany, that it is kept by apothecaries ready for use.

In 1835 Bunsen described some singular compounds which the double cyanides form with ammonia. He contradicted the general statement that ammonium ferrocyanide is formed by boiling prussian blue with ammonia; but showed that it is formed by digesting lead ferrocyanide with ammonium carbonate. He also measured the angles of crystals of many of the double cyanides.

In 1837 he struck the first note of one of his most important and fruitful investigations in a memoir on the existence of arsenic as a constituent of organic bodies. In the year 1760 the French chemist Cadet had observed that a mixture of acetate of potash and white arsenic yields, when heated, a heavy brownish-red liquid, which has a frightful smell and fumes strongly in the air, and this liquid was termed Cadet's fuming arsenical liquid. Little more than the fact of its existence was ascertained concerning this body until Bunsen undertook its examination, and in a series of memoirs which have now become classical, and which extended over many years, placed its composition in a true light, thus giving to the world the first member of the now well-known family of the organo-metallic bodies.

Bunsen showed that Cadet's liquid, as well as its numerous derivatives, contains a radical having the formula C_2H_6As, and that this substance in its chemical relations exhibited striking analogies with a metal, being indeed, as he terms it, "a true organic metal." He succeeded in isolating this body, and this discovery formed not only the starting-point for the preparation of hundreds of other similar bodies, but also contributed largely to the development of one of the most important of our chemical theories, that of compound radicals. This body, like most of its compounds, possesses a most offensive odour, so much so that the air of a room containing a trace of the vapour is rendered absolutely unbearable. Hence to this substance Bunsen gave the name of Cacodyl (κακόδης, a bad smell). Not only however are these compounds unpleasant, but they are highly poisonous, very volatile, dangerously explosive, and spontaneously inflammable. It is difficult enough nowadays for a chemist to work with such substances armed as he is with a knowledge of the danger which he has to encounter, as also with improved appliances of every kind to assist him in overcoming his difficulties. But Bunsen forty years ago was a traveller in an unknown and treacherous land, without sign-posts to guide him, or more assistance on his journey than was furnished by his own scientific acumen and his unfaltering determination. Nor did he escape scot-free from such a labour, for in analysing the cyanide of cacodyl the combustion tube exploded, Bunsen lost the sight of an eye, and for weeks lay between life and death owing to the combined effects of the explosion and the poisonous nature of the vapour. "This substance," he writes, "is extraordinarily poisonous, and for this reason its preparation and purification can only be carried on in the open air; indeed, under these circumstances it is necessary for the operator to breathe through a long open tube so as to ensure the inspiration of air free from impregnation with any trace of the vapour of this very volatile compound. If only a few grains of this substance be allowed to evaporate in a room at the ordinary temperature, the effect upon any one inspiring the air is that of sudden giddiness and insensibility, amounting to complete unconsciousness."

Taking a totally different direction, Bunsen's next important investigations were concerned with the examination of the chemical changes which occur in the blastfurnace. In 1838 he proved, by accurate analyses of the gases escaping, "that at least 42 per cent. of the heat evolved from the fuel employed is lost, and that in view of the ease with which such combustible gases can be collected and led off to a distance for subsequent use, a new and important source of economy in the iron manufacture is rendered possible." This research is however not only noteworthy as pointing the way to a method of economical working without which probably but few ironmasters at the present day could exist, but also as being the first experiment in which an accurate method of gas-analysis was employed. This important branch of analytical chemistry has been created and brought to its present wonderful degree of precision solely by the head and hands of the Heidelberg experimental philosopher. Simplicity and accuracy constitute the rare merits of Bunsen's system of gaseous analysis. To have gone completely through his course of gas analytical manipulations from the sealing-in of the platinum wires in the eudiometer to the absorption- and explosion-analyses of the Heidelberg coal-gas, under the eye and with the guilding help of the hand of the master, is in itself an experimental education of no mean order. But it is only on reference to his "Gasometric Methods" that we learn the general adaptability of this marvellously accurate system to all those numerous problems in which the analysis of a mixture of gases is required.

Next in order (1841) comes the invention of the Bunsen battery, an invention which has proved of the greatest practical value to mankind, inasmuch as this form of battery is now very largely used all over the world, not only as a scientific instrument, but also for ordinary telegraphic purposes. The chief point in this invention consists in the employment of carbon as the negative pole in place of copper or platinum. In his first communication on this subject, Bunsen accurately measures the absolute intensity of the current from his zinc-carbon battery, and compares it with that of a Grove (zinc-platinum) battery, invented a short time before by Sir William Grove.

Bunsen's next great achievement consists in the investigation from both the chemical and the physical point of view of the volcanic phenomena of Iceland. The several memoirs on this subject are the result of a visit to Iceland in 1847. They consist, in the first place, of a careful and extended series of analyses giving the average composition of the volcanic rocks of different ages occurring in the island, upon which he founded a most important and very general theory of volcanic action, a theory which he has since proved is applicable to the formation of other volcanic rocks of widely different origin, both as regards time and locality. This theory consists, to begin with, in a proof that all the Islandic rocks, of whatever age, may be considered as mixtures in varying proportions of two normal silicates, the trachytic and pyroxenic. In the first of these (an acid silicate) the relation of the oxygen of the acid to that of the bases is as 3 : 0·596, whilst in the latter (a basic silicate) the relation is as 3 : 1·998. This result, accompanied by an experimental proof that the melting-point of different bodies is differently raised under increase of pressure, led Bunsen to assume that a crystallisation of these two normal silicates occurs in the earth's interior, and that all the eruptive rocks which reach the surface consist either of one or other of these or of mixtures of the same. In the next place they contain a full and successful research on the so-called pseudo-volcanic phenomena of Iceland, in which he investigates the formation of zeolites and other crystalline minerals by the joint action of heat, acid gases, and moisture on the volcanic rocks. He also examines the composition of the fumerolle gases as well as those issuing from the crater of Hecla, and explains the nature of the changes effected by these gases on the surrounding rocks. Lastly, he investigates the far-famed Great Geyser, and places the cause of the periodic eruption of boiling water on its true physical basis. His accurate observations on the spot, first as to the construction of the geyser-tube, then as to its mode of formation, and finally, his thermometric measurements of the temperature of the water-column taken a few moments before the eruption and at different depths, disposed once for all of what may be called the old tea-kettle theory, and showed indisputably that in no part of the tube did the water reach the temperature of ebullition under the pressure of the superincumbent column, whilst the column is quiescent, but that when the geyser column is elevated by the rush of steam from the volcanic vents at the bottom, the boiling-point of the water at each point of the column thus raised is reached, and "the whole mass from the middle downward suddenly bursts into ebullition, the water above mixed with steam-clouds is projected into the atmosphere, and we have the Geyser eruption in all its grandeur. By its contact with the air the water is cooled, falls back into the basin, partially refills the tube in which it gradually rises, and finally fills the basin as before. Detonations are heard at intervals, and risings of the water in the basin. These are so many futile attempts at an eruption, for not until the water in the tube comes sufficiently near its boiling-point to make the lifting of the column effective can we have a true eruption" (Tyndall).

To do justice to all the contributions with which Bunsen has enriched our science would fill several numbers of NATURE, and to many of them the writer must content himself with a mere cursory reference. One of his favourite and fruitful themes was the preparation by electrolysis of the rarer or more difficultly procurable metals. This is one of the purposes for which he employed his battery. Metallic magnesium was one of the first of his preparations of this kind, and in the description of this preparation his fertility of resource is clearly seen. Metallic magnesium in the molten state is specifically lighter than the fused mixture of salts from which it is obtained. Hence as soon as a globule of the metal is formed, it rises to the surface, and there takes fire and burns. To obviate this difficulty the carbon pole on which the metal was formed was serrated, and the metal on rising was caught, below the surface of the fused salt, in one of a series of small pockets, and thus prevented from burning.

Then followed the reduction of chromium, aluminium, and. in conjunction with the late Dr. Matthiessen, that of the alkaline-earth metals, and more recently with Hillebrand and Norton, of the metals of the cerium, group. These electrolytic researches are marked with the thoroughness and completeness which is characteristic of all Bunsen's work. He seeks for the explanation of the fact that hitherto the reduction of these metals by the electric current had proved a failure, and he finds it in what he terms the density of the current, *i.e.* the electromotive force divided by the area of the pole, the power of the current to overcome chemical affinity increasing with its density. Thus if a constant current be led through an aqueous solution of chromic chloride, the result as to whether hydrogen is evolved, and oxide of chromium, or whether metallic chromium is deposited, depends upon the area of the pole through which the current passes into the liquid.

Nor were these experiments made merely for the purpose of preparing the metals in question. Thus the metallic magnesium was pressed into wire and used in one of the series of photo-chemical researches, to which reference will hereafter be made, for the purpose of drawing an interesting conclusion respecting its light-giving power on combustion, and comparing this with the visual and chemical brightness of the sun, a comparison which led to the commercial manufacture of this metal by the Magnesium Metal Company, and to the wide distribution and general use of this metal as an illuminating agent of great brilliancy. Thus again the electrolytic preparation in the Heidelberg laboratory of coherent masses of cerium, lanthanum, and didymium, had the further object of the determination of the specific heat of these metals by help of the now well-known method with Bunsen's ice-calorimeter, by means of which determination the true atomic weights of these metals and the proper formulæ of their oxides and compounds have been definitely ascertained.

The Bunsen battery has however not only been of service in inorganic chemistry, but has thrown clear light upon the constitution of organic bodies. The classical researches of Kolbe on the electrolysis of acetic acid and the other fatty acids were carried out in the Marburg laboratory, and owe their inspiration to Bunsen. The subsequent equally important labours of Kolbe and Frankland, and those of the latter chemist alone, on the isolation of the organic radicals, have a like origin.

Amongst the numerous physico-chemical investigations which Bunsen has carried out, none perhaps show more clearly the fertility of his experimental ability than the one in which he describes the ice calorimeter, and another devoted to an explanation of a new method of determining vapour densities. Translations of these memoirs are found in the *Philosophical Magazine* for 1867 and 1871, and may be taken as typical of his calorimetric researches.

Another group of researches is formed by those which are closely related to his gasometric methods. One of the most interesting and important of these refers to the law of absorption of gases in water. This subject was first examined by Dalton and Henry at the beginning of the century, and the well-known law which gases follow in absorption is known by the names of these two Manchester philosophers. But although generally admitted, its limits of error had not been ascertained, and the crude experimental methods of the year 1803 required to be replaced by the refined ones of the latter half of the century. These researches, carried on by Bunsen and by several of his pupils, proved that Henry's law of direct—as well as that of Dalton of partial—pressures is exactly true within certain limits; but ceases to be so beyond a given increase of pressure, whilst some gases which obey the law at one temperature do not do so at others, and some again whilst obeying it in the pure state, do not do so when mixed with other gases.

The mere mention of his other researches in the wide field of gaseous chemistry is sufficient to indicate his devotion to this branch of experimental inquiry. We find experiments on laws of gaseous diffusion, on applications of gaseous diffusion in gasometric analysis, on the phenomena of the combustion of gases, on the temperature of ignition of gases, and all these, be it remembered, involving exact measurement, and in many cases elaborate calculations.

Brief reference must next be made to a series of investigations in a totally different direction, viz. on the measurement of the chemical action of light, with the carrying out of which the writer of this article had the great good fortune and pleasure to be connected, and in which he had full opportunity of admiring Bunsen's untiring energy and wonderful manipulative power. In all the difficulties and perplexities by which the experimental investigation of such a subject is beset, the writer never knew Bunsen discouraged or at a loss for an expedient by which an obstacle could be overcome. Cheerful and self-reliant under the most depressing circumstances, he never gave up hope, and thus it was that these somewhat intricate and difficult investigations were brought to a successful close.

Again, in the department of Analytical Chemistry how numerous and valuable have been his contributions! There is scarcely one important problem in this subject which has not benefited from his extensive experience and keen insight. Bunsen's methods of silicate analysis, of mineral water analysis, and a dozen of other complicated laboratory processes, are simply perfect. Then his original method for the estimation of nitrogen in organic bodies will always be remembered as one of the most accurate of its kind when employed by an experimentalist as expert as Bunsen himself, but as most difficult and even dangerous in less able hands. Again, all chemists use and appreciate the much simpler methods for the estimation of nitrogen and sulphur admirably worked out by his pupils—Maxwell Simpson and Russell.

We all employ his beautiful general method of volumetric analysis, but chemists do not always remember that in this research Bunsen first determined the exact percentage composition of the higher oxide of cerium, a determination of the greatest scientific importance as regards the chemistry of the metals of the rare earths. Moreover they may be apt to forget that Bunsen was the first to introduce a general method of the separation of these rare earths, by which he for the first time prepared pure yttria and erbia, and by which subsequently, in the hands of other chemists, many new metals have been discovered. His well-known method of flame-reactions is a standard example worked out by every student. Again, modern chemists can now scarcely carry on the simplest experiment without using the "Bunsen gas-lamp," a burner which is also now employed in every household, and in many manufactories, and has become so necessary that it is difficult to conceive how we worked before its invention. To him we are also indebted for the apparatus for accelerating filtration, the "Bunsen-pump," together with all its appliances, now employed in every laboratory.

Of all the contributions to the advancement of our science, that by which the name of Bunsen has, however, become best known, and by virtue of which future generations will place him on the highest pinnacle of experimental fame, is the foundation, with his no less celebrated colleague Kirchhoff, of the science of Spectrum Analysis, and the discovery by its means of the two new alkali metals, cæsium and rubidium. It is true, of course, that many facts were ascertained and many observations made relating to the power possessed by matter in the state of incandescent gas emitting rays of a peculiar and characteristic kind. Few great discoveries are made at one step. But the glory of having established a new branch of science, of having placed "Analysis by Spectrum Observations" on a sound and firm experimental basis, belongs to the Heidelberg philosophers, and to them alone.

The history of the establishment of spectrum analysis, as that of its enormous recent developments, is too well known to the readers of NATURE to require repetition. All that is necessary here is to recall the masterly way in which Bunsen worked out the properties and showed the relationships of the new metals and their compounds. He first saw the cæsium lines in a few milligrams of the alkaline residue obtained in an analysis of the Dürkheim mineral waters, and the discovery of a second new metal (rubidium) soon followed that of the first. So certain was he of the truth of his spectroscopic test that he at once set to work to evaporate forty tons (44,000 kilos) of the water, and with 16·5 grammes of the mixed chlorides of the two new metals which he thus obtained, he separated the one metal from the other (no easy task) and worked out completely their chemical relationship and analogies, so much so that the labours of subsequent experimenters have done little more than confirm and extend his observations; such a result is truly a marvel of manipulative skill!

Another less widely known, but no less interesting and important research, is that on the spark-spectra of the metals contained in cerite and other rare minerals. In this he shows his power both as physicist and chemist. He first describes a new chromic-acid battery suited to the performance of the special experiments which he afterwards details. He determines with great care all the physical constants of this battery, and then proceeds to investigate the spectra of the earths which give no colour to the non-luminous flame. The spark-spectra of these earths he carefully maps, so completely, indeed, that the separation and identification of these metals now for the first time became possible.

The many hundreds of pupils who during the last half-century have been benefited by personal contact with Bunsen will all agree that as a teacher he is without an equal. Those who enjoy his private friendship regard him with still warmer feelings of affectionate reverence. All feel that to have known Bunsen is to have known one of the truest and noblest-hearted of men.

H. E. ROSCOE

JAPAN

Japan, nach Reisen und Studien in Auftrage der k. Preuss. Regierung dargestellt. Von J. J. Rein, Professor der Geographie in Marburg. Erster Band. Natur und Volk des Mikadoreiches. (Leipzig: Engelmann, 1881.)

Notes and Sketches from the Wild Coasts of Nipon. By Capt. H. C. St. John, R.N. (Edinburgh: Douglas, 1880.)

THE present year has already brought two new contributions to the rapidly increasing stock of Japanese literature in "Japan, nach Reisen und Studien," by Prof. Rein of Marburg, and "The Wild Coasts of Nipon," by Capt. St. John. The two works thus thrown into association by subject and time of publication have however nothing else in common.

Had Capt. St. John's book been written a few generations ago, or had it related to a country previously unexplored, it would have possessed a greater claim upon popular interest; but Japan has in late years been so far the object of careful study by residents, and of descriptions by tourists, that the *raison d'être* of "The Wild Coasts of Nipon" is not easy to perceive.

In the preface the reader is assured that everything stated in the text, with a few exceptions, came under the observation of the author, and there is no doubt that he has scrupulously confined himself to his own personal experience, without seeking to correct or augment it by reference to other sources. The advantage of such a limitation of matter must however depend altogether upon the extent of the experience and the special qualifications of the observer, and we are of opinion that had the author taken the trouble to ascertain what his predecessors have already made known, he would have largely altered his notes.

The author as a sportsman and naturalist displays himself in a more favourable light than as a logician and observer. His sporting memoranda are amusing, and give a character to the volume, while as an amateur naturalist he shows more than average knowledge, and contributes some interesting facts on the subject of the animal kingdom. In the flora he is on less secure ground, and on one occasion, at page 137, confuses, in name at least, two such well known trees as the Hinoki (*Retinospora obtusa*) and the *Cryptomeria Japonica*.

In his remarks upon the people he bears good witness to the simplicity and kindness of the peasantry, of whom he must have seen a good deal. Unfortunately, for a traveller unlearned in the language, and chiefly dependent for his entertainment upon ordinary tea-houses, he has rather rashly ventured into generalisations requiring information that very few foreigners possess. At page 182 the Japanese men, as a race, are said to be "well made, muscular, active, and strong, and averaging about five feet five inches[1] in height," a description applying fairly well to the northern fishermen, but certainly flattering to the nation in general. Again, in several places the author follows a common fashion in deploring the evils brought upon the people by European "civilisation," but makes no allusion to the greater evils it is now

[1] Dr Rein's estimate of the average height of the men is 150 centimetres. This is nearly as much below the mark as Capt. St. John's calculation is above it.