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THE FARADAY BENZENE CENTENARY[1]

AN indescribable feeling of deepest reverence thrills those who know that they are within a holy of holies when standing at this table whence Davy and Faraday and Dewar disclosed their. discoveries to the world.

Consider the immensity of outlook it commands. A few days ago, the glories of Tut-ankh-Amen's most wonderful tomb were depicted, in minute detail, upon the screen behind me. We could realize that man stood higher, in the decorative arts, several thousand years ago, than he does to-day—that man was then deeply reverent in his beliefs. In stark contrast is the change in our civilization—we call it advance—made within the past century, through the application of the discoveries discoursed of within these walls: in large measure fired by the tiny spark first shown to the world, at this table in 1831. What reverence have we for such a discovery? Our men of letters pay no heed to it. The public at large has no knowledge thereof.

Chemists desire to show, by this commemoration, that they are persons mindful of the words of the ancient poet and preacher:

Let us now praise famous men
And our fathers that begat us.
The Lord hath wrought great glory by them
Through His great power from the beginning.
Such as did bear in their kingdoms,
Men renowned for their power,
Giving counsel by their understanding
And declaring prophecies:
Leaders of the people by their counsels
And by their knowledge of learning meet for the people,
Wise and eloquent in their instructions.

"Of them that have left a name behind them," Faraday is one of the greatest, certainly the greatest experimental philosopher the world has yet known. A Sandemanian, deeply religious, from his childhood upwards, throughout life, he advisedly kept his "science" apart from his religion but his moral faith was ever the background of his scientific productivity. His work was all conceived and executed in a deeply religious spirit. It will only be by following his example that wisdom will be made the religion of the

[1] Address delivered at the Royal Institution on June 16, at the celebration of the centenary of the discovery of benzene, by Faraday, and printed in *Nature*.

people. He painted himself, his attitude during the whole of his career, in a lecture he gave in 1816, when only twenty-five years old, in saying—

> The philosopher should be a man willing to listen to every suggestion but determined to judge for himself. He should not be biassed by appearances; have no favorite hypothesis; be of no school and in doctrine have no master. He should not be a respecter of persons but of things. Truth should be his primary object. If to these qualities be added industry, he may indeed hope to walk within the veil of the temple of nature.

Speaking at this table, in May, 1854, addressing His Royal Highness, the Prince Consort, who occupied the chair, Faraday said: "I take courage, Sir, from your presence here this day, to speak boldly that which is on my mind." The lecture was on "Mental Education." In it he dealt with the need of self-education, through attention to "natural things," with the object of improving the faculty of judgment and making it proportionate.

"I will simply express my strong belief," he said, "that that point of self-education which consists in teaching the mind to resist its desires and inclinations, until they are proved to be right, is the most important of all, not only in things of natural philosophy but in every department of daily life."

The lecture was a profession of the attitude of mind in which he had accomplished his work.

Taking courage to speak boldly, in the presence of your Grace, I would say that even the world of science, to-day, is in great need of following counsel such as Faraday gave in his incomparable lecture. We are too prone to speculate—often too inconsiderate in speculation—too little alive to our own individual ignorance—too little bent upon cultivating that breadth of vision and proportionate judgment which is at the root of scientific method. Overcome by the ecstasy of practical achievement, we are too little mindful of the public interest: we are doing too little to make scientific method a public possession. Faraday's dream is in no way fulfilled: the spirit of science in no way enters into our commerce, into our industry, into our public life.

Our best way to praise famous men is to take to heart the lessons of their lives. Consider what Faraday did, at this table, to accomplish the exhortation—"Suffer little children to come unto me." He introduced the Children's Christmas courses and in all his lectures endeavored to come down to the level of his hearers. How different this from our modern practice—our entirely selfish use of jargon.

We seek to-day to direct attention to Faraday's special greatness as a chemist. He is generally thought of in connection with electrical discovery, but it is significant that he began his career as a chemist: that he grew up in the severity of a proper chemical discipline: just at the time, however, when electricity was coming into vogue. Inspired by his great master, Humphry Davy, fascinated by the wonderful use Davy had made of the electric current in liberating the alkali metals and in discovering the nature of so common a substance as lime, gifted with marvellous power of insight and unhampered by the mass of detail which encumbers our modern thought, he could not do otherwise than recognize the reciprocal inseparable nature of chemical and electrical phenomena. He ultimately proclaimed the essential unity of chemical and electrical change—not yet generally recognized by chemists, though in these days even matter is regarded as of electrical origin. We have yet to acknowledge Faraday's prescience and the consequences of this, his prime discovery.

The range of his chemical activity is astounding, the more when we consider his slender equipment and the fact that he did almost everything himself. As one of the earliest workers in organic chemistry, he stands pre-eminent. He not only discovered the hydrocarbon benzene but also three of the five chlorides of carbon; moreover he was the first to study the sulphonic acids, a class of compound now of the first technical importance. His achievement in making these acids was akin, in principle, to that by which Montgolfier's balloon was changed into the airship of to-day, by the introduction, into the car, of the internal combustion engine with its propeller. Naphthalene is an unwieldy hydrocarbon which floats upon water but can not swim in it, being insoluble—Faraday, by introducing the elements of sulphuric acid, made it soluble and mobile. The discovery has been of infinite service in the dyestuff industry. Faraday was one of the first to examine caoutchouc. His name is associated, for all time, with the liquefaction of the gases. He also studied alloys of iron, optical glass and gold in the finely divided state—each an inquiry of major consequence. Many minor issues were examined, always with perspicacity.

The discovery upon which we base this commemoration, that of benzene, will always rank as one of the most fundamental discoveries of chemistry. If not the entire hub of the organic section of our chemical universe, benzene is at least a major part thereof. Our edifice, in fact, has two foundation stones: one, the simple carbon atom, which can be extended endlessly, as links are, in a chain; the other, a closed complex unit or block of six carbon atoms, ranged as in the diamond and associated symmetrically with six atoms of hydrogen. This latter we call benzene. It is, in fact, just a bit of diamond, mounted and preserved in hydrogen, as though this were *aspic*. The beauty of the diamond, however, is as nothing compared with that of benzene in the eyes of its many mistresses.

Faraday separated benzene from the products of the decomposition of oil by heat. He seems to have taken an interest in these products so early as 1818 but did not come into possession of the material for their study until April 26, 1825. Beginning the investigation on this date, he soon isolated benzene and may be said to have discovered it on May 24, the day on which he first determined its composition, by an operation itself a wonderful experimental "tour de force"; the memoir in which he submitted his discovery to the Royal Society is dated June 16. Having studied a material such as he used and knowing its complexity, I marvel at the rapidity with which he carried out the inquiry and the accuracy of his deductions. It is a work of astounding genius.

In those days, formulae were scarce known. Dalton had but recently put forward his atomic theory. Faraday, however, was already alive to their use and called his product bicarburetted hydrogen, C_2H, the value then assigned to carbon being half the present value. He gives the data for the molecular formula, C_6H_6, though molecular formulae were unthought of then. About ten years later, the hydrocarbon was prepared from benzoic acid, by Mitscherlich, who altered the name to *benzin,* which Liebig changed to *benzol.* Later (1834), the systematist Laurent introduced the use of the terminal *ene* (ène); alternatively, he proposed the name *phéne* (from φαίνω, to shine), whence phenyl.

The classic academic event in the history of benzene was the introduction by Kekulé, in 1860, of the conception of a closed system of carbon atoms typified by the world-renowned hexagonal formula. He has told us how the idea first came to him when going home to his lodgings on the top of a London bus. Since then, benzene and its derivatives have been the subject matter of a vast volume of inquiry by all the nations: German chemists, however, were long the leaders.

Attention was first specially directed to the presence of benzene in coal tar in 1845. The process of extracting it was devised, in 1849, by Mansfield, working in Hofmann's laboratory in Oxford Street, London. To-day, the gases formed on heating coal to redness, either in manufacturing town's gas or metallurgical coke, are most carefully stripped of benzene and allied hydrocarbons. Our output of "crude benzol" is estimated at 22,000,000 gallons, which is mostly used as motor fuel. Certain petroleums contain considerable quantities of benzene hydrocarbons.

Benzene only acquired technical importance from 1856 onwards, when our countryman, William Henry Perkin, entered upon his great adventure, at the age of nineteen. He not only discovered the first aniline color, mauve: he also founded the artificial dyestuff industry. To-day, the natural coloring matters are all but displaced by dyestuffs, often superior, derived more or less directly from benzene.

Nothing that has happened since Faraday made his discovery would have given the philosopher greater pleasure than the advance in our knowledge of the origin of color—a subject which once filled his mind. Turning to his remarkable correspondence with the Swiss chemist, Schönbein, whose name comes next to those of Priestley and Lavoisier in the history of oxygen, we find Schönbein, in a letter dated Oct. 17, 1852, writing to him as follows:

> Entertaining the notion that in many, if not in all cases, the color exhibited by oxycompounds is due to the oxygen contained in them or, to express myself more distinctly, to a peculiar chemical condition of that body, I have continued my researches on the subject and obtained a number of results which I do not hesitate to call highly curious and striking. . . . I am nearly sure that you will be pleased to repeat the experiments, for either by mere physical means or by chemical ones you may make and unmake or change the color of a certain substance without altering the chemical constitution of those matters. To my opinion, that wonder is performed by changing the chemical condition of the oxygen of the oxycompound.

To this Faraday replied on December 8:

> Your letter quite excites me and I trust you will establish undeniably your point. It would be a great thing to trace the state of combined oxygen by the color of its compound, not only because it would show that the oxygen had a special state, which could in the compound produce a special result—but also because it would, as you say, make the optical effect come within the category of scientific appliances and serve the purpose of a philosophic induction and means of research, whereas it is now simply a thing to be looked at. Believing that there is nothing superfluous or deficient or accidental or indifferent in nature, I agree with you in believing that color is essentially connected with the physical condition and nature of the body possessing it and you will be doing a very great service to philosophy if you give us a hint, however small it may seem at first, in the development or, as I may even say, in the perception of this connection.

Before you are two specimens, one of quinol, the other of quinone, one colorless, the other colored—yellow. Quinone is the type of all organic coloring matters. In quinol, the simple molecule of water, H·O·H, less an atom of hydrogen, is introduced twice into benzene, in place of two of its atoms of hydrogen: it is colorless. Remove from it two atoms of hydrogen, one from each of the two OH groups: the product, quinone, is yellow in color. It is as Faraday supposed—the condition of the oxygen is altered and certain centers in the molecule become active absorbents of the light waves.

I have ventured to hang upon the inward wall of this great fortress of science, which Faraday occupied to such wonderful purpose, "a banner sable, trimmed with rich expense," bearing a strange device emblematic of benzene. Faraday's initial is enclosed within the hexagon which symbolizes his discovery. This symbol is one that we may aver will last for all time, as upon it may be welded all the facts relating to benzene. It is probably the most significant symbol ever devised, for it has veritable volumes of meaning in the chemist's seeing eye. From it the colors irradiate—though not precisely in prismatic order. Color, at its first appearance, is either yellow or blue, according to the type of compound, yellow being always associated with simplicity of type. As molecular complexity is raised, yellow is gradually intensified and passes into the richest red. Blue, in like manner, becomes intensified and may pass into green, which is the forerunner of black. The changes are due either to changes in the weighting of the absorbing centers or to their cumulative repetition and cooperative action.

Behind me is a curtain of wondrous texture and color, dyed with *Jade green,* one of the latest and most valuable, certainly the most remarkable of the anthracene vat-colors: it was first made in Scotland. Mark its symbol—it is benzene soldered upon benzene, many times over: a *Nonaphene.* The two lone, unsociable, oxygen atoms are the main cause of its color. Note the wonderful change in color when these oxygen atoms are wedded each to an atom of hydrogen—now the *Jade green* becomes a salmon-red, with a most remarkable fluorescent sheen, indicating a simplification of the light-absorbing mechanism. The big hank of viscose silk across the green curtain is dyed with the material in which the green has been thus welded to hydrogen: if oxygen be allowed to take away the hydrogen, the dyestuff again becomes green, may we not say, with envy. Note also this intensely blue hank. In *Jade green* the oxygen atoms are related as are my thumbs when I so juxtapose my fingers that the backs of my two hands are in the same plane. Turning one hand round, my thumbs become related diagonally. Making a like change in the molecule of *Jade green,* converting the dibenzanthrone into isodibenzanthrone, the color passes into blue: wed the oxygen with hydrogen, it passes into red of a blue shade. We can picture what would have been Faraday's and Schönbein's ecstasy of delight at seeing their prophecy verified in such chameleon-like behavior.

I have referred to viscose silk. What would Faraday have said, if told that we had not only found "tongues in trees" and gone far to discover "good in everything" but also that, spider-like, we had made the mere timber of trees into a veritable silken web, carrying colors of every hue made from his benzene, a material found worthy of notice even by a chancellor of the exchequer and actually worn not by queens alone but also by most of their female subjects? Could we tell him these things, might he not well ask what is left for poor nature to do: at the same time, he would be the first to recognize that we had studied "natural things" to some purpose and had he foreseen the power chemists were to wield over nature, he would perhaps have elected to remain a chemist and have thought little of electricity—as do chemists to-day.

We may go further still in tracing the scientific progress of benzene. It is written that "the last shall be first." Benzene, however, retains its dominance and is everlasting. The discovery of the first Fullerian professor, benzene and its descendants are now the objects of most serious attention by the latest holder of the chair. Racked upon his goniometer, tortured by X-rays, they are being forced to disclose the secrets of their inmost atomic centers: their molecular dimensions are being determined in ultra-microscopic terms. Faraday would not have been surprised: he would have been the first to welcome such achievements but with reverence, as well as delight at our progress.

By some uncanny mental process, the chemist has prophesied what X-rays are justifying; and now a new era is upon us, one for which we must prepare ourselves. Like Faraday, we must have many-compartmented minds. We must learn to think in the solid. The chemistry of the future will be spatial in dimensions and distribution. It will be in no slight degree a science of solid geometry. I have here a model of benzene in terms of units such as X-rays reveal to us in the diamond. Mr. William Barlow and I desire to lay this to-day upon Faraday's table as a solid tribute to his memory: it is something more than a mere symbol: we believe it to be a very close approach to the geometrical structure of the molecule. It is something I have hoped for during the whole of my life. There are other models here, made by Mr. Barlow, of various derivatives of benzene, all in close accordance with crystallographic data.

To return to color, the color-chemist to-day is a super-magician. If women could be scientific, they would insist upon being stamped all over, not with a king's cartouche, such as we have seen was used on Tut-ankh-Amen's tomb; no, with the hexagon symbol of benzene, as the emblem of the colors in which they are now arrayed far more gloriously than were ever the lilies which Solomon, we are told, could not rival. To-day, we can paint the lily with its own color. We make the colors of the lily, indeed those of most flowers, in the laboratory, actually from benzene. Faraday, in Sandemanian moments, would almost have regarded this as sacrilege.

To-day is no common occasion and we desire to deal with it in no common way. This commemoration is held at the instance of a remarkable and unusual conjunction: by the Royal Institution, acting together with the Chemical Society, the Society of Chemical Industry and the Association of British Chemical Manufacturers—a trinity completely representative of English chemical interests. Chemists desire to show that for once they can think together. We together acclaim the memory of Faraday—of Faraday the complete philosophic chemist. Moreover, our committee has decided to take in hand the preparation of a medal, to be awarded at intervals, perhaps sexennially, without regard to nationality, for an outstanding achievement in some clear relation with Faraday's discovery of benzene. We desire not only to keep his influence alive but also to extend it. We propose to follow a well-known practice of the clergy and make the first award, in anticipation, to-day. We ask Mr. James Morton, of Carlisle and Grangemouth, to accept promise of the first Faraday Benzene Centenary Medal, in special recognition of the signal service he has rendered to chemical science and industry in Great Britain, during the past ten years, by developing and extending the manufacture of the anthracene vat-dyestuffs and, more recently, by extending their application to silk and wool.

HENRY E. ARMSTRONG

EVOLUTION AND EDUCATION IN THE TENNESSEE TRIAL

PROFESSOR OSBORN has taken a very active part in the scientific side of the Tennessee trial, following conferences between himself and Dr. George W. Rappleyea and Mr. John T. Scopes, in which he was assured of the thoroughly sincere motives that prompted these young Tennesseans to bring on this great trial. It is interesting to note that Mr. Scopes studied evolution under Arthur M. Miller, professor of geology in the University of Kentucky, who took his degree of doctor of philosophy under Professor Osborn.

Great interest in this trial has been manifested in the British press, and Major Leonard Darwin, son of Charles Darwin, cabled to Professor Osborn asking if he could be of any help, prepaying a cabled reply. In response to Professor Osborn's advice, Major Darwin sent to Mr. Scopes the following letter:

> I have been requested by my council to express their great sympathy for you in your courageous efforts to maintain the right to teach well established scientific theories. To state that which is true can not be irreligious, and it is only those who have studied the question insufficiently who deny the broad fact of organic evolution; though how it came about is still a matter of dispute and is likely to remain so for some time. In this country ministers of almost all denominations are allowed openly to proclaim their belief that man has been evolved from some lowly organisms by an unbroken series of modifications; a series somewhat similar to that by which each individual has certainly been developed from a baby and ultimately from a minute living germ. Those who declare that the one process—that of racial evolution—is more contrary to spiritual ideals than is the other process—that of development from an infant, are placing unnecessary stumbling blocks in the paths of all those of their hearers who are not wholly irreligious.
>
> In conclusion, may the son of Charles Darwin send you in his own name one word of warm encouragement.
>
> Yours very faithfully,
> (Signed) Leonard Darwin, President,
> Eugenics Education Society.

Mr. Bainbridge Colby requested a series of statements from the scientific advisers in the case, Messrs. Osborn, Conklin, Pupin, Metcalf, Rice, Miller and Lane, as to the relation which evolution bears as part of educational discipline, not only in zoology and anthropology, but in every branch of science. The scientific advisers complied with written statements in the form of sworn affidavits which Mr. Colby might use if he desires as testimony in the trial. The statements of Professors Metcalf and Rice were not in duplicate and can not be reproduced here, but those before us are as follows:

By Arthur M. Miller, professor of geology, University of Kentucky.

> The affiant, Arthur M. Miller, states that for thirty-three (33) years last past he has been and now is the head of the Department of Geology at the University of Kentucky, and for a portion of said time he was also the head of the Department of Zoology of the said University; and that from his experience as a student and teacher of geology and biology, he affirms that it would be impossible to properly present these subjects to students without implicitly or explicitly accepting the doctrine of evolution as true—as much as the Copernican