

INTRODUCTORY LECTURE.

STUDY OF CHEMISTRY

AND THE

PHYSICAL SCIENCES,

IN RELATION TO EDUCATION.

Delivered at Elphinstone College, June 20th, 1862.

BY

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# INTRODUCTORY LECTURE,

ETC.

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WE are met here to-day to commence a Course of Study of one of the Physical Sciences; and, as to some of you it is a new subject, I propose to explain to you the nature, scope, and objects of Chemistry, and its relations to other departments of science: and in doing this, I shall endeavour also to exhibit the particular sphere which the study of the Physical Sciences should occupy in a System of General Education.

The Science of Chemistry has been gradually built up upon the Alchemy of the Middle Ages, which was very much what the "Kimiya" of eastern countries still is. Many of the alchemists, as Roger Bacon, Basil Valentine, and Van Helmont were true men, earnestly bent upon the discovery of the secrets of Nature; but misguided in their search for the "Philosopher's Stone" and the "Elixir of Life" by false hypotheses and illusory objects. Still we are greatly their debtors; for they *did interrogate nature*, by their innumerable trials and experiments: and although their questioning was blindly and illogically put, yet it resulted in the accumulation of a vast treasure of facts regarding the essential properties of substances; especially of the more common and important metals, as Gold, Silver, Mercury, Antimony, Lead, Tin, and Iron.

But when the spirit of the Baconian philosophy became diffused, and when the Inductive Method of research had reduced the random experiments and isolated facts of the alchemists to systematic procedure and orderly arrangement, then in the hands of Lavoisier and Priestly, Cavendish and Scheele, of Davy and Wollaston, Berzelius and Dalton, did Chemistry take its true rank and position amongst the Physical Sciences; and exhibit that vast array of facts, and expound that high order of natural laws, which characterize it at the present day. Of these facts that which lies at the foundation of the whole science is this, "*that all matter is not of the same kind.*"

Chemists have disclosed the essential distinctions that exist between all material objects, and have explained to a great extent the causes of their different properties. Let us take examples of this in two familiar objects—Chalk and Coal, and see how completely Chemistry determines their inmost and essential differences from each other. True it is that in their very aspect they are “as different as black from white,” and that in texture and density they differ widely from each other. Geology, moreover, proves the one (Chalk) to be a deep sea deposit of 800 or 1,000 feet in thickness, composed of the exuviae of innumerable animal forms; whilst it shows the other (Coal) to be an estuary formation, deposited in thin seams, and formed of the ruins of primeval forests. But Chemistry is able to penetrate deeper into their essential nature, and by the powers of analysis, is able, as by a subtle dissection, to unravel their most intimate structure. By chemical experiment, that is, by bringing them into new relations with other bodies, and submitting them to altered external conditions, they are resolved into their ultimate elements; so that whilst Chalk is shown to be a compound of Carbon, Oxygen, and the metal Calcium, Coal is proved to be composed of large quantities of Carbon and Hydrogen, with a little Nitrogen and Oxygen. Thus, then, you see that Chemistry is essentially an experimental science; whilst Botany, Zoology, and the other Natural History Sciences are sciences of observation. Thus by *observation* of the structure of the seed, the leaf, and the stem, we assign to a plant its place as an Exogen or an Eudogen. Not that careful observation can be dispensed with in chemical pursuits, for by the conjoint employment of *experiment and observation*, chemists have determined that the globe and the objects upon it consist of many kinds of matter, differing from each other in their sensible qualities. And in the present state of our knowledge we are acquainted with about 65 such kinds of matter. We term them *Simple Substances*, because hitherto we have failed in extracting any other substance from them; and *Elements*, because they are the elementary principles of which material substances are composed. Here is a table of the elements. The metals are all Elements, and there are thirteen non-metallic elements.

Out of these 65 elements all the vast diversity of nature and all the infinite variety of natural objects are produced. *All the multiplicity of form in unity of design* which characterizes the Material World. And this diversity results from the wondrous powers of combination possessed by these elements, productive of *Chemical Compounds*. So that we have to deal with two distinct classes of substances—*Elements and Compounds*. We may, for the sake of illustration, compare compounds to words, and elements to the letters of which those words are composed. Most natural objects, as water, the rocks and minerals of the earth, plants and animals, are all compounds. Thus, water, composed of Oxygen and Hydrogen, may be compared to a word of two letters (H O)—chalk, composed of Calcium, Carbon, and Oxygen, to a word of three letters (Ca. C O).

Now at the present day, "Chemistry is the exposition of the differences which subsist between these elements, and it is also a record of all the properties and material relations of each of these elements, and of all their compounds, and of the forces by which the elements are built up into compounds, and by which the compounds may be resolved again into their constituent elements."

But this wide sphere of science has attained this amplitude only in very recent times.

It is but little more than half a century ago when the composition of the air we breathe, the water we drink, and the food we eat, was altogether unknown. Chemistry having thrown no light on these things, Physiology could tell us nothing of the processes of Digestion, Nutrition, Respiration, and Secretion. But now we can trace the elements of animal and vegetable structures through the marvellous cycle of their wondrous transformations.

But it would demand greater knowledge of the subject than many of you can be expected to possess, to enable you to follow me in any sketch I might attempt to give you of the achievements of Modern Chemistry, of the substantial wealth it has produced, of the material wants it has supplied, of the varied and powerful remedies it has placed at our disposal,—how it has relieved pain,—how it has gratified our æsthetic tastes in the arts

of metallurgy, of glass and porcelain manufacture, and of Photography,—how it has almost surpassed nature in the production of the most delicate perfumes, and the most brilliant colours,—how it has brought the ends of the earth, as it were, together by the Electric Telegraph; and lastly, above all, how it has enabled men who aspire to be the “ministers and interpreters of nature,” to catch some glimpses of those laws by which the Creator has constituted and does sustain the fabric of the World, and all that it contains. I say *glimpses* because, as Sir John Herschell says,—“To embody and realize to our conceptions the UNITY OF NATURE,—to soar so high as to perceive its completeness and enjoy the fulness of its harmony, is given neither to man nor to angel. The feebleness and limitation of our faculties repress such longings as presumptuous, and forbid such flights as impracticable. Yet to spring a little way aloft,—to carol for a while in bright and sunny regions,—to open out around us, at all events, views commensurate with our extent of vision,—to rise to the level of our strength, and if we must sink again, to sink, not exhausted but exercised,—not dulled in spirit but cheered in heart,—such may be the contented and happy lot of him who can repose with equal confidence on the bosom of earth, though for a time obscured by mists, or rise above them into empyrean day.”

Now, before proceeding further, I wish to impress very forcibly upon you the conviction that a science, which embraces such objects, and is productive of such results as these, must, if rightly studied, become in your experience something more than a mere means of instruction and information, or an avenue for your minds to ramble carelessly along the pleasant paths of knowledge. On the contrary, if my teaching and your study of this science are conducted aright, it will become subservient to the highest purposes of your education,—viewing that education in its only true light,—as the discipline by which your senses are to be trained, and the several faculties of your minds educated, cultivated, combined, and strengthened in order to fit you for the highest pursuits and purposes of life.

The far too prevalent idea of education is, that its sole object is to impart a certain amount of definite technical information:

• to store the memory with facts, whether of History or Science : to supply the mind with generally received, and, what at the time are considered, rational explanations of those facts : to teach the use of numbers and proportions : to supply the tongue with Languages.

It is doubtless a great privilege to be able by acquired knowledge to penetrate the mists of ignorance and superstition : to gaze with the eye of intelligence upon the heavens : to explain the phenomena of an eclipse, or to predict the return of a comet, to contemplate the beautiful and harmonious economy of our own globe : to give a rational account of the tides, the great oceanic currents, the trade winds, storms, and cyclones.

• Or to be familiar with the distribution of living beings over the earth's surface, and the means whereby the "Balance of Organic Nature" is maintained. To be conversant with the history of the races and nations of mankind, and the deeds and the works of antiquity. To be able to read the Eastern and Western Classics, and imbibe their spirit : or to decipher the Egyptian hieroglyphics and the cuneiform inscriptions on the cylinders of Nimrod. Or, conducted back to an antiquity in comparison with which the sculptures of Nineveh are but as of yesterday, and guided by the discoveries of modern Geology, to be able to learn the hidden structure of the earth's crust, and break open the seals of the most ancient records of creation.

But education has by no means fulfilled its highest aim and object when it has imparted to us these and such like points of information,—this technical knowledge, interesting and useful though it be. The great and by far the most important aim of education is, not merely to supply bare positive knowledge ; to make the mind a mere storehouse of facts—a kind of Encyclopædia or Museum.

But whilst effecting this, or in addition to effecting it, so to educate and cultivate the intellectual and moral faculties or powers, as to give them their fullest development and most perfect harmony : to give keenness to perception, accuracy and patience to observation, subtlety to analysis, insight and the sense of fitness

to combination, severe truthfulness to induction, analogic perception to deduction.

The possession of such qualities as these has placed above the rest of mankind, in connexion with the branches of knowledge to which I just now alluded, the names of—

Newton, La Place, Herschell.	} In Physics and Astronomy.
Lavoisier, Davy, Dalton, Faraday.	} In Atomics and Chemistry.
Cuvier, Hunter, Lyell, Owen.	} In Comparative Anatomy and Geology.
Humbolt, Somerville Maury.	} In Physical Geography.
Bentley, Ewald, Bopp, and Max Müller.	} In Languages.

That the well-ordered and resolute study of such an experimental science as Chemistry may be made a most important agent in education, viewed in the light in which I have just endeavoured to exhibit it, is a proposition that I am certain our labours here will conclusively prove, and which an example or two of the mode of following out a chemical investigation will abundantly illustrate. It is moreover a fact that Chemistry has been thus viewed by some of the greatest *thinkers* of our age, themselves not professed Chemists. Thus Coleridge, whilst writing his "*Aids to Reflection*," sat attentive to the teaching of Sir Humphry Davy; whilst Herschell and Whewell, Chalmers and Sir William Hamilton recognized in chemical inductions some of the highest operations of the mind.

Well do I remember an occasion some 25 years ago in Edinburgh, when the Members of the University and the Fellows of the Royal Society assembled to listen to the lectures of a young chemical discoverer, my dearest college friend. In that assembly one might note Chalmers the great theologian, Sir William Hamilton the metaphysician, Brewster the physicist, Wilson the poet, Jeffery the critic, and many other lesser lights in the galaxy of genius that then adorned our modern Athens.

The lecture over, both Chalmers and Sir William Hamilton returned thanks to the young chemist; and one or two extracts

• from the reports of their speeches, will show what their estimate was of the nature of chemical pursuits.

Chalmers said,—“When I look at the high reach of philosophical thought displayed in these lectures,—at their high generalizations, and the appeal to experiment which we have now seen made, I cannot but entertain the hope that Dr. Brown is destined to clear up many of the most recondite problems in physics, and thereby incalculably to extend the boundaries of our present science. Of course, he has been obliged to have recourse to hypothesis, yet be it remembered that philosophical hypothesis is the earnest and parent of discovery; it is science in conjecture, afterwards to become science in certainty, and to it we owe all the grandest achievements in inductive science.”

Sir William Hamilton said,—“It seems to me that Dr. Brown has made a higher generalization than any previous chemist: he has risen hypothetically to a great principle, and has come down from that to interrogate nature.”

In illustration of what I have advanced I will now adduce an example of a chemical investigation, and will explain to you somewhat in detail our method of procedure in the determination of facts by observation and experiment, in the discovery of a law of nature by the process of induction, and in the framing a hypothesis to explain the law, and to guide to further discovery. I will trace the investigation by which the most important of all chemical laws was discovered, and has been confirmed and established,—*the law, namely, of Equivalent Proportion.*

This law may be thus stated:—

A GIVEN WEIGHT OF ONE SUBSTANCE WILL, IN COMBINING WITH A CERTAIN WEIGHT OF ANOTHER, SATISFY ITS AFFINITY; AND A DIFFERENT WEIGHT OF A THIRD SUBSTANCE WILL PRODUCE THE SAME EFFECT: THE WEIGHTS OF THE FIRST AND THIRD SUBSTANCES ARE THEREFORE EQUIVALENT TO EACH OTHER.

Wenzel's\* first experimental indication of the law in the year 1768.

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\* It would occupy too much space to give the detailed explanations and to describe the experiments by which this part of the Lecture was illustrated. I have, therefore, merely expanded the head-notes employed at the Lecture.



He found that "when two neutral salts decompose each other the products are also neutral."

## EXAMPLE.

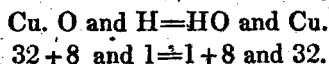
Nitrate of Soda 85.				
Nitrate of Baryta 131.	}	Nitric Acid.. 54.	Soda..... 31.	Sulphate of Soda 71.
		Baryta. .... 77.	Sulph. Acid.. 40.	
Sulphate of Baryta 177.				

Here *different* quantities of acids and bases are shown to be of equal value (equivalent) in neutralizing each other, or in satisfying each other's affinities. The numbers expressing these different quantities of acids and bases represent proportions equivalent to each other in combination.

Thus accurate observation and careful experiment yielded the first indications of the law.

These observations and experiments had reference to certain compounds; but they were extended to the elements, and the same law was found to hold good with them.

Thus when black oxide of copper is decomposed by hydrogen we have—



Here 1 part by weight of hydrogen is found to be *equivalent* to 32 parts of copper in satisfying the affinity of 8 parts of oxygen.

So also, for example, we find that 16 parts of sulphur are *equivalent* to 8 parts of Oxygen, in satisfying the affinities of certain *equivalent* proportions of the metals, as for example:—

Oxygen 8.	}	100. Mercury.....	100	Sulphur 16.
		104. Lead .....	104	
		27. Iron.....	27	
		32. Copper.....	32	
		108. Silver.....	108	

And so a wide induction may be formed, embracing all elements and all compounds—thus imparting accuracy to analysis and mathematical precision to all chemical investigations.

This law was then confirmed by Gay-Lussac's discovery of the manner in which gases combine with each other. He found that if we take the equivalent proportions of oxygen, hydrogen, nitrogen, chlorine, and other gases, and measure the volumes which they occupy, a very close relation will be found to exist between them. In fact, that with few exceptions the specific gravities of elementary substances in the gaseous state are identical with their equivalent weight, and those of compound substances are identical with the halves of their equivalent weights.—*Experimental Illustration.*

Then came the further confirmation of the law from Dulong and Petit's discovery in specific heat; viz. "That the specific heat of a substance is inversely as its equivalent weight; and that therefore the product of the specific heat into the equivalent number gives a constant number, or a multiple of that number."—*Examples.*

The law was moreover confirmed by Faraday's most important discovery in electrolysis: viz. That when substances capable of decomposition by electricity (electrolytes) are subjected to the same current of electricity, they are decomposed in the proportions of their equivalent weights. Thus whilst one grain of hydrogen is set free from water by a given current of electricity, there will be liberated by the same current 32 of copper from chloride of copper, and 104 of lead from chloride of lead, &c., &c.—*Experimental Illustration.*

Lastly, the discovery of Isomorphism by Mitscherlich corroborated the law by showing, "That equivalent proportions of different substances combined in the same way produce the same crystalline form."—*Explanatory Illustration from the Alums.*

Potash Alum.....	KO,	SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.
Ammonia Alum.....	H <sub>4</sub> NO,	SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.
Soda Alum.....	NaO,	SO <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.
Iron Alum .....	KO,	SO <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.
Chrome Alum.....	KO,	SO <sub>3</sub> + Cr <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.
Manganese Alum.....	KO,	SO <sub>3</sub> + Mn <sub>2</sub> O <sub>3</sub> ,	3 SO <sub>3</sub> + 24 Aq.

Then Dalton crowned the investigation by the invention of the hypothesis which bears his name.

He revived the belief in the old doctrines of the Greek philosopher, Democritus of Abdera, regarding the atomic constitution of matter, and by demanding assent to *three postulates* he successfully explained this law of "Equivalent Proportions," and all other "Laws of Chemical Combination." His postulates were—

1st—That Matter consists of Atoms.

2nd—That the Atoms of different kinds of Matter have different weights.

3rd—That combination occurs by Atoms.

Therefore, on the Daltonian hypothesis, as the atoms of different substances are of different weights, and as those different atoms replace each other in combination, so the different weights in which substances combine must be *equivalent* to each other.

You see now the kind of mental discipline we pass through in conducting a chemical investigation. We here not merely analyze and combine *substances*, but we analyze and combine *phenomena*. We have what Lord Bacon describes as "a form of induction, which shall analyze experience and take it to pieces, and by a due process of exclusion and rejection lead to an inevitable conclusion." And, he says, "If that ordinary mode of judgment, practised by the logicians, was so laborious, and found exercise for such great wits, how much more labour must we be prepared to bestow upon this other, which is extracted, not merely out of the depths of the mind, but out of the very bowels of nature."

And in this labour you will perceive that not only is the attention arrested, and the powers of perception concentrated upon the *observation* of forms and phenomena as nature presents them to us, but we appeal to *experiment*; or, as 'tis said, "we interrogate nature."

And then, as Bacon says, we "proceed from one axiom to another, regularly and gradually, so that the most general are not reached till the last; but then, when you do come to them, you find them to be, not empty notions, but well defined, and such as nature would really recognize as her first principles, and such

as lie at the heart and marrow of things." "Our steps are guided by a clue, and the whole way, from the very first perception of the senses is laid out upon a sure plan."

Now, from former experience in teaching, I know, that to the native mind this process, which I have indicated, is unfortunately very distasteful. First of all, the very observation of the physical world, which in pristine periods of your history inspired your poets, and furnished your priests with sublime images and beautiful allegories, is almost dead and extinct amongst you in these latter days.\*

Yet nowhere in the world do the phenomena of nature appear under grander aspects than those with which they manifest themselves in this country. Your neighbouring mountains with their rugged, rocky fastnesses, the vast and varied forms of animal and vegetable life, and the great atmospheric disturbances, that mark the changes of the seasons, all appeal, with almost irresistible allurements to even the most casual scientific observer.

Here it requires only the eye of intuition to convey to the mind impressions from which it may eliminate the principles of order and beauty. And yet I fear it may be said that most of the youths of this country are insensible to the natural grandeur with which they are surrounded.

But still more do our young men shrink from the labour of *tracing effects to their causes and causes in their effects*. They prefer to take explanations, as statements, on trust, and leave to others the labour of investigation, and are content to gather but the fruit of that labour. Hence, in modern times, no native of India has so *interrogated nature* as to have contributed a single important discovery to the records of science. But, if your

\* The Rev. Dr. John Wilson (our most learned Orientalist), writing to me on this subject says:—"It may be very safely said that the ancient Indians were much more attentive and successful observers of Nature than their successors in later ages. The prevalent system of religion in the time of the Vedas was that of physiolatry; and a great degeneration, which has been ever on the increase, till the effects of the European civilization have begun to be felt, was the effect of the establishment in India of idolatry and spiritual pantheism. There is a freshness and liveliness in the Vedic Hymns (alac? without the acknowledgment of the Great Creator), as they recognise the phenomena of the earth below and the heavens above, and the physical agencies by which they are influenced, which are very remarkable."

study of experimental science is to conduce to mental vigour and thus fit you to extend the boundaries of science, you must resolutely undertake the labour of investigation—be the mental wrestling what it may—and thus in time you will remove the possibility of the existence of that defect alluded to by our Chancellor at the late convocation of the University, when he said, that it was an opinion of some people that “the oriental intellect is worn out: that it may possess great capacity to receive and retain knowledge, but that it has no power to analyze and combine.” Now it is this power to analyze and combine, which I trust *all* the studies of this College will tend to foster and develop in you. I say *all* the studies, because I would not have you suppose that I wish to arrogate to the study of Physical Science the sole or even the chief office of disciplining the mind. I have only attempted to indicate its special and particular share in this great work, in which we are all fellow-labourers; for, once more to quote Lord Bacon, “let there be two streams and two dispensations of knowledge: and in like manner two tribes or kindreds of students in philosophy,—tribes not hostile or alien to each other, but bound together by mutual services: let there, in short, be one method for the cultivation, another for the invention of knowledge. And if any man there be, who, not content to rest in and use the knowledge which has already been discovered, aspires to penetrate further,—to overcome, not an adversary in argument, but nature in action: to seek, not petty and probable conjecture, but certain and demonstrable knowledge,—I invite all such to join themselves, as true sons of knowledge, with me; that, passing by the outer courts of nature, which numbers have trodden, we may find a way at length into her inner chambers.” “For man is but the servant and interpreter of nature; what he does and what he knows is only what he has observed of nature’s order in fact or in thought: beyond this he knows nothing and can do nothing. For the chain of causes cannot be broken or loosed, nor can nature be commanded except by being obeyed.\* And so these

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\* “And ruling by obeying nature’s powers,  
And gathering all the fruits of peace and crowned with all her flowers.”

*Tennyson’s Ode at the International Exhibition, 1862.*

twin objects, human knowledge and human power do really meet in one."

Still let it not be forgotten that in the study of the physical sciences are we specially brought in contact with the works of the Great Creator and Father of us all; and that, however diverse our religious creeds may be, here we can happily meet upon one common ground; and, in examining the foundations of Natural Religion, can learn lessons of humility, reverence, and gratitude in the abundant proofs all nature yields of the Power, Wisdom and Goodness of the "Invisible, Universal Lord."

"Who, in the wide expanse  
Of His Creation, left no rock but bears  
Of Grace and Mercy, as of Power the Seal."

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