

them in the hydrokinetic system, by jointed rigid connecting-links, we may arrange for configurations of stable equilibrium. Thus, without fly-wheels, but with fluid circulations through apertures, we may make a model spring-balance, or a model luminiferous ether, either without or with the rotational quality corresponding to that of the true luminiferous ether in the magnetic fluid; in short, do all by the perforated solids, with circulations through them, that we saw we could do by means of linked gyrostats. But something that we cannot do by linked gyrostats, we can do by the perforated bodies with fluid circulation: we can make a model gas! The mutual action at a distance, repulsive or attractive according to the mutual aspect of the two bodies when passing within collisional distance of one another, suffices to produce the change of direction of motion in collision, which essentially constitutes the foundation of the kinetic theory of gases.

There remains, however, as we have seen before, the difficulty of providing for the case of actual impacts between the solids.

Let us annul the solids, and leave the liquid performing irrotational circulation round vacancy, in the place of the solid cores which we have hitherto supposed; or let us annul the rigidity of the solid cores of the rings, and give them molecular rotation according to Helmholtz's theory of vortex motion. As to whether, however, when the vortex theory of gases is thoroughly worked out, it will or will not be found to fail in a manner analogous to the failure already pointed out in connection with the kinetic theory of gases composed of little elastic solid molecules, one cannot at present speak with certainty.

PROGRESS OF CHEMISTRY SINCE 1848.¹

WITH the death of Berzelius in 1848 ended a well-marked epoch in the history of chemistry: with that of Dumas—and, alas! that of Wurtz also—in 1884 closes a second.

The differences between what may properly be termed the 'Berzelian era,' and that with which the name of Dumas will forever be associated, show themselves in many ways, but in none more markedly than by the distinct views entertained as to the nature of a chemical compound.

According to the older notions, the properties of compounds are essentially governed by the qualitative nature of their constituent atoms, which were supposed to be so arranged as to form a binary system. Under the new ideas, on the other hand, it is mainly the number and arrangement of the atoms within the molecule which regulate the characteristics of the compound, which is to be looked on, not as built up of two constituent groups of atoms, but as forming one group. Another striking difference of view between the chemistry of the Berzelian era and that of

what we sometimes term the 'modern epoch,' is illustrated by the so-called 'substitution theory.' Dumas, to whom we owe this theory, showed that chlorine can take the place of hydrogen in many compounds, and that the resulting body possesses characters similar to the original. But there is another change of view, dating from the commencement of the Dumas epoch, which has exerted an influence, equal, if not superior, to those already named on the progress of chemistry, and that is, as to the use of equivalent or molecular weights.

The theory of organic radicals, developed by Liebig so long ago as 1834, received numerous experimental confirmations in succeeding years. Bunsen's classical research on cacodyl, proving the possibility of the existence of metallo-organic radicals capable of playing the part of a metal, and the isolation of the hydrocarbon ethyl by Frankland in 1849, laid what the supporters of the theory deemed the final stone in the structure.

The fusion of the radical and type theories, chiefly effected by the discovery in 1849 of the compound ammonias by Wurtz, brings us to the dawn of modern chemistry. Henceforward organic compounds were seen to be capable of comparison with simple inorganic bodies, and hydrogen capable of replacement not only by chlorine or by a metal, but by an organic group or radical.

At the Edinburgh meeting of this association in 1850, Williamson read a paper on 'Results of a research on aetherification,' which not only included a satisfactory solution of an interesting and hitherto unexplained problem, but was destined to exert a most important influence on the development of our theoretical views: for he proved, contrary to the then prevailing ideas, that ether contains twice as much carbon as alcohol, and that it is not formed from the latter by a mere separation of the elements of water, but by an exchange of hydrogen for ethyl; and this fact, being in accordance with Avogadro's law of molecular volumes, could only be represented by regarding the molecule of water as containing two atoms of hydrogen to one of oxygen, one of the former being replaced by one of ethyl to form alcohol, and the two of hydrogen by two of ethyl to form ether. Then Williamson introduced the type of water (subsequently adopted by Gerhardt) into organic chemistry, and extended our views of the analogies between alcohols and acids by pointing out that these latter are also referable to the water-type, predicting that bodies bearing the same relations to the ordinary acids as the ethers do to the alcohols must exist,—a prediction shortly afterwards (1852) verified by Gerhardt's discovery of the anhydrides.

Again, in 1852, we note the first germs of a theory which was destined to play an all-important part in the progress of the science; viz., the doctrine of valency, or atomicity; and to Frankland it is that we owe this new departure. But whether we range ourselves with Kekulé, who supports the unalterable character of the valency of each element, or with Frankland, who insists on its variability, it is now clear to most

¹ Abstract of an address to the chemical section of the British association at Montreal, Aug. 28, 1884, by Professor HENRY ENFIELD ROSCOE, Ph.D., LL.D., F.R.S., F.C.S., president of the section.

chemists that the hard and fast lines upon which this theory was supposed to stand cannot be held to be secure.

But however many doubts may have been raised, in special instances, against a thorough application of the law of valency, it cannot be denied that the general relations of the elements which this question of valency has been the means of bringing to light are of the highest importance, and point to the existence of laws of nature of the widest significance; as seen in the periodic law of the elements first foreshadowed by Newlands, but fully developed by Mendelejeff and Lothar Meyer. But this periodic law makes it possible for us to do more: for as the astronomer, by the perturbations of known planets, can predict the existence of hitherto unknown ones, so the chemist, though of course with much less reliable means, has been able to predict with precision the properties, physical and chemical, of certain missing links amongst the elements; such as ekaluminium and ekaboron, then unborn, but which shortly afterwards became well known to us in the flesh as gallium and scandium.

Arising out of Kekulé's theory of the tetrad nature of the carbon atom, came the questions which have caused much debate among chemists: 1°. Are the four combining units of the carbon atom of equal value, or not? and 2°. Is the assumption of a dyad carbon atom, in the so-called non-saturated compounds, justifiable, or not? The answer to the first of these, a favorite view of Kolbe's, is given in the now well-ascertained laws of isomerism; and from the year 1862, when Schorlemmer proved the identity of the hydrides of the alcohol radicals with the so-called radicals themselves, this question may be said to be set at rest.

Passing from this subject, we arrive, by a process of natural selection, at more complicated cases of chemical orientation; that is, given certain compounds which possess the same composition and molecular formulae but varying properties, to find the difference in molecular structure by which such variation of properties is determined. Problems of this nature can now be satisfactorily solved, the number of possible isomers foretold, and this prediction confirmed by experiment.

The discovery of the aniline colors by Perkin, their elaboration by Hofmann; the synthesis of alizarin by Graebe and Liebermann, being the first vegetable coloring-matter which has been artificially obtained; the artificial production of indigo by Baeyer; and, lastly, the preparation by Fischer of kairine, a febrifuge as potent as quinine,—are some of the well-known recent triumphs of modern synthetical chemistry.

In no department of chemistry has the progress made been more important than in that concerned with the accurate determination of the numerical, physical, and chemical constants, upon the exactitude of which every quantitative chemical operation depends. Amongst the most interesting recent additions to our knowledge, made in this department, we may note the classical experiments, in 1880, of

J. W. Mallet on aluminium, and, in the same year, of J. P. Cooke on antimony, and those, in the present year, of Thorpe on titanium.

In referring to the work in spectrum analysis, Professor Roscoe recalled some of the more remarkable conclusions to which the researches of Lockyer, Schuster, Liveing and Dewar, Wüllner, and others, in this direction, have led. In the first place, it is well to bear in mind that a difference of a very marked kind, first distinctly pointed out by Alex. Mitscherlich, is to be observed between the spectrum of an element and that of its compounds, the latter only being seen in cases in which the compound is not dissociated at temperatures necessary to give rise to a glowing gas; second, that these compound spectra (as, for instance, those of the halogen compounds of the alkaline-earth metals) exhibit a certain family likeness, and show signs of systematic variation in the position of the lines, corresponding to changes in the molecular weight of the vibrating system. Still, it cannot be said that as yet definite proof has been given in support of the theory that a causal connection is to be found between the emission spectra of the several elements belonging to allied groups and their atomic weights, or other chemical or physical properties. In certain of the single elements, however, the connection between the spectra and the molecular constitution can be traced. In the case of sulphur, for example, three distinct spectra are known. The first of these, a continuous one, is exhibited at temperatures below 500°, when, as we know from Dumas' experiments, the density of the vapor is three times the normal, showing that at this temperature the molecule consists of six atoms. The second spectrum is seen when the temperature is raised to above 1000°, when, as Deville and Troost have shown, the vapor reaches its normal density; and the molecule of sulphur, as with most other gases, contains two atoms; and this is a band-spectrum, or one characterized by channelled spaces. Together with this band-spectrum, and especially round the negative pole, a spectrum of bright lines is observed. This latter is doubtless due to the vibrations of the single atoms of the dissociated molecule, the existence of traces of a band-spectrum demonstrating the fact, that, in some parts of the discharge, the tension of dissociation is insufficient to prevent the reunion of the atoms to form the molecule.

The most remarkable results obtained by Abney and Festing show that the radical of an organic body is always represented by certain well-marked absorption-bands; differing, however, in position, according as it is linked with hydrogen, a halogen, or with carbon, oxygen, or nitrogen. Indeed, these experimenters go so far as to say that it is highly probable, that, by this delicate mode of analysis, the hypothetical position of any hydrogen which is replaced may be identified; thus pointing out a method of physical orientation, of which, if confirmed by other observers, chemists will not be slow to avail themselves.

One of the noteworthy features of chemical progress is the interest taken by physicists in fundamental

questions of the science, — Sir William Thomson's interesting speculations, founded upon physical phenomena, respecting the probable size of the atom; and Helmholtz's discussion of the relation of electricity and chemical energy; and the theory of the vortex-ring constitution of matter, thrown out by Sir William Thomson, and lately worked out, from a chemical point of view, by J. J. Thomson of Cambridge.

Another branch of chemistry which has recently attracted much experimental attention is that of thermo-chemistry, — a subject upon which, in the future, the foundation of dynamical chemistry must rest, and one which already proclaims the truth of the great principle of the conservation of energy, in all cases of chemical as well as of physical change. But here, although the materials hitherto collected are of very considerable amount and value, the time has not yet arrived for expressing these results in general terms; and we must therefore be content to note progress in special lines, and wait for the expansion into wider areas.

In conclusion, Professor Roscoe spoke of the part English chemists had played in the past, and of the marked difference between the data-gathering German work, and the systematizing of the facts known, which is going on in England. He also referred to what he considered the best method of educating chemists, — by giving them as sound and extensive a foundation in the theory and practice of chemical science as their time and abilities will allow, rather than forcing them prematurely into the preparation of a new series of homologous compounds, or the investigation of some special reaction, or of some possible new coloring-matter, though such work might doubtless lead to publication, — and called attention to the prominence of English industrial chemistry.

THE CORRELATION OF GEOLOGICAL FORMATIONS.¹

THIS address was devoted to a consideration of a few remarkable exceptions to the rule that similarity of faunas and floras in fossiliferous formations throughout the surface of the world implies identity of geological age. Some interesting contributions have been made to this question by the geological survey of India, where Mr. Blanford's experience has been chiefly derived, and by the geologists of Australia and South Africa; and he first noticed a few typical instances, several of them Indian, in which the system of determining the age of various formations by the fauna or flora has led to contradictory results, and then showed where the source of error appears to lie. The famous Pikermi beds of Greece, a few miles east of Athens, contain a vertebrate fauna nearly always quoted as miocene; but they overlie strata with well-proved pliocene marine Mollusca. The Siwalik beds that flank the Himalaya north of Delhi are still

classified as miocene by most European writers, but are regarded as pliocene by the Indian survey, on evidence found by tracing them west and south into Sind. The Gondwana system of central India, a great sequence of fresh-water beds probably of fluvial origin, over 20,000 feet thick, is of unusual interest on account of the extraordinary conflict of paleontological evidence it presents to the observer. Its subdivisions are numerous, and vary in almost every place of occurrence. One (the Tálchir beds) contains rounded boulders chiefly of metamorphic rocks up to six feet across, embedded in fine silt: others are characterized by an intermingling of floras and faunas that give rise to a mass of contradictions; beds with a Triassic fauna overlying others with Rhaetic or Jurassic floras. The Australian coal-measures and their associated beds present even a more remarkable instance of homotaxial perversity, a Jurassic flora being of the same age as a carboniferous marine fauna. Some of these beds (Hawkesbury) again contain transported boulders, which occur once more in the lower members (Eccla beds) of the Karoo formation of interior South Africa. The latter presents a striking likeness to the Gondwana system of India. In both countries, a thick fresh-water formation occupies a large area of the interior of the country, whilst on the coast some marine Jurassic and cretaceous rocks are found; and as in India, so in South Africa, the uppermost inland mesozoic fresh-water beds are capped by volcanic.

Other examples of discrepancies in paleontological evidence might be given, but he would add merely a mention of the single case known to him in which the discordant records are both marine, namely, Barrande's 'colonies' in Bohemia; but here the discordance is much less than in the cases before cited, and moreover Barrande's conclusion is disputed by other observers.

In most of the cases he had named, the conflict is between the evidence of marine and terrestrial organisms. Manifestly one or the other of these leads to erroneous conclusions; and in making choice between the two, most geologists accept evidence of the marine fossils. The reason is not far to seek. So far as he was aware, no case is known where such an anomaly as that displayed in the Gondwanas of India has been detected amongst marine formations of which the sequence was unquestioned. Further, if we compare the distribution of marine with that of terrestrial and fresh-water animals and plants at the present day, we shall find a very striking difference; and it is possible that this difference may afford a clew to the conditions that prevailed in past times.

Wanderers into what they fancy unexplored tracts in paleontology are likely to find Professor Huxley's footprints on the path they are following. In his paper on the Hyperodapedon, he says: "It does not appear to me that there is any necessary relation between the fauna of a given land and that of the seas on its shores. . . . What now happens geographically to provinces in space, is good evidence as to what, in former times, may have happened to provinces in time; and an essentially identical land-

¹ Abstract of an address to the geological section of the British association at Montreal, Aug. 28, 1884, by W. T. BLANFORD, F.R.S., Sec. 7, G.S., F.R.G.S., president of the section.