

history, and language will hold their own adequate place in its scheme of instruction, but the newer sciences of animate and inanimate nature will certainly start from a fairer platform than usual, in the North of England. The Victoria University will not be hampered, like its elder sisters, by the traditions of the past. There is a great career before it, and the people of England will watch its development with the deepest interest. They may be reasonably confident of one thing, that the new educational "brand," to adopt Prof. Huxley's felicitous expression, will be of as select a character as any of the "brands" with which they are familiar.

ON THE RELATION BETWEEN THE MOLECULAR WEIGHTS OF SUBSTANCES AND THEIR SPECIFIC GRAVITIES WHEN IN THE LIQUID STATE

UNDER this title I have communicated to the Chemical Society the results of a prolonged investigation on the connection existing between the weights of unit volumes of liquid substances and their relative molecular weights (see *Journal of the Chemical Society* for March, April, May, and June, 1880), and in obedience to a request from the Editor of NATURE I will briefly indicate the scope of the inquiry, and point out the main conclusions to which I have been led. The inquiry, I may say in the outset, has resolved itself into a critical and experimental examination of what are known as Kopp's laws of specific volume. That some definite connection between molecular weight and specific gravity would be traced had been surmised more than forty years since, but all our exact knowledge on the subject is contained in the series of classical memoirs which we owe to Hermann Kopp. Kopp first clearly recognised the necessity of comparing the liquids when under strictly analogous conditions. By dividing the specific gravity of a liquid taken at the temperature at which its vapour-tension is equal to the standard atmospheric pressure—that is, at its ordinary boiling-point—into its molecular weight, we obtain its specific volume. If the specific gravity be referred to the point of maximum density of water, this value represents the number of cubic centimetres occupied by the relative molecular weight of the liquid expressed in grams at its boiling-point under the standard pressure. The numbers thus obtained were first shown by Kopp to exhibit certain definite relations which may be briefly stated as follows:—

I. *In many instances differences in specific volume are proportional to differences in corresponding chemical formulae.*—Thus a difference of  $\text{CH}_2$  in a homologous series corresponds to a difference of about 22 in the specific volume, or  $(\text{CH}_2)_x = 22x$ . On comparing the specific volumes of similarly constituted haloïd compounds, it is seen that the substitution of  $n$  atoms of bromine for an equal number of chlorine atoms increases the specific volume by  $5n$ .

II. *Isomeric and metameric liquids have, as a rule, the same specific volume.*—Exceptions are exhibited by certain oxygen and sulphur compounds.

III. *The substitution of an atom of carbon for two of hydrogen makes no alteration in the specific volume of certain groups of organic liquids.*

On the basis of these conclusions Kopp was able to calculate certain numerical values for the specific volumes of the elements in combination. These values are as a rule constant for the particular element: thus, according to Kopp, carbon has invariably the value of 11, hydrogen that of 5.5. Exceptions are observed in the case of the chemical analogues oxygen and sulphur. Each of these bodies has two values depending, it would seem, on its mode of combination, or on its relation to the remaining atoms in the molecule. For example, acetone and allyl alcohol have each the empirical formula  $\text{C}_3\text{H}_6\text{O}$ , but the specific volume of acetone is 78.2, whilst that of allyl alcohol is 73.8. In the case of acetone the combining power of the oxygen atom is wholly satisfied by carbon; that is, we have reason to know that the oxygen atom is more intimately associated with one of the carbon atoms than it is with any one of those of the other elements; whereas in allyl alcohol a moiety of the combining value would seem to be satisfied by carbon and the remainder by hydrogen. It appears, then, that when oxygen is united to an element by both its affinities its specific volume is 12.2; when it is attached by only one combining unit its specific volume is 7.8. The corresponding values for sulphur are 28.6 and 22.6.

I have already pointed out that these differences in the values for the specific volumes of oxygen and sulphur may be employed to throw light upon the constitution of such bodies as the phosphoryl and thiophosphoryl compounds, and that we may in this way obtain evidence as to the particular affinity-value that an element such as phosphorus, which is variously regarded as a triad and a pentad, exerts, and in the present paper I give additional instances to show that a knowledge of the specific volume of a body is often calculated to furnish valuable information concerning its constitution.

The most accurate method of ascertaining the specific volume of a liquid is (1) to determine its specific gravity at some convenient temperature; (2) to ascertain its boiling-point with the utmost exactitude; and (3) to determine with great care its rate of expansion, say between  $0^\circ$  and this boiling-point.

The space at my disposal forbids me attempting to show how these various physical data were determined for the purpose of the present inquiry. Full details of the methods employed are given in the original paper, and the errors incidental to the various processes are fully discussed. The observations necessitated among other things the frequent determination of the fixed points of the thermometers employed, and the accompanying figure shows how these were found to rise during the progress of the investigation. The abscissæ represent the times in months at which the several observations were taken, and the ordinates the extent of displacement in hundredths of a degree. A represents a thermometer ranging from  $-10^\circ$  to  $50^\circ$  C., B from  $50^\circ$  to  $105^\circ$  C., and C from  $98^\circ$  to  $144^\circ$  C. It will be seen that the extent of the displacement is evidently dependent on, or at any rate is greatly influenced by, the amount of molecular disturbance to which the glass envelope is subjected.

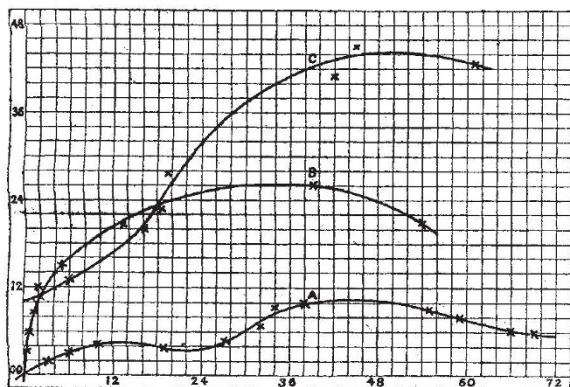
The accuracy of the results is of course in great measure dependent upon the purity of the liquids employed, and this fact to some extent limited the number of compounds which could be investigated. Whenever the mode of



preparation was not a sufficient guarantee of the purity it was established either by analysis or by the determination of its vapour density—a most rigid test, provided that this could be ascertained with sufficient accuracy. I have ventured to modify the original form of the Gay-Lussac-Hofmann apparatus, and I think I may claim that this modification admits of all the precision which the process is capable of yielding. It obviates some of the disadvantages of the original method, such as the liability to crack the tube, and the use of a large quantity of mercury and of liquid to vaporise the body under investigation, and it also permits of a more certain application of the necessary corrections.

Among the many problems suggested by a review of our present knowledge of the subject, the following seemed to me to be specially worthy of solution.

I. Is it definitely established that an element in combination has as a rule an invariable specific volume? May not the volume be modified by the number of the atoms of that particular element in the molecule? Is it



Curves showing rise of fixed points in thermometers.

altogether independent of the general complexity of the molecule, or may not the specific volume of the molecule be a function of its weight?

II. Do the various members of a family of elements possess identical specific volumes, or may not the volume be a function of the atomic weight?

III. Would a re-examination of the cases of so-called variable atomic value serve to show that the specific volume of an element is a function of that value, as Buff supposes?

IV. The hypotheses of Mendelejeff and Meyer indicate the need of additional and more exact determinations of the values for the specific volumes of the elementary bodies?

This scheme of work required the determination of the specific gravities, boiling-points, and thermal expansions of about fifty liquids, and the results of the observations afford material for the calculation of the specific volumes of seventeen elementary bodies. The rates of expansion are represented by formulæ of the form—

$$V = A + Bt + Ct^2 + Dt^3.$$

The labour of reducing the observations, and more especially of calculating the empirical formulæ for so large a number of substances, has been materially lightened by the use of the arithmometer of Thomas (de

Colmar). The investigation has therefore incidentally added very considerably to the data upon which the determination of the general laws affecting the thermal expansion of liquid bodies must depend.

After a discussion of the errors of the observations and a comparison of my results with those obtained by previous observers, whenever these were applicable, I have summarised the main conclusions to which I have been led as follows:—

1. It seems certain that many isomeric liquids, even of the same chemical type (using that phrase in the sense in which it is employed by Kopp) have not identical specific gravities at their respective boiling-points, and hence have not identical specific volumes. Such exceptions are more commonly met with in compounds containing carbon and hydrogen; this fact appears to indicate that the specific volume of one or both of these elements is not absolutely invariable. Benzene derivatives especially show a greater departure from the general law than can be fairly attributed to experimental error. Their variations are of the same order as has been shown to occur in the refraction values for these compounds.

2. We must also suppose that of the additional elements, oxygen, sulphur, and nitrogen have likewise variable specific volumes in conformity with Kopp's conclusions.

3. There is at present no experimental evidence for assuming that any other element has a variable specific volume.

4. Hence in the case of these elements the volume is not modified by the number of the atoms of the particular element in the molecule, and it is therefore altogether independent of the general complexity of the molecule.

5. The different members of a family of elements do not possess identical specific volumes; the volumes of the elements are periodic functions of their atomic weights.

6. The inquiry affords no evidence in support of the hypothesis that the specific volume of an element in combination is modified by any possible variation in the affinity value which it may possess. T. E. THORPE

#### GORDON'S "ELECTRICITY AND MAGNETISM"

*A Physical Treatise on Electricity and Magnetism.* By J. E. H. Gordon. (London: Sampson Low and Co., 1880.)

THE author, in the first paragraph of his preface, draws a distinction between the physical and mathematical points of view in treating the Science of Electricity. Unfortunately, the distinction is at present a real one. Many mathematicians, fascinated by the beauty of the instruments they handle, are disposed to treat physical problems as though the principal function of the universe were to suggest problems to the pure mathematician, instead of the principal function of the pure mathematician being to provide suitable tools for solving physical problems. On the other hand, there are skilful experimentalists who fail to appreciate those powerful methods of deductive quantitative reasoning which they are themselves unable to handle. Mr. Gordon does not profess to be a mathematician, and adopts the experimental point of view.