

The appearance of a new and useful family peculiarity is a boon to breeders, who by selection in mating gradually reduce the preponderance of those ancestral elements that endanger reversion. The appearance of a new type is due to causes that lie beyond our reach; so we ought to welcome every useful one as a happy chance, and do our best to domicile and perpetuate it. When heredity shall have become much better, and more generally understood than now, I can believe that we shall look upon a neglect to conserve any valuable form of family type as a wrongful waste of opportunity. The appearance of each new natural peculiarity is a faltering step in the upward journey of evolution, over which, in outward appearance, the whole living world is blindly blundering and stumbling, but whose general direction man has the intelligence dimly to discern, and whose progress he has power to facilitate.

A NEW THEORY OF COHESION.

SINCE a great part of the relations discussed in a paper by Dr. H. Whiting, on a new theory of cohesion (*Proc. Amer. acad.*, xix. 353), are determined by the equation between the pressure, volume, and temperature of a given quantity of the substance considered, a comparison of the form of this equation as given in this paper with forms previously proposed affords the readiest means of comparing the author's results with those of previous investigators. The equation proposed in 1873 by Van der Waals has the form

$$\left(p + \frac{a}{v^2}\right)\left(1 - \frac{b}{v}\right)v = Rt; \quad (1)$$

that of the present paper (see p. 376, third equation) may be written

$$\left(p + \frac{a}{v^2}\right)\left(1 - \sqrt[3]{\frac{c}{v}}\right)v = Rt. \quad (2)$$

In both equations, p , v , and t denote pressure, volume, and absolute temperature: the other letters denote constants, to be determined by the nature of the substance considered.

We may get some idea of the numerical difference in the indications of these equations, if we observe that the ratio of the volume of the critical state to that which would be required by the laws of Boyle and Charles is 0.375 by the first equation, and 0.536 by the second (the experiments of Dr. Andrews give something like 0.414 for carbonic acid). Again: the ratio of the volume of the critical state to that at absolute zero would be 3 by the first equation (which, however, was not intended to apply to such a determination), and 3.58 by the second.

The equation of Dr. Whiting has an important property in common with that of Van der Waals. If we use the pressure, volume, and temperature of the critical state as units for the measurement of the pressure, volume, and temperature of all states, the constants will disappear from either equation, and we obtain a relation between the pressure, volume, and temperature (thus measured), which should be the same for all bodies. From this property of his equation, independently of the particular relation

obtained, Van der Waals has derived a considerable number of interesting conclusions, which would equally follow from the equation of Dr. Whiting (see the twelfth and thirteenth chapters of the German translation of the memoirs of the former, by Dr. Roth, Leipzig, 1881). One of these is mentioned in Dr. Whiting's treatise, p. 427.

It is well known that the equation of Van der Waals agrees with experiment to an extent which is quite remarkable when the simplicity of the equation is considered, and the complexity of the problem to which it relates. But it was not intended to be applied to states as dense as the ordinary liquid state. Dr. Whiting's equation, on the other hand, seems to have been formed with especial reference to the denser conditions of matter, and, from the numerical verifications which are given, would appear to represent the ordinary liquid state, in some respects at least, much better than the equation of Van der Waals. The principal verifications relate to the coefficient of expansion and the critical temperature. When the pressure may be neglected, as in the ordinary liquid state, equation (2) gives

$$\frac{de}{dt} = \frac{7}{3}e^2 + \frac{4}{3}te^3,$$

where e is the coefficient of expansion $\left(\frac{dv}{vdt}\right)$. A very elaborate comparison is made between this equation and the experiments of Kopp, Pierre, and Thorpe. An empirical formula of Dr. Mendelejeff is also considered, which gives

$$\frac{de}{dt} = e^2,$$

a value of de/dt about one-third as great as Dr. Whiting's. We may add that the equation (1) of Van der Waals would give

$$\frac{de}{dt} = 3e^2 + 2te^3,$$

a value of de/dt about one-third greater than Dr. Whiting's. The result seems to be that the indications of experiment lie between the formulae of Dr. Whiting and Dr. Mendelejeff (pp. 424 ff.). We may conclude that they would not agree so well with that of Van der Waals.

Each of the equations (1) and (2) will give the critical temperature when we know the coefficient of expansion for a given temperature. Dr. Whiting has calculated the critical temperature, by means of his equation, for twenty-six substances for which this temperature has been observed. The calculated and observed values generally differ by less than ten degrees Centigrade. An equation derived by Thorpe and Rucker, in part from the formula of Mendelejeff above mentioned, and in part from a principle of Van der Waals, gives about the same agreement with experiment. We may add that the general equation of Van der Waals, taken alone, would give for the critical temperature t_c the formula

$$t_c = \frac{8(2te + 1)^2}{27e(te + 1)},$$

which does not seem, from the test of a few cases, to agree so well with experiment.

In establishing his fundamental equations, Dr. Whiting, like Van der Waals, treats the molecules as elastic spheres which attract one another when not in contact. The cohesive effect of the molecular attraction is regarded by both as proportional to the square of the density. It is, in fact, represented by the same term $\left(\frac{a}{v^2}\right)$ in equations (1) and (2). This effect is deduced by Dr. Whiting from the hypothesis of a molecular attraction varying inversely as the fourth power of the distance, by supposing a body to expand so that every distance is increased in the same ratio; but such an expansion is entirely unlike any which actually occur in fluids, since it increases the distance within which the centres of molecules do not approach one another. We shall probably come much nearer to the case of nature, if we suppose that the average number of molecules in a fluid, which are between the distances r and $r + dr$ from a given molecule, varies as the density of the fluid. This supposition will evidently make the cohesive effect of the molecular attraction vary as the square of the density. It would seem that any agreement of experiment with the indications either of equation (1) or of equation (2) should be regarded as confirmatory of this law of the distribution of the molecules rather than of any particular law of attraction.

THURSTON'S FRICTION AND LOST WORK.

THIS volume combines characteristics not too often found in a work on this or kindred subjects. It is thoroughly scientific in method, as well as in the treatment of separate problems. It is eminently practical in results, as well as in the selection and range of the problems considered. It is clear, accurate, and minute in the details which give completeness to its discussions, and make them readily available for actual use. It is not merely or principally a compilation. While it brings together the formulæ and results of the standard writers and experimenters upon friction, its laws, modifications, and effects, it also includes the author's own elaborate experiments, made with a view to their bearing upon questions of daily and vital importance to the engineer and the student. The conclusions drawn from these experiments, being always subject to comparison with the facts and knowledge gained by the author in a wide and extensive engineering practice, are rational and reliable. The book comprises eight chapters. The first explains the object of mechanism, the manner of computing work and power, the laws of the per-

sistence and transformation of energy, and the relation of lost work to the efficiency of mechanism. In the second chapter, the theory and laws of friction are developed. The problems which arise in practice are taken up one by one, clearly analyzed, mathematically solved, and the applications of the resulting formulæ pointed out.

The next three chapters form an exhaustive treatise on the lubricants used for reducing friction; their nature and relative values; the means of applying and using; methods of analyzing, inspecting, and testing them. Cuts of the best lubricators in use, and also of the apparatus used in making physical tests; tables giving physical and chemical properties of oils, their color reactions, density, specific gravity, and viscosity; and diagrams showing the relations of viscosity and lubrication, and effects of temperature upon viscosity, accompany the text. Oleography and electrical conductivity are noticed as methods of identifying various oils. The nature and effects of friction, and the kinds and properties of lubricants, having been thus fully discussed, the author proceeds to the subject of experiments, from which must be obtained the values of constants which enter into all the formulæ. Upon the correctness of these values depends the accuracy of results obtained by calculation from the formulæ developed by the theoretical investigations.

The sixth chapter relates to experiments of two kinds: First, those designed to ascertain the relative amounts of friction between different surfaces under varying conditions; to determine constants, or suggest the value and form of empirical formulæ, applicable to friction of both solids and fluids. Second, experiments with machines for testing lubricants, with cuts and descriptions of oil-testing machines. The mathematical theory and method of using Thurston's machine are given in detail, together with tables showing records of oil-tests made by the author with his machine. The seventh chapter gives results of experiments with lubricants, showing their effects in modifying friction; their endurance under different conditions of pressure and velocity; and the effect of changes of pressure and velocity upon the coefficient of friction.

It is impossible to give in a brief review an adequate idea of the minuteness of detail with which the wide range of problems and experiments are discussed. The reader may expect to find, substantially, all that is known upon these subjects through the investigations of earlier writers, supplemented by the results of