

ordinate them to the scheme of the book, and with grasp enough to weld their contributions into a consistent whole. With the experience he has now acquired, and with his own relatively greater knowledge of the subject, Dr. Eastman will doubtless do better in Volume II. Meanwhile this first volume forms a wonderful storehouse of facts, drawings and names; and no more reliable compendium of the paleontology of invertebrate animals is to be obtained.

The copy submitted for review bears date 1900, and there is no indication of the fact that pages 1-352 were first published in November, 1896. They were issued in a separate wrapper, with title marked Vol. I., Part I., and dated London and New York, 1896. But as it happens, this Part I. was *not* published in London: the publishers refused, and still refuse, to sell it in England, and I owe my copy to the kindness of Dr. Eastman. Therefore both title pages are bibliographically incorrect—"for trade reasons." I am also informed that the sections by Dr. Dall and Professor Hyatt were distributed some time ago; but that was no doubt a private matter, which cannot affect the date of the new names.

Trade reasons must also account for the fact that the English editions of so many German scientific works are printed with a smaller page, into which the illustrations do not fit. But it is to be hoped that there is no real need for such works to be printed on porous paper. This is particularly unfortunate in the case of really useful books, such as the present, deserving of permanent correction and annotation.

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*The Meyer's Kinetic Theory of Gases.* OSKAR EMIL MEYER, translated from the second revised edition by ROBERT E. BAYNES. London, New York and Bombay, Longmans, Green & Co. 1899. Pp. xvi + 472.

"I undertook therefore to exhibit the kinetic theory of gases in such a way as to be more easily intelligible to wider circles, and especially to chemists and other natural philosophers to whom mathematics are not congenial. To this end I endeavored, much more than was otherwise usual, not only to develop the theory by calculation, but rather to support it by observation, and found it on experiment."

This extract from the Author's Preface, apparently written in English by the author, will be recognized by all who know his treatise in any form, old or new, as an accurate description of his work. Boltzmann, in the *Vorwort* to his *Gastheorie*, remarks: "Jedoch verfolgt das Meyer'sche Buch, so anerkannt vortrefflich es für Chemiker und Studierende der Physikalischen Chemie ist, völlig andere Zwecke." The contrast between the purpose of Meyer and that of Boltzmann is as marked now as it ever was; for the new edition of Meyer follows very closely the lines of the first. The nut is still cracked for us in the first part of the book and the kernel exposed, while the shell is carefully saved in the mathematical appendices for those who may be disposed to try their teeth upon it.

The clear yet compendious character of the treatise has made it an excellent book to consult; and it has therefore seemed to the reviewer worth while to make a somewhat detailed comparison of the new English edition with the old German one, in order to note the developments which have been made during the past twenty-three years in what may be called the physicist's, as distinguished from the mathematician's, knowledge of gases. The following quotations are accordingly selected to illustrate the most important of these changes. They touch many, but not all, interesting features of the kinetic theory. It will be seen that the time since the first edition of Meyer appeared, in 1887, has been for this theory a period of confirmation and careful improvement rather than one of revolution or rapid advance. The nature and results of intermolecular attraction, the conformation and internal properties of the molecule, these are the problems with which the theory is now engaged, and these are problems with which progress may well be slow.

In the following reviews the title of each successive chapter, up to the mathematical appendices, will be given, even when the chapter contains nothing deserving of special mention as new.

CHAPTER I.—*Foundations of the Hypothesis.*

CHAPTER II.—*Pressure of Gases.*

CHAPTER III.—*Maxwell's Law of the Unequal Distribution of Molecular Speed.*

"Its discoverer, J. Cl. Maxwell, first proved it by the assumption of a principle which, though true, itself needs proof. Since Maxwell himself recognized this defect, he later gave a second proof, the basis of which is subject to no doubt" (p. 45). "L. Boltzmann completed and perfected this proof by employing stricter mathematical work, and thus removing just ground for doubt. A further step forward [1887] we owe to H. A. Lorentz, who raised a new objection and improved the calculation, thereby inciting Boltzmann to again give a new proof [1887], which proof may now be considered as quite free from objection.

"Further, Kirchhoff has given a proof of the law in his Lectures [1894]; but against this, too, according to a remark of Boltzmann, objection may be made.

"In a different way the proof of this law was attempted in the first edition of this book. The weak points of this attempt were removed by N. N. Pirogoff [1885], and a varied form of Pirogoff's proof is given in the second of the Mathematical Appendices [of this book]" (p. 46.)

§ 34, on pressure of a gas in motion, and § 35, on reaction and cross-pressure, contain matter especially referred to in the preface as not in the first edition. They have perhaps nothing more quotable than the last paragraph of § 35, which is notable as including the only mis-translation that I have observed in the English edition. The paragraph reads, "Since these formulæ contains the velocity only in its square, they are independent of the direction of the motion, *and hold, therefore, as well for to-and-fro oscillations as for propagation of the longitudinal waves of sound.* On this depend the apparent attractions and repulsions in air when sounding and in the ribbed dust-figures of Kundt." The German of the lines which I have underscored is, "*gelten also auch für hin und her gehende Schwingungen, wie sie bei der Fortpflanzung der longitudinalen Schallwellen auftreten?*"

From § 38, on thermal effusion, "Just as effusion results from a difference of pressure at the two sides of a porous partition, so can a similar phenomenon be brought about by a difference of temperature of the two sides of a partition; and the latter phenomenon, according

to Maxwell's suggestion, is called thermal effusion.

"The possibility of in this way producing a flow of gas by means of an unequal distribution of temperature, was first pointed out by Carl Neumann when he was attempting to explain the production of a thermo-electric current by analogy with a thermal diffusion."

#### CHAPTER IV.—*Ideal and Actual Gases.*

"From numerous observations which Galitzine has partly made by himself and partly drawn from other sources, the pressure of a mixture [of gases] is sometimes greater and sometimes less than the sum of the pressures exerted by the components separately" (p. 92). § 47 deals very briefly with attempts to improve upon the formula of van der Waals's.

#### CHAPTER V.—*Molecular and Atomic Energy.*

"That monatomic gaseous molecules also may be capable of oscillatory motions in their interior we may look upon as probable, since in their spectra whole series of different lines are found. But these motions, as we may assume in accordance with E. Wiedemann's observations, require so small an expenditure of energy that its amount does not come at all into account, in comparison with the kinetic energy of the molecular motion.

"Hence monatomic molecules need in no way be rigid massive points; it is only necessary that they should be very small particles in whose interior only such motions can come into play as demand but very little energy. It therefore does not appear impossible that the ratio  $C - c = 1.67$  should be found in the case of chemically compound molecules also, if the connection of the atoms is so firm that internal motions are excluded" (p. 121).

The last quotation brings us near a very active crater of debate, the eruptions of which have been familiar to readers of English scientific periodicals for years; namely, the question of equal distribution of energy among the different degrees of freedom of a system. Into the general question Meyer does not go, but insists, as in his first edition, that, with such limited freedom as the atoms have within the molecule, the law of uniform distribution of energy among the various degrees of freedom

does not generally hold. "We shall be inclined to consider the rule, that *in gases with polyatomic molecules the mean energy of an atom is smaller than the translatory energy of a molecule*, to be a veritable law of nature, which, like Boyle's and the other laws of gases, admits exceptions under certain circumstances" (p. 130). "Since the bonds of the atoms by which they are bound together in the molecule allow of neither perfect freedom nor perfect fastness, it does not seem admissible simply to count the kinds of movability" (p. 144).

#### CHAPTER VI.—*Molecular Free Paths.*

There is little new except in § 71, where the various hypotheses to account for the observed relations between temperature and mean free path are stated and that of Sutherland is discussed at some length.

#### CHAPTER VII.—*Viscosity.*

We find (p. 187) "From these measures [by Crookes] it resulted that Maxwell's law of the constancy of the coefficient of viscosity in actual gases holds down to pressures which are so small that they can no longer be measured with accuracy. Only at a much higher rarefaction there occurs a sudden drop in the value of the coefficient of viscosity." "Just as at very low pressures, so also at very high pressures, Maxwell's law of the constancy of viscosity-coefficient loses its strict validity." A slightly smaller value of the coefficient is now given than the one stated in the first edition.

"By the entrance of more atoms into the molecule the section  $\pi s^2$  will in most cases increase, while the molecular speed will diminish; the interval  $T$  between successive collisions may therefore be constant. In this case the coefficient of viscosity must also be constant" \* \* \* "Hence all gaseous substances which contain a large number of atoms in their molecule have nearly equal coefficients of viscosity" (p. 200).

§ 80, on viscosity of gaseous mixtures, deduces from theory a formula which is followed by this passage: "Puluj has made measurements of the internal friction of mixtures of carbonic acid and hydrogen, has compared his results with the formula, and has found a really good agreement. So, too, has Breitenbach. By these observations a striking fact was con-

firmed, which was first noticed by Graham as he allowed mixtures of hydrogen with other gases to flow through capillary tubes. Although the viscosity of hydrogen is less than that of carbonic acid, a slight admixture of hydrogen has the effect of increasing and not of decreasing the viscosity of carbonic acid; nor does a diminution begin until the mixture contains a largish amount of hydrogen."

In § 85, on the influence of temperature on viscosity, the views of Sutherland in regard to the effects of molecular attraction are again made prominent. "The reasons for the assumption that the sphere of action [of the molecule] diminishes as the temperature rises have been given." \* \* \* "But in the question of actual gases, those attempts at explanation will certainly meet with most acceptance which do not assume a real diminution of the molecules or their spheres of action, but only an apparent alteration. From this point of view Sutherland's view deserves to be preferred to all others. According to him we have not to deal with the real sphere of action [that is, the sphere of which the radius is the smallest distance apart of the centres of the particles at the moment of collision], but with an apparent sphere which is [owing to intermolecular attraction] larger than the real one." "The amount of this enlargement depends on the speed with which the particles move, and, therefore, on the temperature of the gas; it is the greater the less the speed or the lower the temperature." "In bringing forward this hypothesis to explain the phenomena Sutherland had really the greatest success."

§ § 86-92, dealing with the viscosity of vapors and with viscosity as affected by dissociation, are made up of matter which did not appear in the first edition. They contain, perhaps, nothing more striking than the fact that condensation, occurring when a vapor, originally saturated, flows with some expansion through a small tube, makes the coefficient of viscosity, as estimated from rate of delivery, smaller than if the vapor were dry.

#### CHAPTER VIII.—*Diffusion.*

This chapter differs from the corresponding part of the first edition mainly by the

introduction of Sutherland's use of molecular attractions and by a more detailed effort of the author to justify, from experimental results, his own contention that the coefficient of diffusion of two gases is variable with the proportions of the mixture. "*D* therefore assumes a different value at every different place in the mixture that is being formed by the diffusion" (p. 262). He admits that his own formula for *D* makes the calculation of diffusion 'excessively laborious,' and is charitable to those who have preferred to use a more convenient though, as he maintains, inaccurate one.

#### CHAPTER IX.—*Conduction of Heat.*

In his first edition the author derives from theoretical considerations the formula

$$k = 1.530 \, \eta c,$$

where *k* is the thermal conductivity,  $\eta$  the coefficient of viscosity, and *c* the specific heat at constant volume. He now finds 1.6027 instead of 1.530. Other changes are indicated by the following quotations: "In fact, the assumption has many times been made, especially by Stefan and Boltzmann, that the kinetic energy of the molecular motion is passed on from place to place with greater speed than the remaining energy, which in Chapter V. we have termed the atomic energy. We were at that time obliged to yield to this view, because no other possibility was seen of bringing the theoretical law  $k = \frac{1}{2} \eta c$  into a complete agreement with the observations then published" (p. 284). But now, "The excellent agreement of the calculated and observed values" \* \* \* "justifies in us, on the contrary, the conviction that the accuracy of the theoretically deduced relation between the conductivity and viscosity of gases is no longer to be doubted, and that we may take it as proved that a gas has the same conductivity for every kind of energy. From this result of theory we see finally that viscosity, diffusion, and conduction of gases depend in the same way on the free path of the gaseous particles, and that each of these three phenomena may be employed to determine the value of the molecular free path" (p. 296).

#### CHAPTER X.—*Direct Properties of Molecules.*

§§ 111 and 112 of this chapter carry further than the old edition does the argument in proof of the general flatness of molecules. "These examples seem to indicate that the section of a molecule is equal to the sum of the sections of the atoms which form it" (p. 302). "If the hypothesis were general and exact that the section of the molecule of a chemical compound is equal to the sum of the sections of its atoms, it would allow of but a *single* interpretation, and thereby permit an interesting peep into the circumstances of arrangement of the atoms. We should not be at liberty to make any other assumption than that the atoms which are bound together into one molecule are all in one plane" (p. 304). "When four atoms are joined together to form a molecule it is in general no longer necessary for them to possess the property of being a plane system; the possibility, however, of the system being of such a character is shown by the example of ammonia." \* \* \* "We shall consequently be unable to make any other supposition as to the molecular constitution of ammonia than that usual with chemists, viz, that the three atoms of hydrogen are so arranged that their common centroid is always within the atom of nitrogen, and that they circle about this atom in plane orbits" (p. 305). "And so good an agreement is exhibited by the great majority of the values at 0° for gases and vapors that we have to conclude in general that *their molecules have a shape that is flat, and not spread out on all sides into space.* This view seems to be the most probable, at least for the gaseous state" (p. 309).

The last paragraph of § 116 reads thus: "From these considerations we can conclude only that the gaseous molecules are smaller than a sphere whose diameter is one-millionth of a millimetre. But we may add as very probable that the size of the gaseous molecules will in no way appear to be vanishingly small when compared with that small sphere. This is justified on many other grounds, which we have still to mention."

§ 118, on calculation of the size of the molecules from the dielectric capacity, is new. "The molecules of such substances [dielectrics] are

assumed to be good conductors of electricity, while the interspaces between them are taken to be insulating. According to this assumption the dielectric polarisation must depend on the size and distance apart of the molecules, and therefore on the same elements which regulate the molecular free path" (p. 327).

§ 123, on molecular forces, makes near the end a more detailed reference to the work of E. Wiedemann on luminous vapors. "He compared the light radiated by sodium vapor with that coming from a platinum wire made to glow by the passage of an electric current; from the resistance of the wire and the strength of the current he could determine the luminous energy in heat units, and compare it with the total heat-energy contained in the vapor. He found that the energy needed for the illumination is vanishingly small in comparison with the total energy. An atom, therefore, must be a structure in which pendulous movements can be produced by very small forces."

§ 124 is an enthusiastic statement of the general features and possibilities of the vortex atom theory. It is probable that Meyer has never seen the letter written by Lord Kelvin to the late Professor Holman, which ends thus: "We may expect that the time will come when we shall understand the nature of an atom. With great regret I abandon the idea that a mere configuration of motion suffices."

This brings us to the mathematical appendices, which extend through 112 pages. The new matter in these is, for the most part, closely connected with the changes already noted in the earlier portions of the book. In several cases the changes in numerical values of important constants are based on the computations of Conrau.

The translation is well done, though an occasional awkward phrase may show that the translator's ear for English is slightly and temporarily dulled by attention to the original. Thus, on p. 264, 'much too little for there to be found in it,' on p. 270 'has concluded the law,' and on p. 250 'relation' \* \* \* 'which' \* \* \* 'did not succeed in disclosing itself with full clearness.'

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*The Digestibility of American Feeding Stuffs.* By WHITMAN H. JORDAN and FRANK H. HALL. U. S. Department of Agricultural, Office of Experiment Station, Bulletin No. 77. Pp. 100.

Since farm animals, like man, live not upon what they eat but upon what they digest and assimilate, data on the digestibility of the various feeding stuffs are essential for judging of their relative feeding value and for calculating rations for animals under different conditions. Experiments on this subject have formed quite a feature of the work of a number of the agricultural experiment stations of this country, and these experiments have accumulated until at present they furnish a comprehensive series of digestion coefficients. The Bulletin brings together the results of these digestion experiments up to the end of 1898, and summarizes them in convenient form for use. Of the 378 experiments compiled, many of which were made with a number of animals, 59 were with green fodders (grasses and corn), 34 with silage (largely of corn), 143 with dried fodders (hay, corn fodder, etc.), 8 with roots and tubers, 24 with grains and seeds, 62 with by-products (brans, gluten feeds or meal, oil meals, etc.), 1 with milk, and 47 with mixed rations. The digestion coefficients are first arranged according to the stations at which the experiments were made. They are then grouped by classes of feeding stuffs and by the kind of animal (cow, steer, sheep, pig or horse) used in making the experiment. The latter classification gives both the individual experiments and the averages for the different classes of material. It is therefore the one which will be most generally used in practice. In the light of the data presented, the effects of various factors on digestibility are considered at some length. Under this heading are included the influence of the kind and condition of the animal used, the stage of growth of the crops, the effect of drying and curing, ensiling, grinding, cooking and moistening of the feed, etc. In many cases the need of more extended data is evident before deductions can be safely drawn.

The general methods of conducting digestion experiments are described and discussed, together with the limitations of the present