of the falls, the other works of preservation — the timber apron, the rolling dams above, and the crib which had been placed below, the falls — were described and commented upon.

Dr. C. E. Emery read a short paper, and submitted a table, showing the cost of steam engines and boilers complete, and the cost of operating the same for three hundred and nine days in the year, including repairs and renewals, and giving, upon the data assumed, the total cost per horse-power maintained continuously. He pointed out why small engines were comparatively more expensive to maintain than were large ones. The discussion of this paper was postponed until the next day.

The convention re-assembled at the state capitol on Wednesday morning. The discussion of Messrs. Farquhar and Emery's papers was first in order. The question was asked whether the amount expended in the preservation of St. Anthony's Falls would not have sufficed to establish and maintain an equivalent plant of steam-engines. Dr. Emery thought not.

Prof. T. Eggleston followed with a paper on 'An accident to steam-pipes arising from the use of blast-furnace wool.' He attributed a corrosion and subsequent explosion of steam-pipes at Columbia college to the setting-free of sulphur from the wool by the action of extremely diluted solutions of organic acids and the rapid corrosion of the pipe by the sulphuric acid, sustaining his position by reports of analyses and tests.

He was strongly opposed by Dr. Emery, who claimed that the corrosion was due to leakage and moisture, with alternate wetting and drying of the pipes, and that blast-furnace wool was entirely innocuous.

Mr. John Lawler of Prairie du Chien described the construction of the two pontoon draws in the railway-bridge across the Mississippi at that place. Each pontoon is four hundred and eight feet long, six feet deep, thirty-six feet wide on bottom, and forty-one feet wide on top. The interior details, the regulation of height of track, the means for fastening and for manoeuvring the draws, were described at length; and the cost was stated as one-sixth of the estimated cost of the usual iron swing-bridge. The bridge was built in 1874, and has been in continued use ever since. This bridge was seen from the train on the trip from Chicago.

The last paper at this session, by G. Lindenthal of Pittsburgh, Penn., was upon the rebuilding of the Monongahela bridge at that place, from his design and under his direction. The first portion of his paper entered minutely into details of the new structure, and was illustrated by tracings. The latter portion was occupied with a discussion of the old suspension-bridge, built in 1846 by John A. Roebling, the condition of the same before removal, the tests of the material removed, and the effect of the excessive overloading to which it had been exposed for years by the increasing and heavy traffic over the bridge.

After a brief discussion, the convention then adjourned; a portion of the members repairing at once to Lake Minnetonka, and the remainder going to Minneapolis, where visits were made to the Washburn flouring-mill and to the bridges.

(To be continued.)

KINETIC CONSIDERATIONS AS TO THE NATURE OF THE ATOMIC MOTIONS WHICH PROBABLY ORIGINATE RADIATIONS.[1] — I.

THE assumption that the mean kinetic energy of translation of the molecules of a gas is the measure of its temperature is one whose beautiful agreement with experiment has led to its acceptance as a necessary part of the kinetic theory of gases, and it has often led to the thoughtless conclusion that this translatory motion is also the mechanical source of the disturbances in the ether which originate radiations. But there are many difficulties in the way of accepting this view. One of the first, and perhaps the least, is the difficulty of conceiving how such a motion of translation, which is essentially longitudinal, can originate a lateral vibration, such as light and radiant heat must be.

A greater difficulty appears to be found in the extremely moderate mean velocity of translation which the molecules of a gas are found to have. Molecular velocities, which are of the same order of magnitude as that of sound or of a rifle-ball, seem hardly fitted to cause the necessary compressions or disturbances in a medium in which the rate of propagation is so immense; or, to state it in another way, if molecules, in describing their paths, originate radiations, then the motion of a rifle-ball ought also to do so, or, indeed, any much more moderate motion, such as that of a vehicle or animal.

A still further difficulty is, that there is another part of the kinetic theory which appears to be so related to this that both cannot

[1] Presented in abstract to the Section of chemistry and physics of the Ohio mechanics' institute, April 26, 1883.

be rigorously true at the same time, as appears from the following considerations. The most probable distribution of the component molecular velocities of a gas in equilibrium is the same as that of errors of observation. This distribution is brought about by fortuitous molecular encounters, and its permanence is insured by reason of them. But in case the progressive motion of a molecule gives rise to radiations, those molecules whose velocities are the greater are the hotter, and consequently radiate more heat to other molecules than they receive from them. They therefore lose part of their progressive energy before the next encounter. The whole effect would be to retard the motion of those molecules whose kinetic energy is greater than the mean, and accelerate those whose kinetic energy is less. This would cause a constant interference with the distribution of velocities according to the law of probabilities; and the interference would, so far as we are at present able to form an estimate of its amount, be sufficient to cause the kinetic energy of each molecule to approach indefinitely near its mean value during the time in which it describes a very small fraction of the mean path between two successive molecular encounters. If this is the case, the kinetic energy of any molecule does not differ for any appreciable time from its mean value, and is in effect the same during the whole path, so that there is no such distribution of velocities as has been assumed. In case the interference with the assumed law is not so complete as this, it must apparently exert an important influence upon the distribution of velocities, especially in the case of rarified gases, in which the encounters are comparatively infrequent.

Again: if the progressive motion of the molecules can originate radiations consisting of transverse vibrations, it would appear highly improbable that their rotary motion should not also do the same. But, as has been shown in a former paper,[1] the kinetic energy of translation differs from that of rotation for imperfect gases; and the temperature cannot be simply proportional to the mean rotary energy, though it might possibly be proportional to the sum of the rotary and translatory energies combined.

But aside from these difficulties, which may serve to show the intrinsic improbability of the supposition that the progressive motion of the molecules originates radiations, we seem to reach pretty decisive evidence against the supposition, when we consider the specific heats of solid bodies, or when we consider the nature of the radiation itself as revealed by the spectroscope.

The experimental law of Dulong and Petit, and the analogous results of Neumann,[1] show that in solid bodies we must consider the temperature to be measured more nearly by the energy of the atom than by that of the molecule. Now, it is hardly supposable that the translatory motion of a gaseous molecule should originate radiations, while that of a solid should not. We shall not, at this stage of the discussion, consider the spectroscopic evidence as to the nature of the motions which originate radiations, further than to notice that the characteristic spectra of gases appear wholly inexplicable, on the supposition that they are originated by translatory motions, with velocities distributed according to the law of probabilities, or with velocities reduced by radiation to an approximate equality, as it has been shown they might be; for even the simplest gases have spectra consisting of at least several lines.

If these reasons compel us to distrust the supposition that radiations originate in the progressive or rotary motions of the molecules, does the supposition that radiations originate in the vibratory motion, with respect to each other, of the atoms in the molecule, afford a better explanation of the facts? Such a motion, analogous to the elastic vibrations of a bell or other sonorous body, might very readily, perhaps, be shown, in case of a complex molecule, to have such a relation to the molecular encounters, and thus to the mean kinetic energy of translation, that its energy would be directly proportional to it for each given gas. In case this were established, such vibrations, considered as the physical cause of radiations, would explain the phenomena of gases as well as the supposition that they are due to the progressive kinetic energy; and they might possibly be shown to explain those of solids also.

But there is at least one difficulty, in the way of accepting this supposition, which seems insuperable in the case of monatomic molecules; for, if radiations could only originate in the vibrations of atoms with respect to each other within the molecule, monatomic molecules could not radiate heat at all, and could not have a temperature. That this should be true is not only inconceivable, but contrary to the known fact that monatomic mercury gas has a perfectly ascertainable temperature: hence

[1] An extension of the theorem of the virial, etc. — (*Sc. proc. Ohio mech. inst.*, March, 1883.) See also SCIENCE, i. 65.

[1] *Ann. phys. chem.*, xxiii. Wüllner's *Experimental-physik*, iii. 506.

the motions which originate radiations are not confined to such vibrations of atoms, even if it be possible that such vibrations do originate radiations. And this consideration leads us to what appears to be the truth of the matter, which is, that the atoms themselves are in a state of internal vibration. As will be seen subsequently, this internal vibration is, no doubt, accomplished under the action of internal forces, which permit extremely small deformations only of the atom by any external forces which can be brought to bear upon it; i.e., the modulus of elasticity of an atom is very large indeed, and very large, no doubt, when compared with that of the molecule. Indeed, if such vibrations exist within the atom itself, it is not difficult to prove that the force which binds the parts of an atom together (and consequently its modulus of elasticity) is much greater than the chemical force binding the atoms together into a single molecule; for it has been shown, in my paper upon the internal molecular energy of atomic vibration, that the amount of energy which can be imparted to a system like this is inversely as the modulus of elasticity. But chemical atoms are bodies which we are now supposing to be in internal vibration, but to which it has been found impossible to communicate energy in amount sufficient to cause them to fly to pieces. Since atoms do not become decomposed, while molecules do under various circumstances, it must be that their modulus of elasticity is much larger than that of molecules.

This view accords with that of Lockyer,[1] who has endeavored to explain the coincidence of lines in the spectra of different elements, and the relation of temperature to spectra, by the supposition that the so-called chemical elements are merely molecules which have never yet been decomposed by chemists. It must be admitted that the experimental evidence he adduces is of a very cogent character; and it seems to me that the demonstration by which I have shown that the mean energy of such a vibration would be extremely small explains how such a vibration can exist without decomposing the more complex atoms even at the highest artificial temperatures, though Lockyer has reason to think that they are decomposed in the hotter stars, where only the spectra of the elements of low atomic weight are to be found.

Were it true that every degree of freedom must have the same kinetic energy, we could not admit the possibility of such a vibration; for not only would such large amounts of energy be required by the degrees of freedom which seem certainly to exist between the atoms of complex molecules as to entirely contradict experimental values of the specific heat, but the supposition of additional degrees of freedom within each atom would require an amount of energy, on the whole, many times the actual specific heat of such bodies. But when the amount of energy required by such degrees of freedom is nearly a vanishing quantity, as I have shown, there is nothing to prevent us from assuming that to be the truth which spectroscopic evidence makes most probable.

We may notice, in passing, that the principle upon which this paper rests, that vibrations of this character can exist without absorbing an appreciable amount of kinetic energy, enables us to explain at the same time the extremely moderate rate at which exchanges of heat take place between bodies by radiation. They become only very slowly of the same temperature, which fact needs explanation in view of the extremely rapid propagation of radiations themselves. Now, according to our supposition, during a molecular encounter the molecules are roughly shaken, and there is a determinate distribution of energy to be found among the atoms, at its conclusion, in the form of internal atomic vibration, which distribution is due to the circumstances of the encounter. Those atoms which by chance have more energy than others radiate more rapidly; and since the velocity of radiation is so great, and the atomic distance so small, we may assume that the several atoms acquire almost instantaneously an energy of internal vibration sensibly equal to the mean, so that in a gas this is their condition during almost the entire free path of a molecule. In case the gas is becoming cooler by radiation to surrounding bodies, the atoms which radiate to these bodies lose more of their vibratory energy than they otherwise would, and thus have less mean energy of internal vibration than they should have under the law of distribution which determines what fraction this energy shall be of the mean kinetic energy of the molecules. At the next encounter, the atoms receive their proper share of the mean kinetic energy, which, being partially lost by radiation, is again supplied; and so on. And because this transformation into internal atomic vibration must take place before it can be radiated, and because at the same time the energy of this vibration is but an unappreciable fraction of

[1] Discussion of the working hypothesis, that the so-called (chemical) elements are compound bodies (*Nature*, Jan. 2 and Jan. 9, 1879). Necessity for a new departure in spectrum analysis (*Nature*, Nov. 6, 1879).

the total kinetic energy, the process of exchange by radiation is, on the whole, slow. Were, however, the translatory motion the direct cause of radiation, the exchanges between diathermous bodies must apparently be nearly instantaneous.

(*To be continued.*)

OYSTER-CULTURE IN HOLLAND.

THE first of a series of papers on the European oyster and oyster industry of the Eastern Schelde[1] has just been published by Mr. P. P. C. Hoek, secretary of the commission of the zoölogical station of the zoölogical society of Holland. It is to be followed by a series of papers gotten up in similar style by eminent specialists: 1°. On the embryology of the European oyster; 2°. On its food, parasites, and commensals; 3°. A review of the fauna of the Eastern Schelde; 4°. A report on the physical conditions presented by the Eastern Schelde; 5°. A report on experiments made to determine the conditions under which the fixation of the larval oyster occurs.

In this report the author devotes a short chapter to a discussion of the classical allusions to the animal, from the Homeric period to the time of Oppian. Then comes a chapter on the references to the oyster found in Conrad Gesner's *Historia animalium*, lib. iv., edition of 1620; followed by an exhaustive bibliography of ninety pages, in which the works of upwards of two hundred and seventy-five authors are mentioned, covering the period from 1685 to 1883, or nearly two hundred years.

Then follows a paper on the organs of generation of the oyster, by Mr. Hoek, accompanied by an excellent series of lithographic plates representing microscopic transverse sections of the European oyster. The text of this is in Dutch and French on alternate pages. A chapter is devoted to a historical *résumé* of our knowledge of the anatomy of the generative organs, and is succeeded by an account of the author's investigations.

A second part is devoted to the physiology of reproduction, and is preceded by an historical sketch of this part of the subject, from the time of Leeuenhoek to the present. The author gives a summary of his results, both anatomical and physiological, as follows: the genital gland is not a compact organ: it lies on the surface of the body of the animal under a thin layer of connective tissue (mantle), below which branched ducts spread out over the reproductive organ, connected on the inner side with the reproductive follicles, which have a generally vertical direction to the surface of the visceral mass, and which anastomose with each other. The generative products develop on the walls of the follicles, the ova and spermatozoa being formed side by side. The author inclines to the belief that the generative products are developed from the ectoderm. The ova are developed from single epithelial cells adherent to the wall of the parent follicle, while the mother-cells of the characteristic masses of spermatozoa are only portions of such cells. The organ of Bojanus does not have a compact structure as in other lamellibranchs, but is composed of a mass of ducts and blind sacs, which forms a thin flat plate of considerable extent. Contrary to what may be noted of the reproductive glands, the organ of Bojanus extends somewhat into the mantle. The ducts and cavities of the organ of Bojanus pour their contents into a longitudinal cavity, — the urinary chamber, — the walls of which are also excretory in function, and open outwardly by way of a short urinary canal. The external orifice of the renal organ opens into the same cleft as the genital duct, a little behind the latter, but they do not actually join. These genito-urinary sinuses lie below the adductor on either side of the ventral process of the body-mass. A reno-pericardiac canal connects the urinary chamber with the pericardiac cavity. It is probable that the auricles of the heart also exercise an excretory function.

An oyster which has fry in the branchiae is the parent of the same. At the moment of emission from the ovaries, not only have the ova been fertilized, but they have also passed through the first stages of segmentation. The sperm necessary for fecundation does not come from the same parent. The water which flows over other oysters in the vicinity charged with sperm, which they have set free, is carried into the mantle-cavity of egg-bearing individuals, and into their genital ducts and their branches. The oysters of the Eastern Schelde are two years old before they have brood; they are most prolific at the age of four or five years. There are more sperm-bearing oysters in the Eastern Schelde than egg-bearing ones. All of the mature eggs are laid at once; the production of sperm is probably continued for a longer time. In every instance that was investigated, the production and emission of ova is followed by a period during which no sperm is produced. A large proportion of the spat found fixed on the banks in the Eastern Schelde was probably not derived from the oysters inhabiting the cultivated beds. Culture appears to act injuriously upon the reproductive powers of the animal. In old oysters the liver is much more developed than in younger ones. This greater development of the liver is dependent upon the less marked development of the reproductive organs. J. A. RYDER.

[1] *Verslag omtrent onderzoekingen op de oester en de oestercultuur betrekking hebbende. Aflevering i.* (With title in French: *Rapport sur les recherches concernant l'huître et l'ostréiculture. Livraison i.*) Leiden, *E. J. Brill*, 1883. 253 p., 5 lithographic plates. 8°.

GALTON'S HUMAN FACULTY.

Inquiries into human faculty and its development. By FRANCIS GALTON, F.R.S. New York, *Macmillan*, 1883. 12 + 380 p., 6 pl. 8°.

MR. GALTON'S researches have for a good while attracted the attention of English and American students of psychology and anthropology. As they are here brought together,