wasting his time, but their necessary preservation strikes at a still more vital point in using up funds which could otherwise be employed for the publication of the results of researches. They also equally interfere with the purchase of delicate instruments, the employment of labor to directly assist in carrying out the purposes of research, prevent the purchase of such specimens or collections as may be essential, and cut off opportunities for travel and study in other museums or parts of the world.

We think, therefore, that, while the National museum may open some paths to the investigator, it will neither directly do the very best work in this direction, nor give us any grounds for believing that it will introduce a new era of prosperity for abstract investigation. It will add one more to the useful scientific institutions of its kind, it will undoubtedly contribute to the progress of science by increasing the opportunities for employment and by the example of its officers; but it will not do much for them or for us in the way of an exalted ideal.

If the museum of education had been limited by a wise policy of selection in its accumulations of materials, and placed under a distinct staff, we could have made no such objections; then the practical objects of its existence would not have suffered, as they now surely will, from the psychological tendencies of the investigating curators; nor, on the other hand, would the investigators themselves have been distracted by having a double purpose in all that they were doing, and frequently obliged to sacrifice one or the other. We do not wish to imply that the museums should not be under one general head, and have all the benefits of mutual association, but simply insist that the ideals are quite distinct, and the officers should realize this by being under different regulations, and under a different government, in each of the two museums. The investigator cannot avoid placing on exhibition the record of his own and others' work; and he will find a thousand good reasons for crowding the cases with fine collections, because they are fine, and because they are important in research, or unique, or remarkable; and the educational idea will be subordinate or completely lost in such parts of the museum, so far as the average student is concerned.

The cost of the museum will be enormous; but if its lessons can be easily mastered by the average student, and in this case the student is the average congressman, he will not begrudge the funds which are necessary for its support. It must be remembered that these are keen men, quick to see the advantages of such lessons as the museum can teach them; especially if, like the library, it can make itself really useful to them, and keep up with the times by illustrating the new results of discovery and research in all departments of learning in an explanatory and popular way. We imagine that they will not be slow in calling upon the officers of the museum whenever they have need of their services, and that they will be rather disgusted if any of the requirements of research interfere with their desire for information.

While we wish the greatest success to the National museum and its energetic and deservedly popular director, and have the highest respect and friendliest feeling towards their undertaking, and a faith that they will finally work out a better result than is promised, we think that neither this faith nor their great scientific achievements, of which we are justly proud, nor the liberality of the government, can entirely make up for the absence of the public recognition of a more purely scientific ideal in *our* National museum.

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

HAVING now sufficiently cleared the field of inquiry by this preliminary discussion, let us consider the proposed hypothesis somewhat more closely, both as to what it is precisely, and as to how far it is in accordance with the phenomena. The whole outcome of Lockyer's investigations, to which we have referred, leads to the conclusion that atoms of the chemical elements are complex bodies, all of which

[1] Concluded from No. 24. See also *Proc. Ohio mech. inst.*, ii. 89.

are formed of ultimate atoms of the same kind; so that, on this hypothesis, there is but one kind of substance from which all others are compounded. Chemical atoms might be compared to a chime of bells all cast from the same material, but each having its own special series of harmonic vibrations.

A necessary result flowing from this hypothesis would be, that the atomic weights should all be exact multiples of some fraction of the atomic weight of hydrogen, which would include Prout's hypothesis as a particular case. The experimental data are, perhaps, not yet sufficiently precise to enable us to obtain a trustworthy result as to the probability of the truth of Prout's hypothesis; yet Clarke's[1] results as to the atomic weights seem to show that the hypothesis has a high degree of probability.

If the chemical atoms of all bodies are assumed to be formed of ultimate atoms, which are in all respects equal and alike, this hypothesis furnishes a basis for investigation at once definite and simple, some of whose consequences we shall now endeavor to show to be in accordance with experimental facts.

We wish, in the first place, to show that this hypothesis will make the temperature of a gas proportional to its mean kinetic energy. A chemical atom may be assumed to be a perfectly elastic body, as its deformation is assumed to be extremely small. But according to the mathematical theory of elastic impact,[2] "when two such bodies come into collision, sometimes with greater and sometimes with less mutual velocity, but with other circumstances similar, the velocities of all particles of either body at corresponding times of the impacts will always be in the same proportion;" from which it is clear, that in a mixture of two kinds of gas, as hydrogen and oxygen for example, when the mean velocity of the molecules is so increased that the vibration of the ultimate atoms of the hydrogen is increased a certain per cent, then that of the ultimate atoms of the oxygen is increased by the same per cent. But the circumstances of the encounters and the forces acting between the ulitmate molecules determine what fraction the mean kinetic energy of vibration of the ultimate atoms shall be of that of the molecules whose encounters cause these vibrations. Since the circumstances attending the encounters are dependent simply upon the forces acting between the ultimate atoms assumed to be in all respects equal, the energy of their vibration will be the same in an atom of hydrogen as it is in an atom of oxygen; for each degree of freedom of every ultimate atom of either element is similarly circumstanced, both as regards forces between itself and other ultimate atoms of the same chemical atom, and also as regards the impacts of other molecules. The proposition of the kinetic theory which makes the energy of each degree of freedom the same, which has been erroneously applied to the degrees of freedom of molecules, can therefore be correctly applied to the ultimate atoms.

But it might not, at first glance, be apparent whether these vibrations are caused by, and are proportional to, the mean progressive energy of the molecules, or to their rotary energy combined with it. But it is not difficult to show that the vibrations of the chemical atoms with respect to each other are proportional to the mean progressive energy alone, and then to show the same for the ultimate atoms. Although, in the paper upon the vibratory motions of atoms within the molecule, we have for mathematical purposes considered the centrifugal force as causing vibrations of atoms with respect to each other, yet in fact the vibrations so caused are vanishing quantities, compared with those caused by the component of the impulsive force acting during an encounter along the line joining the atoms of a molecule. The magnitude of such a vibration, other things being equal, depends upon the suddenness of the impulse; and the suddenness of the force called into play during a change of rotary velocity, by deviation from motion in a tangent to motion in a circle, can bear no comparison to the suddenness of a direct impulse along the radius of the circle. Hence the direct impulse due to the progressive motion need alone be considered.

It thus appears that the energy of vibration of chemical atoms with respect to each other in a simple gas is proportional to its mean progressive energy. The same is true of the vibrations, with respect to each other, of the ultimate atoms which form a chemical atom, and for the same reasons; for the forces which act upon the ultimate atoms are the impulses due to the encounters of other molecules, and those due to the remaining chemical atoms of the same molecule. The energy of the latter of these motions is proportional to the former, as has just been shown; hence their sum is so also: therefore the energy exerted to deform a chemical molecule, and set it in vibration, is proportional to the mean progressive energy.

[1] Constants of nature, part v. A recalculation of the atomic weights. Washington, 1882.
[2] Thomson and Tait's Natural philosophy, 1867, art. 302.

But it is to be noticed that the impulses due to the vibrations of the chemical atoms within a molecule are vastly more frequent than the molecular impulses; and it appears probable that the vibrations of the chemical atoms set up during an encounter will rapidly decay, even in case they do not themselves directly originate radiations. The vibratory energy of this kind may then be changed almost instantly into that of vibration of the ultimate atoms.

According to the hypothesis which we are now considering, the temperature of the body and the intensity of the radiation depend solely on the vibratory energy of the ultimate atoms; but, since these ultimate atoms are assumed to be in all respects equal, they vibrate under the action of the same forces, and have the same degrees of freedom and constraint within the chemical atoms of one element as they do within those of a different element. Hence it appears, that if the ultimate atoms of two different gases have the same vibratory energy (i.e., cause vibrations of the same intensity), so that the flow of radiant energy is the same from all the ultimate atoms of each gas, then there will be no disturbance of this equilibrium when these gases are mixed; in which case the distribution of energy is effected by molecular encounters, which distribute equal mean amounts of energy to each molecule, instead of by radiations, which distribute equal mean amounts of energy to each ultimate atom.

In attempting to account for the high specific heat of liquids, I have elsewhere given reasons for supposing that it is due to a certain per cent of dissociation, which increases with the temperature. It appears probable, that, although some small amount of dissociation may exist in gases also, there is not so large a per cent as in the liquid state, nor does the per cent necessarily increase with the temperature; for by reason of the free progressive motion in a gas, which does not exist in a liquid, any dissociated atoms have a much better opportunity to recombine; and, as the velocities (especially those of free atoms) increase with the temperature, these opportunities increase, as well as the number of dissociations occurring in a unit of time; so that, at a high temperature, an atom of gas may not stay dissociated so long as at a lower temperature, while in a liquid this interval will not be sensibly affected by the temperature.

It is thought that the law of Dulong and Petit receives reasonable explanation on the hypothesis that the ultimate atoms have each the same kinetic energy at the same temperature, as will be shown in a subsequent paper; but, perhaps the strongest direct evidence in favor of the proposed hypothesis is found in the fact that even the simplest elements, such as hydrogen or mercury, have spectra of several lines at least, showing that the source of the light must be sufficiently complex to be able to vibrate in a number of different ways, such as may well be possible for an atom formed of a number of ultimate atoms, but such as is inconceivable in a molecule consisting of one or two perfectly hard atoms. H. T. Eddy.

THE NATIONAL RAILWAY EXPOSITION.[1] — IV.

The exhibit of locomotives was remarkably complete, and comprised engines differing widely in size and power, and adapted for every variety of work; but a certain uniformity of the design of the main features would seem to indicate that locomotive practice has settled down into a certain groove, and that the methods of construction now adopted are so satisfactory that few exhibiters propose to greatly improve upon them by any radical alterations, though one or two of these new departures, such as the Wootten firebox and the Stevens valve-gear, seem likely to come into extensive use.

The main tendency of locomotive design seems to run rather in the direction of larger bearing surfaces and stronger working parts than in any novel methods of construction; while sound and accurate workmanship, and plenty of good material judiciously distributed, are relied on to make a locomotive durable, hard-working, and trustworthy under trying conditions.

Mr. E. Shay of Haring, Mich., exhibits a model of an engine of peculiar construction for 'logging' purposes. These small railways are exceedingly light in construction, and the rails and ties are generally laid directly on the surface of the ground, without any great attention being paid to preliminary grading or alignment; and therefore a suitable locomotive must unite considerable tractive power with great flexibility of wheel-base, and a small weight, on any one pair of wheels. Mr. Shay accomplishes this by using a Forney type of locomotive, having a pair of drivers under the barrel of the boiler, and a four-wheel truck, carrying the tank and fuel, behind the firebox. All the wheels being made of the same diameter, a pair of vertical engines are secured to one side of the firebox, working a longitudinal shaft which

[1] Continued from No. 25.