for the great body of our fellow creatures that high improvement, which both their understanding and their morals fit them to receive, is an object sufficiently brilliant to allure the noblest ambition. Without claiming such lofty aspirations, the promoters of "SCIENCE" yet look forward to the time when their efforts to establish this journal may be recognized as at least a step in that direction.

ON THE AMPLITUDE OF VIBRATION OF ATOMS.

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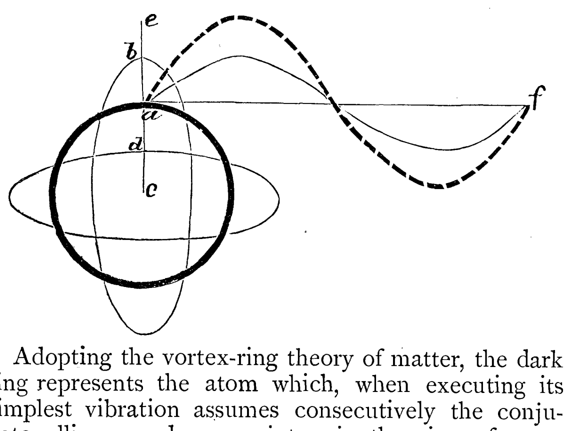
There is now sufficient evidence for the belief that the kinetic energy of atoms and molecules consists of two parts, one of which is the energy of translation or free path, the other of a change of form due to vibrations of the parts of the atom or molecule toward or away from its centre of mass. The pressure of a gas is immediately due to the former while the temperature of the gas depends solely upon the latter. These two forms of energy must indeed be equal to each other in a gas under uniform conditions; for if one exceeded the other in energy when there is as free a chance for exchange as among the atoms of a gas, there would result an increase of pressure on the one hand, or an increase of temperature on the other. Now the kinetic energy of a mass m and velocity v is expressed by $\frac{m v^2}{2}$ and applies as well to an atom as to a musket bullet, and if we take the mass of the hydrogen atom as unity and employ the calculated velocity of hydrogen atoms at 0° Cent. and 760 mm. pressure, namely 1860 metres per second, the energy will be $\frac{(1860)^2}{2}$.

We know also how many times the hydrogen atom vibrates per second, by dividing the velocity of light per second by some chosen wave length λ; so that $n = \frac{v}{\lambda}$. If attention be now directed to the vibrating atom possessing the same energy as in the free path movement, it will be seen that its *velocity of vibration* must also be equal to 1860 metres per second. But vibratory velocity is the product of a number n into an amplitude a, so that $v = na = 1860$.



Adopting the vortex-ring theory of matter, the dark ring represents the atom which, when executing its simplest vibration assumes consecutively the conjugate ellipses and any point a in the circumference will move over the line $b\,d$, the latter distance constituting the amplitude of the vibration. The limits to this movement must clearly be between $b\,d = 0$ when there is no vibration, the absolute zero of the atom and $c\,e$ which can never exceed $\frac{1}{2}\,\pi r$ and indeed must always be less than that value; for when half the major axis of the ellipse is equal to that it has become a straight line. As atomic vibrations result in undulations in ether it is evident that amplitude $b\,d$ will give an undulation $a\,f$ shown in continuous line, while maximum amplitude $c\,e$ would give same wave length shown in broken line. The greater the actual thickness of the ring the less must be the possible maximum amplitude.

The amplitude then becomes comparable with the diameter of the atom, and in this discussion the assumed diameter is the one given by Maxwell, namely .0000005 mm.

The numerical value of $\frac{1}{2}\,\pi r$ for such a diameter is .0000004 mm. which represents the theoretical maximum amplitude for a hydrogen atom.

If any hydrogen wave length be taken, say $C =$ .0006562 mm. the ratio of wave length to maximum amplitude is $\frac{.0006562}{.0000004} = 1640$, that is wave length is 1640 times such amplitude. But hydrogen C is not the fundamental vibration, but according to Stoney is the 20th harmonic of a fundamental having a wave length of .013127714 mm. and $\frac{.013127714}{.0000004} = 32819$. That is, it is 32819 times greater than the amplitude.

Now, Sir William Thomson, in his calculations on the amount of energy in the ether, assumed that the amplitude should not exceed one-hundredth of the wave length, but that value is evidently very many times too large. An undulation with the wave length of this fundamental for hydrogen is nearly twenty times longer than the longest one that can be seen; and as the sensation of light depends upon wave length and not upon amplitude, or what the energy of the ray, it follows that Dr. Drapers' deductions concerning the temperature of bodies beginning to be luminous will not necessarily apply to gases, for when extra energy is imparted to the atoms of a gas it is the amplitude of their vibrations that is affected, and if the impacts are sufficiently frequent some of the harmonic vibrations may appear continously, but they will not thereby necessarily indicate a higher temperature, but show that the energy is distributed in two or more periods, some of which have resulting undulations which may be seen; but this will depend upon the density of the gas. Suppose a body capable of vibrating a times per second for its fundamental, be struck b times per second; then will the rate of vibration be interfered with $\frac{a}{b}$ times. If b be less than a, then will the fundamental vibration have more than its required interval between impacts, and a certain number of these fundamental vibrations will be made per second. If b be equal to a, then, after the first impact, a will vibrate in its own period with increasing amplitude, without interference. If b be greater than a then will the impacts interfere in all phases of the vibrations, the fundamental will be destroyed, and only some harmonics and irregular vibrations will be possible; but the number of impacts per second depends upon the density, and in solids and liquids this secures the destruction of the fundamental vibrations as the energy of vibration is increased, at the same time developing the multitude of irregular ones shown in the spectrum; while in a gas the number of impacts per second is many times less than the regular rate of vibration, and this secures the time for either fundamental or harmonics, and the consequent spectra. The number of vibrations *n* the hydrogen atom makes when the wave length is .0131277 mm. will be $n = \frac{v}{\lambda} = \frac{3\times10^{11}}{.131277} = 2286\times10^{10}$.

Let v^1 represent the velocity in free path motion of the atom at 0° Cent. and 760 mm. pressure = 1860000 mm. Their amplitude *a* will equal $\frac{v^1}{n} = \frac{1860000}{2286\times10^{10}} = 8134\times10^{-11}$ m. Comparing this with the diameter of the atom $\frac{8134\times10^{-8}}{5\times10^{-7}} = .162$. That is the amplitude is equal to .162, the diameter of the atom at 0°.

Assuming a temperature higher than this, say 273° Cent., then the energy of the atom in its free path motion compared with that it has at 0° will be as $\sqrt{2} : 1$ and $1 : \sqrt{2} :: 1860 : 2630$ m. per second, and as before amplitude *a* will equal $\frac{v^1}{n} = \frac{2630000}{2286\times10^{10}} = 115\times10^{-7}$. This compared with the diameter of the atom gives $\frac{115\times10^{-7}}{5\times10^{-7}} = .23$. That is, the amplitude is equal to .23 the diameter at 273° Cent., a difference of .068 for 273°.

With same data the maximum temperature of the hydrogen atom may be calculated for as

$$(.162)^2 : (.7854)^2 :: 273^\circ : 6419^\circ$$

which would be the highest temperature the atom could have if it could have such an amplitude, and this will be reduced as the thickness of the ring increases. Any additional energy the atom would receive could not possibly heat it but would be expended either in rotating it or in giving to it a free path motion. In like manner the amplitude for a single degree is found to be .0098 diameter, or very nearly one-hundredth the diameter.

For other atoms than hydrogen when they have the same energy their amplitude must vary inversely as their mass, so that for oxygen the amplitude at 273 would be $\frac{.162}{16} = .01$ its diameter, and its maximum temperature will be $6419\times16 = 102704^\circ$ Cent., a number altogether too high for the same reason as was given for hydrogen, namely it assumes that the ring has no thickness.

If these computations have any value they may be applied to the solution of the temperature of the sun.

The elements having the greatest density must have the highest maximum temperature. In the sun twenty-five elements have been determined spectroscopically and the average density of these twenty-five is 63. Now on the hypothesis that these elements exist in equal quantities in the sun, which is not very probable, the maximum temperature of that body woulp be about 400000° Cent.

As at absolute zero each atom is quite independent of every other atom, that is, matter has not a molecular structure, so, at certain high temperatures that differ for different substances, all molecular groupings must be broken up and the atoms are quite dissociated from each other, and this dissociation must occur before the maximum temperature is reached; it would appear that whenever at the sun the temperature approached its maximum, then the elements would be elementary, uncombined, and if compounds are observed or appear probable from phenomena witnessed, that will be the best evidence that the temperature is decidedly lower than the above figure. For hydrogen the dissociation temperature is only about 700° Cent. which is only about one-ninth its maximum.

MARSH'S ODONTORNITHES.*

Were there no other proofs of his zeal and success in extending the bounds of knowledge, the writer of this magnificent monograph would be famous as—for ten years at least,—the sole discoverer, describer and possessor of the remains of Extinct Toothed Birds of North America.

It may befall almost any diligent explorer to find the remains of some species previously unknown, but few have had— or so well-deserved—the privilege of presenting to the world a new series of facts embodying a new idea, at once easily appreciated by the many, and serving the few as material for profound consideration. That a bird with teeth is, most literally, a *rara avis*, may be conceded without extensive acquaintance with either Latin or Ornithology; on the other hand, it is probable that naturalists have not yet wholly realized the import of this fulfillment of a prediction which might have been made legitimately—though we are not certain that it ever was —at any time during the last twenty years.

Aside from the Appendix, the present volume embraces detailed descriptions of the bones and teeth of *Hesperornis* and *Ichthyornis;* a general description of the "Restoration" of each genus; and a "Conclusion" embracing the author's views upon the taxonomic relations, and probable evolution of these two forms, together with *Archæopteryx.*

The following are the principal characteristics of the two American genera, chiefly as recapitulated upon p. 187. In *Hesperornis*, the articular ends of the vertebral centra are saddle-shaped, as in recent birds; in *Ichthyornis* they are biconcave, as in many fishes: *Ichthyornis* has a prominent sternal keel for the attachment of the muscles of the well-developed wings; in *Hesperornis*, the sternum is without a keel, and each wing is represented by only a rudimentary humerus: the wing-bones of *Ichthyornis* have tubercles evidently for the attachment of feathers; no signs of feathers have been observed with *Hesperornis*, but they doubtless were present in life: in both genera, the caudal vertebræ are few, so that the bony tail is short as in recent birds: in both, the mandibular rami seem to have remained permanently ununited by bone: in both, as indicated by casts of the cranial cavity, the prosencephalon was narrower than in recent birds of

*Odontornithes: A Monograph on the Extinct Toothed Birds of North America; with thirty-four plates, and forty woodcuts. With an Appendix giving a Synopsis of American Cretaceous Birds. By Othniel Charles Marsh, Professor of Palæontology in Yale College, Memoirs of the Peabody Museum of Yale College, vol. 1; pp. 201. This memoir will also form vol. vii, Survey of the 40th parallel.