A large number of molecular diameters have been calculated in this way and the data obtained will be discussed in a further paper.

TABLE V.

Molecular Diameters.

Substance.	From $\rho_0 = e^{3/2}\rho_c$.	From Viscosity Measurements. (a)	(b) Sutherland.
Hydrogen	2·88	2·47	2·17
Helium	2·82	2·18	1·92
Argon.................	3·03	3·36	2·66
Nitrogen	3·21	3·50	2·95
Oxygen	3·01	3·39	2·71
Nitrous Oxide	3·30	4·27	3·33
Carbon Monoxide...	3·21	3·50	2·74
Carbon Dioxide ...	3·27	4·18	2·90

Summary.

It is shown that the density ρ of a fluid can be represented by the equation

$$\rho^{1/3} - \alpha T \log \rho^{1/3} = \rho_1^{1/3} - \alpha T \log \rho_0^{1/3},$$

where ρ_0 is the "maximum" density of the substance, and ρ_1 and α are constants. Further $\alpha = \rho_c^{1/3}/T_c$, where the subscript denotes data at the critical temperature.

It is shown that $\rho_1^{1/3} = \frac{3}{2}\rho_c^{1/3}$ and $\rho_0^{1/3} = e^{1/2}\rho_c^{1/3}$. A "reduced" equation containing no constants peculiar to a particular substance is also obtained. These equations hold very closely for liquids, approximately for saturated vapours.

The internal latent heat of vaporization L_i is discussed and it is shown that Mills's Equation $L_i = K(\rho^{1/3} - \sigma^{1/3})$ (ρ = density of liquid, σ = that of vapour) can be deduced from kinetic considerations and does not depend as he supposed upon an inverse square law for intermolecular attractions.

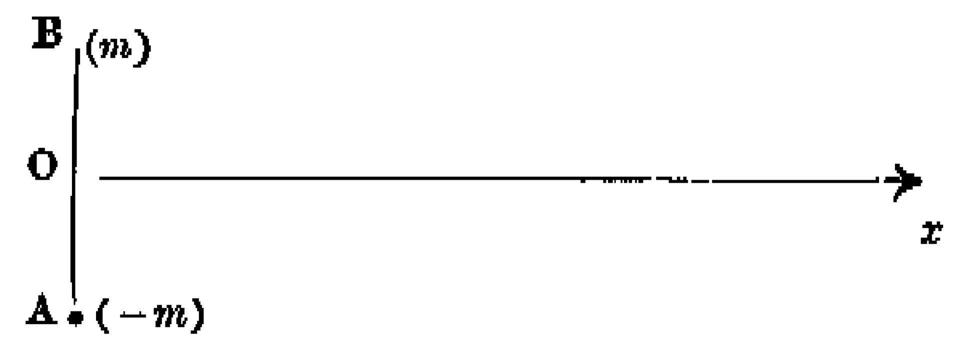
From the "maximum" density ρ_0 the diameters of molecules can be estimated.

CVI. *On a Simple Light-Quantum.*

By Prof. E. T. WHITTAKER, *F.R.S.**

THE light-quantum described below is a solution of the ordinary Maxwell's equations of the electromagnetic field, and therefore behaves in accordance with the "classical" theory so far as refraction, interference, polarization, etc., are concerned. But it has the property, which is required for "quantum" phenomena, that if, after it has travelled any distance, however great, from its source, it encounters an atom, then the atom will in certain cases absorb *the whole* of the energy of the light-quantum, even though that energy was, immediately before the encounter, distributed over a very large region of space.

Consider first an ordinary elementary magnetic molecule at a point O, whose axis is in the line AB. We shall for the moment regard this in the old-fashioned way as the limit of



a positive magnetic charge m at the point B, together with a negative magnetic charge $-m$ at the point A. This molecule sets up a magnetic field extending over all space.

The ordinary law of action of magnetic charges asserts that the charges at A and B attract each other, so they must be supposed to be kept apart by some arrangement in the material molecule in which they are embedded.

Now, let Ox be a direction at right angles to AB, and suppose that the magnetic molecule is set in motion in the direction Ox. Since a moving magnet generates an electric field which can act on another moving magnet, the force between the charges A and B is now affected by this additional force, which diminishes the original force between them. As the velocity of the magnetic molecule along Ox increases, the total force between the two charges continually decreases, until in the limit when the molecule is moving with the velocity of light, the force is exactly null: the electromagnetic force due to the motion exactly neutralizes the purely magnetic force. Thus if the molecule is moving

* Communicated by the Author.

with the velocity of light, we have no longer any need of the material framework to keep the two charges apart, and we can suppose the charges completely disembodied.

Now consider what has happened to the field. As was shown long ago by Heaviside, when the molecule is set in motion in the direction Ox, the lines of magnetic force due to the molecule tend to draw in nearer to the molecule so far as the direction Ox is concerned, so that they concentrate towards the plane through O perpendicular to Ox; until in the limit, when the velocity of the molecule is the velocity of light, the lines of force are entirely confined to this plane (which, of course, is travelling with the velocity of light), the field in the rest of space being null. There will now be lines of electric force (due to the motion of the magnetic charges) as well as lines of magnetic force, and the lines of electric force will be everywhere perpendicular to the lines of magnetic force: in short, what we now have is essentially a plane wave of ordinary light. The original magnetostatic field has become a plane wave of light, by merely setting it in motion with the velocity of light.

This plane wave of light, however, will have two peculiarities which distinguish it from the plane wave of light of the ordinary text-books. In the first place, the intensity of the disturbance is not the same over the whole of the infinite plane wave-front, but diminishes as we go outwards from the centre O of the plane, and is null at infinity. This is a satisfactory feature, since Baldwin and Jeffery have shown recently * that the old-fashioned plane-wave, with its intensity the same all over its infinite front, is an impossibility in general relativity. In the second place, our wave has a singularity at the point O, representing, in fact, the disembodied form of the magnetic molecules with which we started. This singularity we shall call the "*speck*" on the wave-front.

As a matter of fact, if we take the axis of z along AOB, and take an axis of y at right angles to the axes of x and z, then the electric force (E_x, E_y, E_z) and the magnetic force (H_x, H_y, H_z) in the wave-front are given by the equations

$$E_x=0, \qquad E_y=\frac{\partial}{\partial z}\left(\frac{z}{y^2+z^2}\right), \qquad E_z=-\frac{\partial}{\partial y}\left(\frac{z}{y^2+z^2}\right),$$

$$H_x=0, \qquad H_y=-E_z, \qquad H_z=E_y,$$

and this field satisfies Maxwell's equations, except at the point $(y=0, z=0)$, which is the "speck."

* Proc. Roy. Soc. cxi. p. 95 (1916).

It is the "speck" which confers on the wave the desired "quantum" properties, for in the original magnetostatic field, anyone who takes hold of the magnetic molecule and moves it about, thereby moves the whole of the magnetic field; the magnetic field is, so to speak, led captive by the magnetic molecule. This property—that the whole field is an appanage of the magnetic molecule and can be carried about with it—still persists in the limiting case which we have considered, in which the magnetic molecule has shed its materiality and has become the "speck" on the wave-front of the light: it is still true that anyone who can take hold of and capture the "speck" thereby captures the whole of the energy in the light-wave, which is really a mere appanage of the "speck."

Now the "speck" retains the property possessed by the original magnetic molecule, of being acted on by magnetic forces (and, since it is in motion, by electric forces also); and therefore, if the "speck" happens to impinge on an atom, or to pass very near to one, there is a possibility that the speck may be attracted into the atom and swallowed up and, so to speak, digested by it. The result will be that *the whole* of the energy in the light-wave will now have become the property of the atom: it may be partly located in the space outside the atom, but it belongs to the atom in the sense that wherever the atom moves, this bundle of energy henceforth moves with it. Thus the theorem which Einstein many years ago deduced from thermodynamic reasoning, namely, that *every parcel of light-energy which is emitted from an atom is ultimately entirely absorbed by a single other atom* is here seen to be a consequence of the strict classical electromagnetic theory of light. If this fact has not been clearly perceived before, it is because the expounders of the classical theory have been led astray by that artificial and (as we now know) physically impossible creation of mathematical analysis, the infinite plane-wave of light.

October 4th, 1926.