Number of Molecules in Unit Volume of a Gas.

THE following is an attempt to calculate the number of molecules of helium in unit volume directly, that is, without assuming Avogadro's hypothesis and the known value of the number of molecules of any gas per unit volume.

Various methods can be adopted leading to the five results given below:—

(a) Meyer, in his "Kinetic Theory of Gases," has calculated the molecular free path of helium at 0° and atmospheric pressure to be $L = 24 \times 10^{-8}$ cm. ("Kinetic Theory of Gases," p. 194, second edition).

Now let Q = sum of the diametral sections of the spheres of all the molecules contained in unit volume, then, by the formula

$$Q = 1/4 \sqrt{2} L \dots \dots \dots (1)$$

we calculate Q for helium = 7402 sq. cm. nearly.

It is also proved in treatises on the kinetic theory that $S = 6\sqrt{2} \nu L$, where S = radius of the sphere of action of the molecule, ν = space actually occupied by the molecules contained in unit volume or the coefficient of condensation. Now this coefficient of condensation is always less than the ratio E of the densities of the substance in the gaseous and liquid states, so that, putting E for ν in the above formula, we shall get the superior limit to the value of S . We have then $E_{\text{Helium}} = \Delta/\delta$, where Δ, δ are the densities of helium in the gaseous and liquid states. Putting $\delta = 0.15$ (Onnes), we have

$$S_{\text{He}} = 2.4 \times 10^{-7} \text{ cm.} \dots \dots \dots (2)$$

(b) This value is probably high, and Meyer has shown that a method involving deviations of the gas from Boyle's law is more accurate. Onnes gives the value 0.0007 for b in van der Waals's equation for helium (quoted in NATURE, October 22, 1908, p. 635). Accordingly, assuming Maxwell's relation $b = 4u$, where u = co-volume or volume actually occupied by the molecules per unit volume, we get the known formula $S = (3/\sqrt{2})pbL$, where p = pressure in metres of mercury, for which the value of L which is employed holds good. We have, then,

$$S_{\text{He}} = 2.5 \times 10^{-8} \text{ cm. nearly} \dots \dots \dots (3)$$

(c) Adopting the relation $b = 4\sqrt{2}u$ instead of Maxwell's, we get

$$S_{\text{He}} = 1.76 \times 10^{-8} \text{ cm. nearly} \dots \dots \dots (4)$$

This calculation has, it seems, a claim to greater accuracy, since the relation $b = 4\sqrt{2}u$ has been confirmed experimentally by Holborn (Exner's Report, 1891, xxvii., p. 369) and by Sydney (Chem. News, 1898, lxxviii., p. 200).

(d) Calculating S_{He} by another method, which has been found, in many cases, to give an inferior limit to the value of S from the formula $g = (\mu^2 - 1)/(\mu^2 + 2)$, where g = fraction of the volume containing the gas which its molecules actually occupy, and μ = index of refraction. Hence, replacing ν by g in Loschmidt's formula, we have

$$S = 6\sqrt{2}gL.$$

Taking data from the paper by Cuthbertson and Metcalfe (Phil. Trans., A, vol. ccvii., p. 138, 1907), we get

$$g = \frac{3}{2}(\mu - 1) = 37 \times 10^{-6}$$

nearly, whence

$$S_{\text{He}} = 0.5 \times 10^{-8} \text{ cm. nearly} \dots \dots \dots (5)$$

(e) Lord Kelvin found that there must be from 200 to 600 molecules in the volume of one wave-length of the light emitted by the body. Taking the lower limit, 200, the mean distance between molecules is found to be

$$x = 5 \times 10^{-3} \times 5876 \times 10^{-8} \text{ cm.} \dots \dots \dots (6)$$

If N = number of molecules per unit volume, we find

$$\begin{aligned} N_{\text{He}} &= 0.017 \times 10^{19} \text{ nearly from (1) and (2)} \\ &= 1.4 \times 10^{19} \quad \quad \quad \text{,, (1) and (3)} \\ &= 2.8 \times 10^{19} \quad \quad \quad \text{,, (1) and (4)} \\ &= 36 \times 10^{19} \quad \quad \quad \text{,, (1) and (5)} \\ &= 4 \times 10^{19} \quad \quad \quad \text{,, Equ. (6). } N\lambda^3 = 1. \end{aligned}$$

Comparing these values of N for helium, we see that the value obtained from the density of liquid helium is very low, whereas the refractivity method gives a very high value. Greater accuracy seems to belong

to those obtained from van der Waals's equation; of these two, the latter value obtained from $b = 4\sqrt{2}$ is probably the best. Hence, no doubt, it is safest to adopt 2.8×10^{19} as the value of N . It is interesting to compare with this the value of N as obtained by Rutherford and Geiger from their recent counting experiment (NATURE, November 5, 1908, p. 14), viz. $N = 2.72 \times 10^{19}$.

P. GHOSE.

Physical Laboratory, Presidency College,
Calcutta, January 14.

An Electromagnetic Problem.

I AM glad to get Mr. Campbell's views (NATURE, January 21) on the electromagnetic problem which I submitted (NATURE, November 19, 1908). His method of going back to fundamental definitions is, of course, in general the only safe way where any doubt may enter.

His remarks, however, considered as an answer to my question, are not quite to the point. As I carefully stated in the original letter, I am not desirous of setting up a conservation of energy paradox, but merely wish to show that apparently the ordinary expression for the energy of any electromagnetic field is, in the present case, not in harmony with the first law of energy. The accepted expression for the energy in any electromagnetic field is

$$\frac{1}{8\pi} \int (E^2 + H^2) d\tau,$$

where E is the force in dynes on a unit stationary test charge, H the force in dynes on a unit stationary "magnetic pole," and $d\tau$ is the element of volume. The test charge and pole are not parts of the system.

This expression for the energy does not appear to remain constant while the sphere of electricity is allowed to expand under the mutual repulsion of its parts, for the magnetic force on the test pole is obviously always zero, while the region of integration for E^2 is constantly diminishing. The difficulty, then, is with this generally accepted expression for the energy, and this is the only difficulty to which I refer.

D. F. COMSTOCK.

Institute of Technology, Boston, Mass., February 10.

I AM sorry if I have misunderstood Prof. Comstock, but many others besides myself thought that he maintained that the difficulty vanished in some way if the distribution of the electrification on the sphere was discontinuous. My letter was directed against this contention.

I do not know how the integral expression for the energy is "generally" interpreted, but if it is interpreted with intelligence it will give perfectly accurate results. The system by which Prof. Comstock measures the electrostatic energy is a uniform distribution of "test points" throughout space. When the sphere expands the "region of integration" diminishes, since some of the points pass within the sphere; but the loss of energy, as calculated by the integral due to this cause, is balanced by the amount of work which the sphere does in passing over these points. If we do not neglect to consider this work, the ordinary integral gives the amount of electrostatic energy whether the distribution on the sphere is continuous or not.

NORMAN R. CAMPBELL.

Trinity College, Cambridge, February 24.

The Production of Prolonged Apnoea in Man.

IN NATURE of March 4 Mr. Royal-Dawson recalls a statement of Faraday to the effect that Mr. Brunel, jun., and a companion were able to stay under water about twice as long as usual if they had previously been breathing air at double the normal atmospheric pressure, and he inquires whether a similar relationship might not hold after forced breathing and oxygen inhalation, and so enable the maximum time of 8m. 13s. for which I could hold my breath under such conditions to be doubled. Increased pressure would, as a matter of fact, have scarcely any influence. As I pointed out in my letter of February 18, the essential conditions of prolonged apnoea are a previous removal of as much carbon dioxide as possible from the