

As a result of this investigation at first hand, Dr. Foster was convinced that Dr. Knowlton and the other men of the faculty at Salt Lake City have assumed no greater freedom of speech than every member of the Reed College faculty has as a matter of course.

DISCUSSION AND CORRESPONDENCE

ON THE PRODUCTION OF RARE GASES IN VACUUM TUBES

TO THE EDITOR OF SCIENCE: A number of investigators, among them Sir J. J. Thomson, Sir W. Ramsay, Winchester, and Collie, have found that helium and neon are produced in vacuum tubes by electrical discharges. These gases were not accompanied by argon, and therefore not due to leaks in the apparatus.¹ A thoroughly satisfactory explanation of the appearance of the gases remains to be given, although a very plausible hypothesis has been advanced by Professor Winchester. Winchester² finds that helium and neon are given off from aluminium electrodes only during the first few hours of long-continued discharges, and he therefore concludes that the gases must have been occluded on the surfaces from the atmosphere.

This explanation agrees with a number of facts. For example, we may explain a *second* liberation of helium and neon, sometimes noticed in vacuum tubes after many hours' continuous running, by supposing that a surface layer (*e. g.*, slag), imbedded in the metal when it was poured, becomes exposed when the electrode is partly "spluttered" away. The non-appearance of these gases when very heavy discharges (*i. e.*, large currents) are used, as in one experiment with uranium, by Collie,³ would mean that the surface layer is spluttered away before any considerable amount of gas has been liberated.

There is an alternative explanation which

fits the facts equally well, if we admit the possibility of changes of a radioactive nature taking place in an ordinary vacuum tube. But there is, in the first place, no good evidence that ordinary inactive matter can be transformed by the radiations of radioactive substances;⁴ and consequently, in view of the great energy of the α particles, there is reason for supposing that the swiftest ions in a vacuum tube are equally incapable of producing disintegration of atoms (or rather, according to recent views, disintegration of nuclei; the resultant positive charge upon which determines the chemical properties of atoms⁵)—unless, perhaps, there were present in the tube enormous differences of potential. Nevertheless, in an experiment by Sir W. Ramsay,⁶ evidence is given which suggests an inter-relationship between the elements helium, neon and oxygen.

Certain experiments performed by the writer upon the conduction of electricity at contacts of dissimilar solids⁷ show that, however carefully a metal may be cleaned in air, or in pure electrolytic oxygen, a surface film remains, sufficient to give electrical properties to such a surface, markedly different from those obtaining upon a surface that is cleaned mechanically in vacuo, or in pure electrolytic hydrogen. This being the case, it is seen that all electrodes hitherto employed in the production of rare gases have had a layer of oxide on the surface—traces of which must have remained until all the original surface had been removed by the action of the discharge.

In view of this fact it seems desirable that a tube be constructed, with electrodes similar to those used by Winchester⁸ (which were found to liberate the gases rapidly); it being possible to clean these electrodes on all sides,

⁴ Rutherford, "Radioactive Substances and their Radiations," 1913, § 116.

⁵ Rutherford, *Phil. Mag.*, Vol. 27, 6 ser., pp. 488-98, March, 1914.

⁶ Sir W. Ramsay, Collie, and Patterson, *Nature*, Vol. 90, p. 653, February 13, 1913.

⁷ R. H. Goddard, *Phys. Rev.*, Vol. 28, No. 6, pp. 405-28, June, 1909.

⁸ Winchester, *loc. cit.*

¹ T. R. Merton, *Roy. Soc., Proc., Ser. A*, 90, pp. 549-53, August 1, 1914.

² G. Winchester, *Phys. Rev.*, N. S., Vol. 3, pp. 287-94, April, 1914.

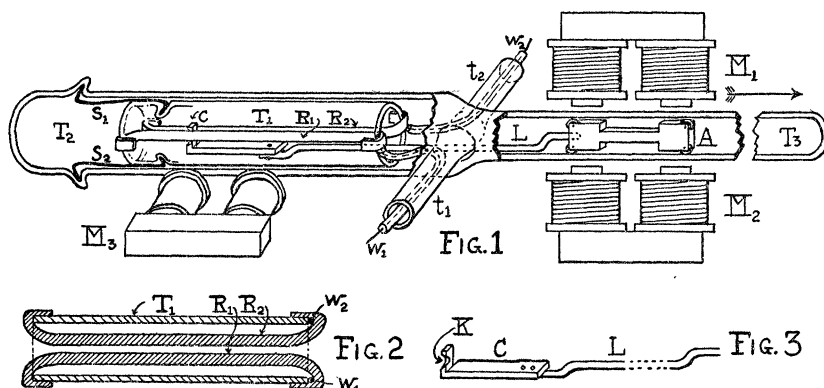
³ J. N. Collie, *Roy. Soc., Proc., Ser. A*, 90, pp. 554-56, August 1, 1914.

mechanically, in vacuo; the apparatus, moreover, occupying but a small volume. The writer ventures to suggest the apparatus described below as being one which embodies the above essentials; the electrodes being substantially the same as those used by Winchester, which were in the form of circular loops of 2 mm. wire, 7 cm. in circumference, and 1 mm. apart.

Referring to Fig. 1, the electrodes are two straight parallel aluminium rods R_1 , R_2 , 2 or 3 mm. in diameter, and 8 cm. long. They are fastened to the glass tube T_1 by being bent around the ends of this tube, shown clearly in the horizontal section, Fig. 2.

and R_2 in turn by means of another strong electromagnet, M_2 —the cutting stroke being in the direction of the arrow. This operation scrapes but one side of each rod, R_1 , R_2 . To scrape the other two sides, A must be turned through 180° , which is accomplished by turning M_1 , M_2 through this angle. After the rods have been cleaned, A , L , C is moved into the tube T_2 , out of the way. It will be noticed that the apparatus is, essentially, a "spoke shave" in vacuo.

By using the above tube after the electrodes have been cleaned in pure (electrolytic) oxygen, it should be possible to demonstrate conclusively the transference of oxygen into



This tube, T_1 , is held in a larger tube, T_2 , by springs S_1 and S_2 (wires), the ends of which fit into dents in the glass tubes T_1 and T_2 . Leading-in wires w_1 and w_2 , attached to the ends of R_1 and R_2 , respectively, are sealed into the two side tubes t_1 and t_2 , Fig. 1; said side tubes connecting with a pump and a spectroscopic tube of the usual type.

A cutter, C , of hardened steel is attached by a flexible brass rod, L , to an armature, A . The cutting edge, K , Fig. 3, is semi-circular, to fit the rods R_1 and R_2 . The armature A has small brass rollers at the corners, to prevent scratching the inside of T_2 , and can be moved back and forth within this tube by means of electromagnets, M_1 and M_2 .

While the armature, A , is being moved in the tube, the cutter, C , is pressed against R_1

helium and neon, if such indeed exist. On the other hand, if (as seems more likely) the helium and neon which appear in vacuum tubes have previously been occluded by the metal from the atmosphere, it should be possible, by means of the apparatus, to study the rates of, and the conditions governing, such absorption.

It is by no means certain, however, that the action in question consists simply in the liberation of absorbed gases, for Sir J. J. Thomson⁹ has discovered evidence of a genuine production of helium and X_3 from elements (lead) and chemical compounds (salts of sodium and potassium) which suggests an actual atomic change, if not a genuine disintegration. The

⁹ Sir J. J. Thomson, Roy. Soc., *Proc.*, Ser. A, 89, pp. 1-20, August 1, 1913.

whole problem is very complicated, and it is the writer's purpose merely to call attention to the importance of surface conditions in the production of the rare gases.

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THE FUNDAMENTAL EQUATION OF MECHANICS

MR. KENT, in his recent communication, invites expressions of opinion from Professor Huntington and myself regarding his method of explaining the principles of dynamics. My own view is that Mr. Kent's explanation of the effect of a constant force in giving motion to a free body initially at rest is entirely sound. It is, in fact, substantially the explanation I have long used in the classroom as a first step in establishing the fundamental equation of motion. Perhaps it is permissible to quote from my text-book on "Theoretical Mechanics," first published fifteen years ago:

If a force of constant magnitude and direction acts, for a certain interval of time, upon a body initially at rest, the body will have at the end of the interval a velocity whose direction is that of the force, and whose magnitude is proportional directly to the force and to the duration of the interval, and inversely to the mass of the body.

Since mass has already been defined as quantity of matter, this statement is seen to be identical in meaning with Mr. Kent's statement that "the velocity varies directly as the time and as the force, and inversely as the quantity of matter."

Mr. Kent's equation $V = KFT/W$ is entirely satisfactory and sufficient so long as our study is confined to the case in which a force whose direction and magnitude remain constant acts upon a body otherwise free and initially at rest. This is, however, a very exceptional case. The fundamental principle in its generality can be expressed only by introducing the notion of *instantaneous rate of change of velocity*, i. e., acceleration. When this is done Mr. Kent's statement quoted above must be replaced by the statement that "the acceleration varies directly as the force and inversely as the quantity of matter," while his equation $V = KFT/W$ is superseded by the more general one $a = KF/W$. This is

identical with equation (5) of my former communication,¹ except that quantity of matter is there represented by m instead of W .

To pass from the equation

$$\text{acceleration} = K \times \frac{\text{quantity of matter}}{\text{force}} \quad (1)$$

to the equation

$$\text{acceleration} = \frac{\text{quantity of matter}}{\text{force}} \quad (2)$$

of course requires that units should be defined so that unit force acting on unit quantity of matter causes unit acceleration. Mr. Kent regards this as an objection to equation (2). If the objection is valid a similar one seems to apply to his own procedure. His equation

$$V = 32.1740 \frac{FT}{W}$$

is true only because his unit force is defined as the force which would give a pound of matter an acceleration of 32.1740 ft./sec.² The statement that the accurate value $K = 32.1740$ is found as the result of "the most refined experiments, involving precise measurements of both F and W , and of S , the distance traversed during the time T , from which V is determined" is quite misleading. The stated value of K is not based upon any refined measurements of the character described, but upon a purely ideal definition of the unit force; just as the value $K = 1$ results from a different ideal definition.

If there is any reason for preferring the set of units which makes $K = 32.1740$ to that which makes $K = 1$ in equation (1), it is not because the former is any more easily understood than the latter. "The force which, acting upon a pound of matter, would cause an acceleration of 32.1740 ft./sec.²" is the same kind of a definition as "the force which, acting upon a pound of matter, would cause an acceleration of 1 ft./sec.²" It is true that the former of the two units of force thus defined

¹ SCIENCE, April 23, 1915, p. 609. It is well known that Mr. Kent objects to the use of the word mass for quantity of matter; my present object is to make my meaning clear rather than to invite an unprofitable discussion over a purely verbal question.