Photoelectric and Metastable Atom Emission of Electrons from Surfaces

I. Langmuir and C. G. Found[1] concluded from experiments that resonance radiation is able to travel a considerable distance out into a tube away from the region of a discharge in Ne and cause the production of metastable atoms. They measured currents to charged electrodes which they attributed to conductivity imparted to the tube as a result of the emission of electrons from the glass walls and metal surfaces by metastable atoms. Experiments of the writer at pressures of 0.1 to 2 mm with somewhat similar apparatus confirm the conclusion of Langmuir and Found that resonance radiation travels long distances out into a tube and produces metastable atoms. These experiments indicate, however, that currents similar to those Langmuir and Found observed are made possible chiefly by the ionization of traces of impurities in the gas by metastable atoms.[2] In the case of currents to negatively charged electrodes it has been found that the emission of electrons by metastable atoms is small compared with the photoelectric effect.

In one type of experiment currents are measured between a thin nickel disk, which can be rotated so that its plane is either parallel or perpendicular to the axis of the tube (and therefore to the direction of the radiation), and a gauze cylinder symmetrically surrounding it. If the disk is made suitably negative to the cylinder approximate saturation currents are obtained which are several times greater when the disk is perpendicular to the axis of the tube than when it is parallel to this axis. For a given discharge current, these currents increase as the pressure is decreased. The ratio between the currents also increases. These facts are in accord with the view that the currents are due to a photoelectric emission from the disk, rather than to any action of metastable atoms.

Currents between disk and cylinder in the case of pure Ne are changed by only a relatively negligible extent by shining strong Ne light through the gauze from an external source. This indicates that metastable atoms are not appreciably involved in the flow of these currents. If, however, there is a trace of impurity present, say 0.005 percent A, the currents flowing are considerably larger and the external Ne light then causes a considerable decrease in them. These experiments indicate that the A is ionized by the metastable Ne atoms, and that the additional current flowing as a result of this ionization decreases as the metastable atom concentration causing it is decreased by the external Ne light. That the external Ne light used is a powerful destroyer of metastable atoms is shown also by the following experiments. Measurements of ion concentration either by a Hertz positive ion detector or by probe measurements[2] made close enough to the discharge (e.g. two tube diameters) so that the usual interpretation probably applies, show that this concentration is enormously increased by adding a trace of A to Ne. Further both types of test show that provided the argon percentage is not too great (<0.05 percent) the ion concentration is markedly decreased by shining the external source of Ne light on the tube. The effect of the Ne light is negligible in pure Ne, reaches a maximum with a few thousandths of a percent of A and again becomes negligible when the A percentage has become of the order of 0.1 percent. Meanwhile, the ion and electron concentration increases many hundred fold. These results indicate that metastable atoms are only involved in these experiments when a trace of another gas has been added which they can ionize. Further, with a sufficient amount of this other gas, the rate of destruction of metastable atoms by this ionization process becomes large compared with the rate of destruction by the external Ne light.

These experiments and conclusions are in agreement with the results of Penning[3] obtained from studies of the breakdown potential in Ne as influenced by traces of A and by irradiation with Ne light.

Experiments have been carried out in which metastable atoms have been destroyed by applying heat and also in the case of A by admitting N_2. In no case has evidence been obtained that emission of electrons by metas-

[1] I. Langmuir and C. G. Found, Phys. Rev. **36**, 604 (1930).

[2] T. E. Foulke (unpublished work) found that the conductivity of a tube such as is here considered is enormously increased by adding a trace of a gas the ionizing potential of which is lower than the metastable potential of the main gas.

[3] F. M. Penning, Zeits. f. Physik **57**, 723–38 (1929), Phil. Mag. **11**, 961–79 (1931).

table atoms under the present circumstances is comparable with the photoelectric effect.

The present experiments indicate that the emission of electrons by metastable atoms is small compared with the photoelectric effect even where the concentration of metastable atoms is high enough to give a visible beam by scattering. Hence it is believed that in much recent work[1,4] involving effects which have been ascribed to the emission of electrons from surfaces by metastable atoms too great an efficiency has been assumed for this process and too small an efficiency for the photoelectric effect.

Oliphant[5] found an apparently high efficiency for the emission of electrons from surfaces by metastable He atoms having velocities corresponding to 2000–120 volts. It would seem that for the relatively very slow (room temperature) metastable atoms of the present experiments a smaller efficiency must be assumed.

Photoelectric studies have been made in He and A as well as in Ne. Strong irradiation with light of the gas in question, as well as experiments with the disk above mentioned perpendicular and parallel to the tube show that, in these gases also, electron emission by metastable atoms is small compared with the photoelectric effect.

Rough calculations made on the basis of the experiments indicate that the photoelectric effect in this far ultraviolet region of the spectrum, (around 700A in the case of Ne) is considerably more efficient than in the nearer ultraviolet regions usually studied.

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[4] P. M. Morse and W. Uyterhoeven, Phys. Rev. **31**, 827 (1928); W. Uyterhoeven, Phys. Rev. **31**, 913 (1928), Proc. Nat. Acad. Sci. **15**, 32 (1929); C. G. Found, Phys. Rev. **34**, 1625 (1929); W. Uyterhoeven, and M. C. Harrington, Science **70**, 586 (1929), Phys. Rev. **35**, 438 (1930), Phys. Rev. **36**, 709 (1930).

[5] M. L. E. Oliphant, Proc. Roy. Soc. **A124**, 228 (1929).