# Emission of Negative Electricity from Nickel when Bombarded by Positive Lithium Ions

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A nickel target was bombarded with positive lithium ions and observations were made of the number of negative charges emitted per positive ion striking the target. The energies of the bombarding ions were within the ranges 1000 to 2000 electron-volts and 5000 to 20,000 electron-volts, approximately. Observations were made with the target at room temperature and at a yellowish-red heat. There is a marked difference between the curves found for the two cases. For the cold target the curve has a maximum between 10,000 and 11,000 volts, while the number of negative charges emitted per positive ion from the hot target increases from 0.13 at 1000 volts to 2.35 at 20,000 volts, no maximum having been found.

## Introduction

The emission of electrons from a metal target bombarded by high speed positive ions has been studied by Füchtbauer,[1] Campbell,[2] Baerwald[3] and others.[4] The reported data are in very poor agreement. In general it has been found that the emission increases with the velocity of the bombarding ions but saturation points and maxima have been found, beyond which an increase no longer takes place. Two conclusions given by Baerwald are: (1) the chemical character of the primary rays is without influence upon the amount or speed of the secondary electrons, and (2) the nature of the metals bombarded is without influence upon the amount or speed of the secondary electrons. None of this work appears to have been done with hot or outgassed targets, hence it is possible that the observed emission is really not characteristic of the metal of the target but that the emission was largely from a layer of gas on the surface. In fact, the recent work of Thompson[5] and Woodcock[6] has shown that when the target is covered with a gaseous layer the results may be further obscured by the emission of negative ions of the gas or of impurities on the surface. The author has made measurements of the emission of negative charges from a nickel target bombarded by positive lithium ions by use of an apparatus in which the target could be kept at a yellowish-red heat while observations were being made.

[1] Füchtbauer, Phys. Zeits. **7,** 153 (1906).

[2] Campbell, Phil. Mag. **29,** 783 (1915).

[3] Baerwald, Ann. d. Physik **41,** 643 (1913); **60,** 1 (1919); and **65,** 167 (1921).

[4] For a more complete bibliography and discussion of previous work the reader is referred to the Handbuch der Physik, Volume XXIV, pp. 105ff.

[5] J. S. Thompson, Phys. Rev. **38,** 1389 (1931).

[6] K. S. Woodcock, Phys. Rev. **38,** 1696 (1931).

## Experimental Arrangement and Method

The source of positive ions was a small crystal of spodumene on a heated platinum strip. This is an abundant source of $Li^+$ ions. The ions were accelerated toward the brass plate *B*, Fig. 1, by a potential which was in most cases about 800 volts. Those going through the hole in the brass plate were then accelerated toward the target *T* by a variable potential supplied by a transformer and kenotron. The target was mounted just inside a 6 mm hole in the end of a brass cylinder but could be moved below the hole by a magnetic device. The cross-section of the positive ion beam was much less than the area of the hole in the end of the cylinder and the alignment of the apparatus was checked by observing the position of the small spot produced on the target by the positive ions. The connections for heating *T* are not shown.

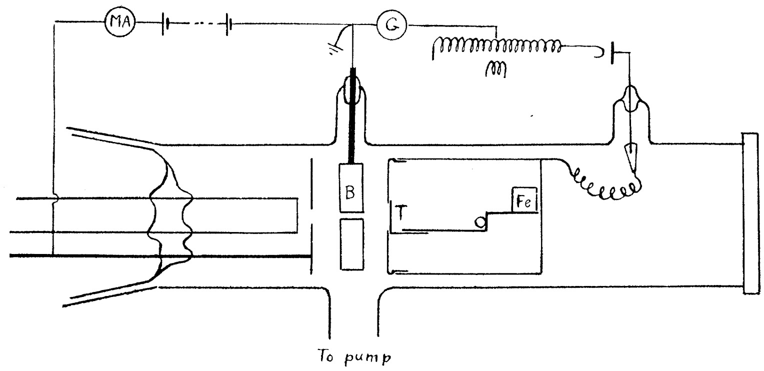


Fig. 1. Experimental arrangement.

The method of making observations was essentially that used by Füchtbauer. When the target is removed the positive ions strike at such a depth within the brass cylinder that no secondary electrons can get out. The galvanometer then registers $I^+$, the amount of the bombarding positive current. When the target is in front of the hole the secondary electrons go back to the brass plate. The galvanometer current then is $I^+ + I^-$. To find the number of electrons released by each positive ion, that is, $I^+/I^-$, we need use only the two galvanometer readings taken above. Thus

$$(I^+ + I^-)/I^+ = 1 + I^-/I^+ \text{ or } I^-/I^+ = (I^+ + I^-)/I^+ - 1.$$

The potential supplied by the transformer was measured by a spark gap, the range of voltages used being approximately 5000 to 20,000. A liquid air trap was always used to keep Hg vapor from the condensation pump out of the apparatus. The zero reading of the galvanometer, that is, with the platinum strip cold, was taken at each potential since it was found to vary somewhat with the potential. The current $I^+$ was of the same order of magnitude for each reading.

## Observations

The first observations were made with a cold target which had not previously been outgassed by heating. Fig. 2 shows typical curves. The data for curve *b* were obtained 24 hours later than those for *a*, the target meanwhile having stood in a high vacuum. The curves reach a maximum between 10,000

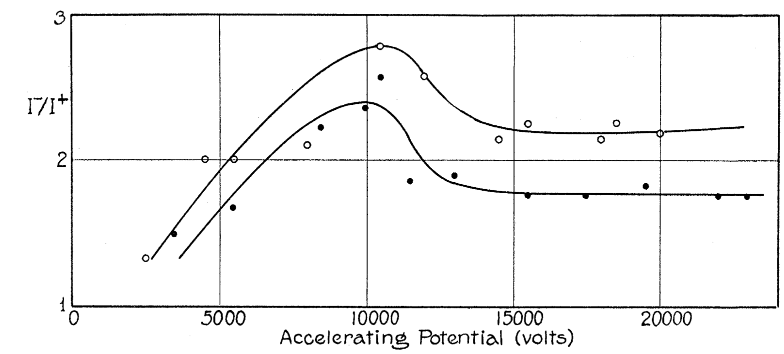


Fig. 2. Emission from cold target.

and 11,000 volts accelerating potential. This maximum appears to shift slightly toward lower voltages as the target becomes better outgassed.

Fig. 3 shows the results obtained when the target was hot. Curve *a* was obtained with the target just hot enough to emit visible light. There is noticeable only a faint trace of the maximum which appeared in the curves for the cold target and it comes at about 9000 volts instead of between 10,000

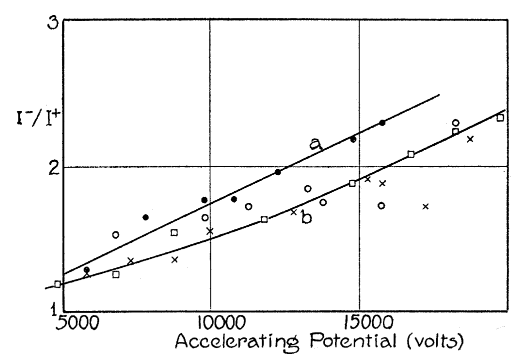


Fig. 3. Emission from hot target. Dots: Target just hot enough to omit visible light. Circles: Target dull red. Crosses: Target bright cherry red. Squares: Target bright yellowish red.

and 11,000 volts as before. The results obtained when the target was a bright cherry-red and a yellowish-red, represented by curve *b*, are identical within experimental error hence it is logical to assume that the emission is not affected by adsorbed gases if the target is kept at a yellowish-red heat but is the true emission from the metal. Under these conditions the emission of negative charges from Ni under the bombardment of positive Li ions appears to differ but very slightly from a linear function of the energy of the bombarding ions over the range studied. The other set of points shown in Fig. 3 are for an intermediate temperature and are not of any special interest.

Observations of the emission from the hot Ni target were also made at lower voltages, from 1000 to 2000 volts. The apparatus was the same as before except that the transformer and spark gap were replaced by batteries and a voltmeter. The emission curve, Fig. 4, is not quite a straight line but its slope increases slightly with accelerating potential. Thus far no satisfactory measurements have been made over region from 2000 to 5000 volts but it is

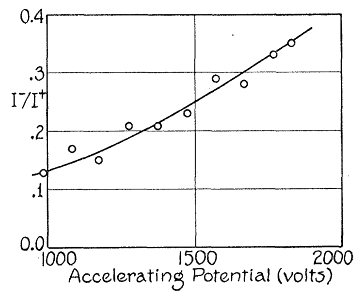


Fig. 4.

quite likely that the slope of the curve gradually decreases in that region since the average slope in the range 5000 to 20,000 volts is only about 1/3 of that in the range 1000 to 2000 volts. Furthermore measurements taken in the range 2000 to 5000 volts point to the same conclusion although the potential readings were in error by an undetermined factor so that they could not be used in plotting the curve.

The difference between the curves obtained before and after heating the target is very probably due to a layer of adsorbed gas on the cold target, but the explanation of how a layer of adsorbed gas could cause a maximum such as observed here is obscure. Campbell[2] has observed a maximum in the emission curve of copper bombarded by hydrogen ions but this was at a much higher potential, about 40,000 volts, and was followed by a steady drop. The maximum in the present case appears similar to a "line" superposed on a slowly increasing function. Before attempting an explanation an analysis of the negative particles liberated should be made to determine their mass and charge.

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