# THE REFLECTION OF POSITIVE RAYS BY A PLATINUM SURFACE

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ABSTRACT

**Intensity, energy and directional distribution of $Li^+$ and $K^+$ ions reflected from platinum.**—In studying the reflections of positive rays by a platinum surface an apparatus similar to a spectrometer was set up in a good vacuum. A beam of lithium ions accelerated through a known *P. D.* impinged upon a platinum reflector. The intensity, energy and direction of the reflected beam were measured by means of a rotating collector. Providing the reflector were "clean," i.e. white hot or cold but a few seconds, a considerable reflection was observed at certain angles. The angle of reflection was approximately specular but varied slightly with the accelerating voltage. The percentage reflected depended markedly upon the accelerating voltage. The maximum occurred approximately at 48 volts where approximately 75 percent were reflected. The reflected beam consisted of ions which had lost the major portion of their energy. Using a beam of potassium positive rays, approximately the same type of results was obtained.

THE reflection of positive rays from a metallic surface has hitherto been studied mainly in connection with the problem of the production of secondary electrons. Of the more recent work Klein[1] deduced from observations that a large number of slowly moving positive rays were reflected. Jackson[2] was unable to repeat these observations and attributed the results of Klein to the geometrical and electrical arrangement of the apparatus and not to the reflection of any considerable portion of the incident positive rays. The experiments described in this paper were undertaken to determine the relative amount reflected under various experimental conditions and especially to investigate the distribution in angle of the reflected rays.

The experimental arrangement is shown in Fig. 1. The apparatus resembles a spectrometer with fixed collimator and reflector and a rotating collector. The source $S$ was a layer of spodumene on a platinum strip which could be heated electrically. According to Hundley[3] the emission from spodumene ($Li_2O \cdot Al_2O_3 4SiO_2$) at a dull red temperature consists almost entirely of the heavier lithium isotope. The ions could be accelerated through a known potential difference applied between the anode and the cathode about one cm above it by means of the potentiometer arrangement shown. The portion of the beam that passed through the slit in the cathode entered the main portion of the tube which was shielded by the gauze $G$ and impinged upon the reflector $R$. The reflector consisted of a platinum strip $1 \times 2 \times 0.001$ cm. It was supported by current leads which were insulated from the cathode and which served to raise the reflector to a white hot temperature.

[1] Klein, Phys. Rev. **26**, 800 (1925).
[2] Jackson, Phys. Rev. **28**, 524 (1926); **30**, 473 (1927).
[3] Hundley, Phys. Rev. **30**, 864 (1927).

The collector $C$ consisted of two thin nickel strips insulated from each other. The inner one served as a guard allowing only a narrow beam of rays to reach the outer. It was found that the angular dimensions of the initial beam of positive rays were so large that the two strips could be connected together and used as a single collecting electrode with no appreciable loss of resolution. Because of this and the very considerable gain in intensity, the second arrangement was used almost entirely. The collector could be rotated through an angle of 320° by means of the ground joint shown. The current to the collector was measured by means of a string electrometer and compensating ionization chamber similar to that used by Dempster.[4]

At the beginning of a series of observations the collector was turned so as completely to cover the slit in the cathode; this position corresponding to the angle 0°. The current to the rear of the collector was taken as the measure of the number of positive ions impinging on the reflector. A number

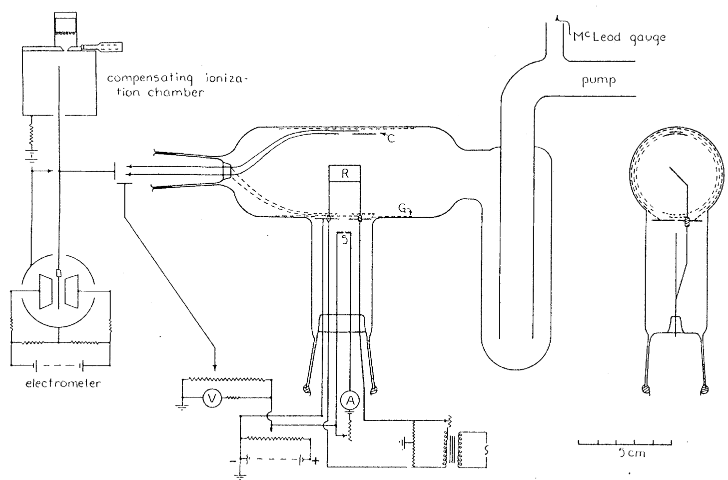


Fig. 1. Experimental arrangement.

of readings was then taken with the collector at known angles. In these cases the current to the front of the collector was taken as a measure of the number of reflected ions. Usually one or more extra readings were taken at zero to check the constancy of the source even though there was little change.

The tube containing the apparatus was directly connected to a liquid air trap as shown. This was done in an attempt to get rid of the vapors from the two ground-glass joints. As is customary, the wax did not extend the full length of either seal. The line to the pump consisted of tubing of at least 20 mm outside diameter. The pumping system was made up of two mercury diffusion pumps with an oil backing pump.

It was found that the fraction of the positive rays reflected depended very markedly on the condition of the reflector. If the reflector were white hot, a considerable reflection was observed at certain angles. This reflection

[4] A. J. Dempster, Phys. Rev. **18**, 415 (1921).

persisted for a short time after the heating current had been cut off, but gradually became less and less until after a few minutes no ions at all were reflected. This behavior suggests that a film of gas or vapor on the platinum surface prevents reflection. In the experiment the observations were therefore taken within a few seconds after the reflecting strip had been cleaned by heating to a high temperature for a short time. As no reflection was found from an old surface, it may be assumed that the current to the collector is a measure of the ions falling upon it.

In general the type of results obtained with a "clean" reflector bombarded with $Li_7^+$ ions is shown in Figs. 2 and 3. In both these the relative intensity of the current due to the reflected rays with respect to that of the incident rays is plotted against the angle of the collector. The direction of the incident

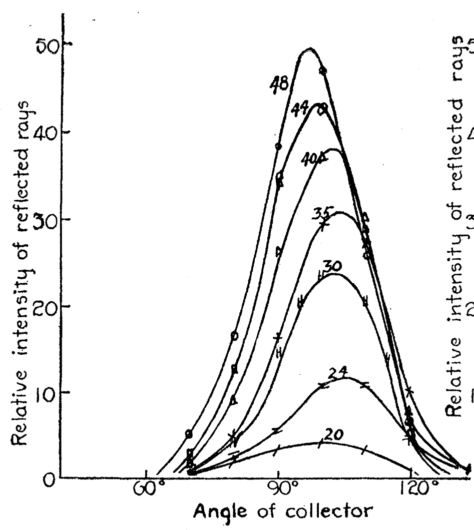


Fig. 2. Variation with angle of reflected positive rays. Accelerating potentials 48 volts and less.

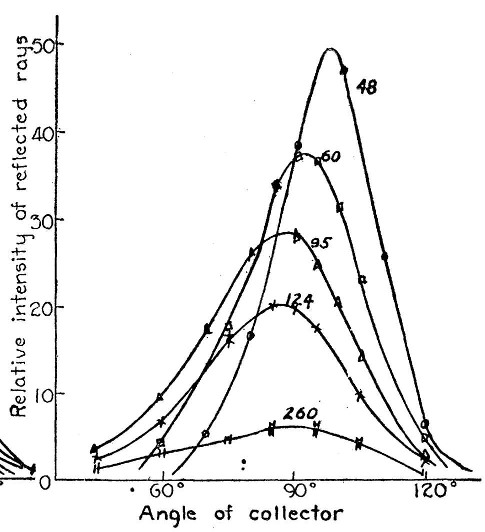


Fig. 3. Variation with angle of reflected positive rays. Accelerating potentials 48 volts and greater.

beam is taken as 0°. As the reflector is placed approximately at 45° to this beam, the reflected beam, for which the angle of reflection equals the angle of incidence, occurs at 90°.

In Fig. 2 the ratios of the collector current at various angles to the total ion current are shown for different accelerating potentials of 48 volts and less. Fig. 3 shows the same type of results for accelerating potentials greater than 48 volts. It is seen that the reflected beam is distributed fairly widely about a maximum which falls near the angle of regular reflection, i.e., 90°. The angular breadth of the reflected beam is large because of the divergence of the incident beam and the width of the collector.

Figs. 2 and 3 show that the number of ions reflected depends upon the accelerating potential. The maximum reflection occurs at 48 volts. The relation of the ratio $I$ (reflected)/$I$(incident) to the accelerating potentials is shown in more detail in Fig. (4). At 48 volts approximately 75 percent of all the incident rays are reflected. The number of positive ions reflected decreases sharply as the accelerating potential is decreased from 48 volts and also decreases although more gradually as it is increased.

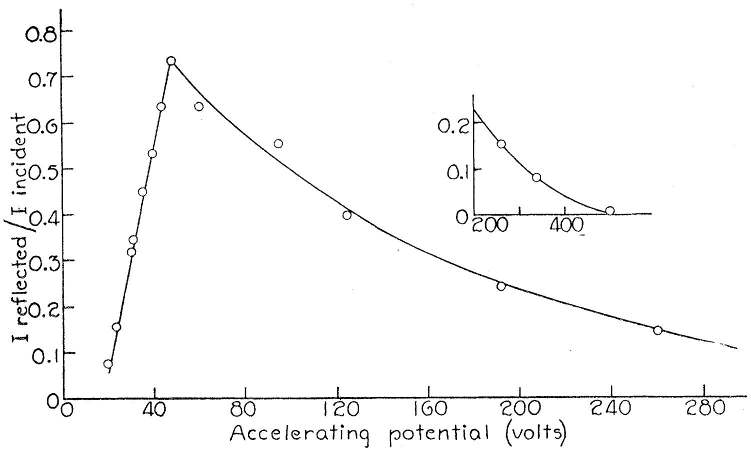


Fig. 4. Variation of $I$(reflected)/$I$(incident) with accelerating potential.

Figs. 2 and 3 also show that the angle at which the maximum reflection occurs varies with the accelerating potential. Fig. 5 indicates this variation. The angle of maximum reflection appears to approach 90° as the accelerating voltage is decreased from 30 volts. As the accelerating potential is increased from 30 volts the angle of maximum reflection becomes greater than 90°, and then appears to approach it again at much higher voltages. In this region and in that of small accelerating potentials there was difficulty in taking accurate measurements because of the small relative intensity of the reflected beam.

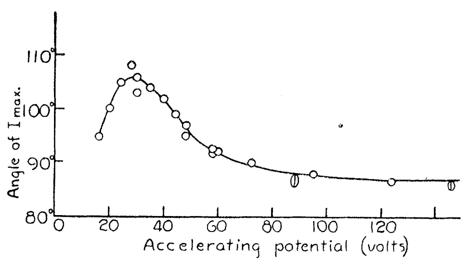


Fig. 5. Variation of angle of maximum reflection with accelerating potential.

Fig. 6 shows the energy distribution of the positive particles in the reflected beam. The data for this curve were taken by applying various retarding potentials between the reflector and collector and measuring the current to the collector. The ratio of the current $I$ with a given retarding potential $V$ to that of the current $I_0$ with zero potential difference $V_0$ is plotted against the ratio of the retarding to the accelerating potentials.

The curve in Fig. 6 does not continue on through the axis of abscissas, showing that the production of secondary electrons was not an important factor. This point was checked by applying a magnetic field to the tube. No effect was noticed so that we may conclude that within the range of this experiment the production of secondary electrons was not a disturbing factor.

In all the above work the $Li_7^+$ positive rays impinged upon a "clean" platinum plate, the angle of incidence being 45°. In this work the "clean" plate may be hot or cold with approximately the same results. After a few minutes, however, the cold plate becomes ineffective as a reflector. In general the same type of effects are found when the angle of incidence is 30° or 60°.

With leucite as a source of $K^+$ ions similar results were obtained. In general, however, the percentage of ions reflected did not vary as markedly

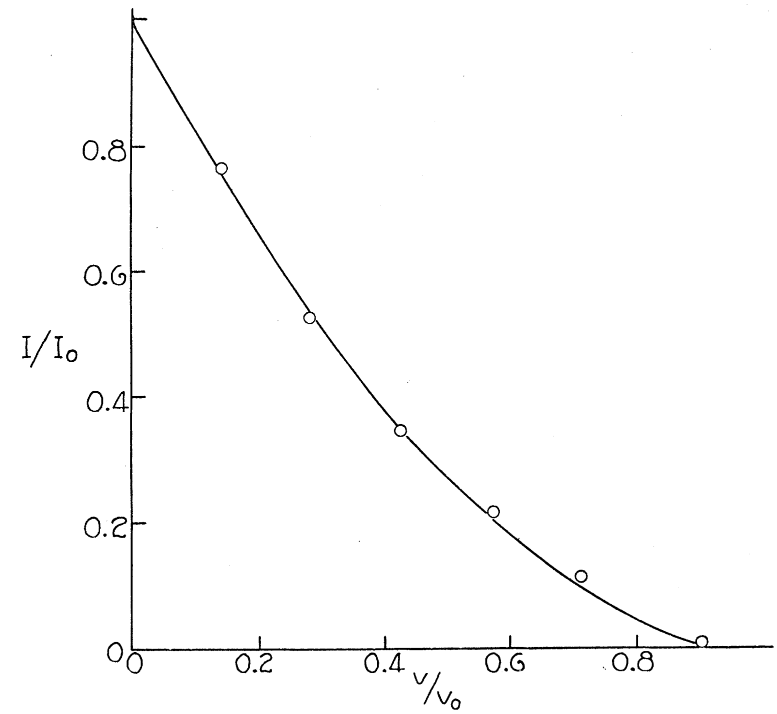


Fig. 6. Energy distribution of reflected positive ions.

with the accelerating potential. The relative energy of the reflected ions is less than in the case of $Li_7^+$.

The results of this investigation seem to show that alkaline positive rays are partially reflected from a "clean" platinum surface. The percentage reflected depends markedly upon the accelerating potential. While the reflection is approximately specular the angle of reflection varies slightly with the accelerating voltage, also the energy of the reflected beam is appreciably smaller than that of the incident beam.

The above work was done at Ryerson Laboratory, University of Chicago. The writer wishes to express his thanks to Professor Dempster, who suggested the problem and gave valuable criticism during the course of this investigation.

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